UNIVERSITA' DEGLI STUDI DI PADOVA

DIPARTIMENTO DI SCIENZE ECONOMICHE ED AZIENDALI "M.FANNO"

CORSO DI LAUREA MAGISTRALE IN ECONOMICS AND FINANCE

TESI DI LAUREA

THE REAL EFFECTS OF UNCERTAINTY SHOCKS ON ECONOMIC ACTIVITY: THEORY AND EMPIRICAL EVIDENCE.

RELATORE:

CH.MO PROF. GIOVANNI CAGGIANO

LAUREANDO: PIERGUIDO BORTOLI

MATRICOLA N. 1081935

ANNO ACCADEMICO 2015 – 2016

Il candidato dichiara che il presente lavoro è originale e non è già stato sottoposto, in tutto o in parte, per il conseguimento di un titolo accademico in altre Università italiane o straniere.
Il candidato dichiara altresì che tutti i materiali utilizzati durante la preparazione dell'elaborato sono stati indicati nel testo e nella sezione "Riferimenti bibliografici" e che le eventuali citazioni testuali sono individuabili attraverso l'esplicito richiamo alla pubblicazione originale.

Firma dello studente

____

Abstract:

How does uncertainty affect the real economy? Is there a comovement among output, consumption, investment and worked hours after an uncertainty shock? To answer these questions, I examine the theoretical predictions of two widely used general equilibrium models, i.e. the Neo-Classical Business Cycle Model and the New-Keynesian DGSE Model, and provide empirical tests of whether they replicate the business cycle comovements observed in the data. The VAR-based analysis shows that an uncertainty shock triggers a negative response in real activity and prices, consistent with the claim that uncertainty shocks act as negative aggregate demand shocks. These findings lend support to the predictions put forth by the New-Keynesian theoretical framework.

TABLE OF CONTENTS

1. INTRODUCTION

In these first fifteen years of the 21st century, we have experienced wars, an economic and financial crisis known as the Great Recession and the European Sovereign Debt Crisis, political instability in Eurozone countries and stock markets have been noted for high volatility. All these events and many others have caused uncertainty and fear for future prospects and an economic upswing.

Downturn periods are characterized by an increase in uncertainty and volatility at both macro and micro levels. In many works, economists find out how these uncertainty shocks, through various channels, exacerbate the negative impact of bad economic times on aggregate economic activity.

However, how can an uncertainty shock depress the real economy? This question is the central idea of this work. The purpose of this dissertation is: (1) to investigate the negative role that uncertainty shocks have on the real sector, (2) to figure out how real variables as GDP, investment, consumption and worked hours reacted in presence of this kind of shock and (3) if a co-movement among these variable exists. In my view to summarize the negative effects that the Great Recession has had on our lives can useful to support the importance of this topic.

The recent Global Financial Crisis has been matched with strong increases in volatility in both stock markets and the economic activity. During the 2008 Financial Crisis, the VIX (a proxy of future volatility on S&P 500 Index option prices) hit its historic high of 89.53 on 24th October 2008 This is shown in **Figure 1**. Prior to this crisis, the VIX peaked at 49.53 during the Long Term Capital Management Crisis.

Furthermore, the spikes in volatility seen in the second half of 2008 did have historical precedents. However, comparing this evidence with the Great Depression, when stock volatility rose and remained high for many years, stock volatility returned to more normal levels fairly quickly after the 2008 crisis. Later on in this recession, the VIX had hit 48.20 and 48.00 during the Greek Government Debt Crisis in 2010 and during the Italian Government Debt Crisis in 2011 respectively. **Table 1** sums up the periods that triggered VIX to its highest peaks.

Moreover, in the US the Real GDP (**Figure 2**) decreased at an annual rate of 6.3 percent in the fourth quarter of 2008, the Real Gross Private Domestic Investment (**Figure 3**) dropped at an annual rate around 32% in the same period compared to the previous one, while Real Personal Consumption Expenditures (**Figure 4**) decreased 4.7 percent, compared with a decrease of 3.8 percent in the third one. The Unemployment Rate (**Figure 5**) doubled from almost 5% on April 2008 to 10% in October 2009.

In December 2008, the indicator of production of the US economy, the ISM Manufacturing: Production Index (**Figure 6**) hit 26.3, its lowest level since May 1980. Unfortunately, during the Great Recession, many businesses reduced their production volume around 30-40%.

Another important measure is the Consumer Sentiment (**Figure 7**) which plummeted to its lowest level of 57.6 in November 2008. This result suggests that consumers were pessimistic about the economic situation and the chance of a prompt recovery.

Looking at the current situation, there have been several uncertainty shocks like the fall in oil prices in the second half of 2014, the Citi's Economic Surprise Indexes has fallen down in the negative area during the first quarter of 2015 (the disappointment for the US economy has been high relative to consensus forecasts), the Chinese Stock Market Crash in June 2015, the Greek bailout referendum in July, the devaluation of the Yuan on August to keep Chinese economy up, consequently prices of commodities hit a series of lows.

All these recent turbulences have affected the global financial markets and the VIX set a record in August, since it rose 118% in a week at a value of 40.74. These threats could lead to a new slowdown in activity growth in the rest of the world and not keep within the bounds of the countries affected by these shocks.

Policymakers encounter difficulties in managing these fluctuations; indeed, on 24th September 2015 during a speech at the University of Massachusetts, Janet Yellen said:

> "*Global economic and financial developments highlight the risk that a slowdown in foreign growth might restrain U.S. economic activity somewhat further.*"

The Federal Reserve Chairman during this intervention expounded the reasons why there will be no monetary policy changes for the remainder of the year, leaving the interest rates at the current levels. The explanations are the weak US economic growth, the lower than expected realized data, expectations as well as the unexpected shortfall in US inflation in 2015 with a value too far from 2% annual as desired.

However, two months ago, J. Yellen in another speech to the City Club of Cleveland said:

> "*But I want to emphasize that the course of the economy and inflation remains highly uncertain.*"

These two statements prove once again that we are living in a period that doesn't allow to easily forecast the economic outlook, causing disagreement among politicians, central bankers and economists about what will happen in the next years. All this increases pessimism and fear amongst people.

These threats are also perceived among consumers as the recent data from the Consumer Sentiment revealed in September with a reduction of 12% compared to January 2015.
As we know in the Keynesian Theories, negative views among consumers and investors about the future economic situations have depressive effects; they lead to a reduction in consumption, in investments and as well as in output.

All things considered, in the first part after a recall of the literature, the different economic meaning between risk and uncertainty, I describe from a theoretical point of view how uncertainty shocks affect the real economy. The results are different considering the Neo-Classical framework with respect to New-Keynesian view. However, the findings from a Neo-Classical model are not coherent with the empirical data. The existence of an economy with imperfect competition and consequently the stickiness of the prices are useful to understand the mechanism through which an unforeseen shock affects the economy.

The second part is dedicated to a quantitative analysis, by estimating a vector autoregressive (VAR) for post 1964 U.S. data. I conduct my analysis with and without the sub-period 2008-2015. The reason behind this choice is the exceptional monetary policy adopted by the FED. As proxy of uncertainty, I use the VIX and a dummy HP VIX. The quantitative findings suggest that a rise in uncertainty causes a large decline in consumption, investment, and output. These depressive effects not only contract the economy but they lead to a decrease in inflation and the intervention of the monetary authority to lower the nominal interest rate, if necessary until the reach of ZLB.

The rest of this paper is organized as follows. Section II reviews related empirical literature on uncertainty effects on the real economy. Section III describes the different meaning between risk and uncertainty. Section IV summarizes the main measuring of uncertainty. In Section V and Section VI, I sum up the opposing results applying the Neo-Classical Theory and the New-

Keynesian one. Section VII recaps the data used in my analysis. Section VIII describes the empirical implementation. In Section IX, I perform my empirical analysis and discuss my findings. Section X shows the robustness tests. Section VI concludes my research.

2. LITERATURE

The text references the effects of uncertainty shocks on business cycles which have continued to grow over the last ten years, not only concentrated on the nature and the role of these kinds of shocks, but also on the effectiveness of monetary and fiscal policies in order to restore the economy.

Using several proxies of uncertainty, these works trace out the task and the mechanisms of propagation of these unpredictable events during the Great Recession, proving their role as one of the causes of the prolonged effects of the crisis and the sluggish economic recovery as detailed by Basu and Bundick (2014) .

A wide set of paper documents the features of uncertainty shocks in the US as Bloom (2009), Baker, Bloom and Davis (2013), Leduc and Liu (2013), Bloom, Floetotto, Jaimovich, Saporta-Eksten and Terry (2014), Basu and Bundick (2014), and Jurado, Ludvigson, and Ng (2015) demonstrate their deflationary effects. Moreover, as proved by Caggiano, Castelnuovo and Nodari (2015) the responses of real activity to uncertainty shocks is different in good and bad times: during a recession their impact is more meaningful and sudden than during an expansion period.

On the theoretical side, using partial equilibrium analysis, Hartman (1976), Abel (1983), Bernanke (1983) and Leland (1968) have studied the mechanisms of propagation of these bad events. They identified three main different channels through these kind of shocks that affect the real economy: Hartman-Abel Effects, Real Options Effects and Precautionary Savings. However, they lead to contrasting results.

First, Hartman (1976) and Abel (1983) demonstrated that a rise in uncertainty might accelerate investments and boost the economic activity. Their explanations is the following: under certain assumptions, the firms' investment choice is an increasing function of the variance of price and total factor productivity, therefore, an increase among these variables positively affects the demand for capital and thus for investments.

However, the other two cases reveal negative consequences on the real economy. In 1983, applying the real option theory, Bernanke showed how investors, firms and consumers postpone their spending in presence of a positive variation in uncertainty. In this scenario, their option value to wait and see is larger, investors are willing to postpone their irreversible investments in order to receive more information in future, firms are reluctant to hire and invest and lastly consumers become parsimonious. This preference of waiting and seeing has been recalled in an interview of Blanchard (2009) and in other papers as Bloom (2009) and Orlik and Veldkamp (2014).

Leland (1968) proposed another explanation, using the precautionary saving theory. Faced with higher uncertainty, agents may both reduce their consumption and be willing to work more in order to self-insure themselves against future shocks. However, in a closed economy, a positive accumulation of savings leads to an increase in investments. Summarizing, this channel explains how in presence of an unpredictable negative shock it does not affect the aggregate output, but this overall result cannot be determined a priori. Bachmann and Bayer (2011) showed, in a general equilibrium model, how adjustments in real interest rate rates and in wages significantly reduce the investment response to a shock. Therefore, in a general equilibrium framework, the precautionary demand for saving lowers wages and real interest rate, driving up output and investment.

Conversely, as detailed in Bloom (2009) there is empirical evidence that these negative events generate a rapid drop, rebound and overshoot in employment, investment, output and productivity growth. Moreover, my results show that the behavior of uncertainty shocks is comparable with negative demand shocks, and this feature is consistent with Alexopoulos and Cohen (2009), Leduc and Liu (2013), and Johannsen (2014). Arellano, Bai and Kehoe (2010) demonstrated how output and employment decrease when the banking system is hit by uncertainty shocks, since credit is more restricted.

Another recent work by Basu and Bundick (2014) extends this investigation and reports the existence of business cycles comovements among output, investment, consumption and hours worked from changes in uncertainty. This paper inspired my work, but while we have a common goal, i.e. prove the presence of comovements among those real variables, the empirical analysis is slightly different; using different proxies of uncertainty, I wonder if the responses of these measures are more marked in presence of high uncertainty shocks. My proxies of uncertainty are related to those of Bloom (2009), since I use the same method of calculation.

Gourio (2012) and Christiano, Motto and Rostagno (2014) showed how higher uncertainty affects both productivity and financial markets, demonstrating how an unexpected and large shock causes a decline in macroeconomic variables (output, investment and employment) as well as in stock prices and interest rate.

A small part of this literature explains how monetary uncertainty and fiscal uncertainty contributed to drive business cycle fluctuations. Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez and Uribe (2010) and Fernandez-Villaverde, Guerron-Quintana, Kuester and

Rubio-Ramirez (2011) have showed how these situations affect output, consumption investment and worked hours.

Instead, the results from Born and Pfeifer (2014) reveal that while policy uncertainty rose during the Great Recession, its pure effects did not play a large role during the crisis. Many economists have investigated the role of monetary policy as instrument to boost the economy after an uncertainty shock. The FED came to the rescue during the Great Recession, but Bloom (2014) and Vavra (2014) have demonstrate how in periods of high volatility the real economy responds less to these stimuli and even the fiscal policy are less effective. These stimulus policies may be outstanding and wider; furthermore, they can reduce uncertainty and fear among the economic agents. Basu and Bundick (2015) demonstrated how the inability of the FED to enforce a monetary policy in presence of interest rate constrained to zero increases volatility and has additional negative consequences on the real economy.

Policymakers have to intervene in order to reduce uncertainty: this message was publicized by Blanchard (2009). The former IMF Chief Economist called upon the FED and US Government to adopt monetary interventions and fiscal stimulus. In this way, through these programs the economic downfall may be curbed, pushing consumers and firms to resume their spending and activities.

3. RISK AND UNCERTAINTY

Almost all of us are risk adverse people: investors are afraid to lose their money when they invest in bonds or stocks, therefore they have to judge the riskiness of their investments; managers don't want to fail when they have to finance a new project or launch a new product on the market; banks have to assess the creditworthiness of their debtors. These are some examples of how uncertainty affects our behaviour.

Starting from 2008, the words risk and uncertainty have become catchwords, even if they have been used as synonyms in the news, newspapers, reports and talk shows and have become a catchword. However, a distinction of these two concepts exits and it can be useful to understand the behavior of households and investors.

Frank Knight, a Chicago economist, in his work *Risk, Uncertainty and Profit (1921)* gave a distinction between the profits made from a new business opportunity for taking a known risk and that for taking an unknown risk. Whereas a "known risk" can easily be converted into an effective uncertainty, a "true uncertainty" is not measurable. Risk can be defined as unknown outcomes, but the odds of happening can be measured or at least learned about. Instead, uncertainty, as uncertain events, is typical of that we do not even know how to describe, given that we are not able to set precise forecasts.

Nonetheless, Knight related the concept of uncertainty to individual experiment; on the other hand, at a macro level, uncertainty could be treated as risk due to the law of large numbers.

The distinction suggested by Knight may be useful to analyze and understand the behavior of investors, firms, households, before and after the financial crisis in the US. In the time period before 2008, investors may have considered their odds as precise and reliable, therefore they were operating in a situation of "known risk". In this economic optimism, firms were able to plan their production and their investments and households were heavily leveraged. In a period that coincided with a housing boom, many people were moving homes in an effort to take advantage of market conditions, despite being already indebted. This stage was characterized by marked out overconfidence and optimism.

Once the crisis arose, investors had to recognize that their instruments and knowledge were inadequate, therefore they were acting in a world of "true uncertainty", and they had to revise their investment policies, but in presence of huge losses and inability to forecast, they held back from making trades or providing capital. The effects weren't only in the financial market, but also in the real economy. In this negative framework, many households lost their houses and their jobs, while the surviving firms stopped investing, fired their workers and scaled down their expectations about future prospects, due to lack of information and inability to set accurate odds. This higher level of insecurity, which involved investors, firms and households, weakened the economy and fueled the crisis.

Until 2008, the US economy lived a period of low volatility, known as Great Moderation, and there is evidence about how uncertainty influenced expectations. Regarding the role of uncertainty in affecting the economic beliefs, John Maynard Keynes wrote in his famous book *The General Theory of Employment, Interest and Money (1935)* as well as in his paper *The General Theory of Employment (1937),* that macroeconomic mechanisms cannot be understood without taking uncertainty as a fundamental factor. According to Keynes, there are some events where there is no scientific basis on which to form any calculable probability. This inability affects investors' mood and it could lead to economic downturns, and drives people to increase their preference for holding money or similar instruments of value, the money taking on its famous role as a "store of value", rather than goods or services.

Indeed, when economic prospective are uncertain, consumers are extremely cautious. Their beliefs drive their choices and if they are insecure, they reduce their consumption causing an effective downfall. This view finds evidence with the consumer's behavior during this severe crisis, as shown in **Figure 7**, therefore it may be helpful to lead policymaker to take the right decision, as acting in order to restore the level of confidence among the households, to get the economy out from the recession.

4. MEASURING UNCERTAINTY

The existence of a measure of uncertainty is crucial to assess its persistence and its effects on the economy. Measuring uncertainty, as its definition suggests, is by its nature difficult. There are several potential sources used by economists. In this wide range of uncertainty proxies, there are: disagreement among forecasters, stock market volatility, corporate bond spread, fluctuation in interest rates, fluctuation in tax rates and Economic Policy Uncertainty index .[1] As can be seen, during the Great Recession these proxies of uncertainty were high and hit their peak.

Figure 8 reports the following proxies of uncertainty: CPI disagreement among forecaster, CITI surprise index, VIX (stock market volatility), BofA Merrill Lynch US Corporate BBB Option-Adjusted Spread (corporate bond spread), Policy Uncertainty Index. However, these common measures of uncertainty could be considered biased by some factors not related to the notion of uncertainty, for this reason Jurado, Ludvigson and Ng (2015) have proposed a measure of economic uncertainty.

The time series are from the first quarter 1985 until the third quarter 2015 and the recession period is indicated in a grey area. The contrast between the fluctuations since the fourth quarter of 2007 and the prior period from 2003-2007 is partly a reflection of the unusually low market volatility in the period prior to the financial crisis and low uncertainty. All these proxies reached spikes in late 2008.

The first measure is the forecasters' disagreement about what the growth rate of GDP is going to be a year from now. The Federal Reserve Bank of Philadelphia in the Survey of Professional Forecasters publishes one of the most famous proxy of disagreement. They release another useful measure the forecast dispersion of average CPI. This proxy is directly influenced by monetary and fiscal policy actions. In period of economic stability, there is an increase in agreement among economists, i.e. during the first half of the 2000s, since the economy is more predictable. Instead, during bad times, as the Great Recession, the disagreement rises significantly.

Scheduled macroeconomic announcements are important for financial markets, since the data released are useful to understand the economic situation and the soundness of stock prices. The

[1] There are other ways to measure uncertainty as dispersion of productivity shocks to firms or firm stock-return dispersion as suggested by N. Bloom *(2014)*.

Chief of the Board of Governors of the Federal Reserve System, Scotti Chiara, elaborated two indexes: Surprise index and Uncertainty one. The aim of the first measure is to summarize recent economic data surprises. It provides an idea whether economic agent are more optimistic or pessimist about the real economy. A positive sign means that agents were more pessimistic about the current situation. However, this index can be considered as a proxy of complexity for economists to forecast the economic outlook and a measure of uncertainty, since the volatility of this index is high during uncertainty period. It had its lower level during the Great Recession. Instead, the Uncertainty Index measures how uncertain agents are about current real activity situation; it provides a proxy of the uncertainty related to the state of the economy. Large values are associated with high uncertainty period, in fact this index peaked during 2008.

The financial news often refers to the Economic Surprise Index realized by Citigroup. This index tries to mimic the market effect of surprises, giving more weight to recent figures and to high impact data of the US economy. It hit its lowest value in late 2008: it indicates how during the Great Recession there was extreme disappointment among economists with respect to their expectation of the US economy performance.

The second measure is the stock market volatility, when for investors it is difficult to assess the proper value of a firm or the uncertainty about the economic outlook is really high, the more they start to buy or sell stocks. There are several indexes that replicate this volatility in different stock markets, the most famous is VIX and it represents the market's expectation of volatility over the next 30 days in S&P 500. It is often referred to as the fear index: the higher the value of VIX is, the more pessimistic investors are. For instance, there are peaks during the Asian Financial Crisis or the Dot-Com Bubble and more recently the Subprime Financial Crisis.

If investors become optimistic about corporate profits and thus reduce their expected probabilities of default, the costs of financing for that firm decreases. Instead, during a period of high uncertainty, potential bondholders charge a significant risk premium. Therefore, Corporate Bond Spreads can be a useful proxy of uncertainty shock. For instance, BofA Merrill Lynch US Corporate BBB Option-Adjusted Spread represents the spreads between a computed OAS (Option-adjusted spread) index of all bonds in a given investment grade category BBB and a spot Treasury curve: on 15th December 2008 it rose to 8% while one year before his value was around 2%.

Interest rate volatility represents another useful way to describe uncertainty. Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez and Uribe (2010) have used this measure and they showed how fluctuations of the real interest rate in small open emerging economics affect real variables. This happens because in a period of high uncertainty people tend to trade bonds more frequently and this has an impact on real interest rates.

Another measure of uncertainty is the tax rate volatility; Fernandez-Villaverde, Guerron-Quintana, Kuester and Rubio-Ramirez (2011) proposed it. In their paper, they found out the adverse effects of fluctuations in fiscal volatility on economic activity and inflation. Harder odds about future return on capital firms reduce investment or increase prices.

At last, Baker, Bloom and Davis have constructed a measure of economic uncertainty, the Economic Policy Uncertainty index. It has three underlying components: the first one quantifies newspaper coverage of policy-related economic uncertainty, the second one reflects the number of federal tax code provisions set to expire in future years, the last one uses disagreement among economic forecasters as a proxy for uncertainty. Using this broad measure, they discovered that an increase in economic policy uncertainty forecasts a decline in economic growth and employment in the following months.

According to Jurado, Ludvigson and Ng (2015) the common proxies of uncertainty are not related to macroeconomic activity and linked with notions of macroeconomic uncertainty. In their paper, they demonstrate how the previously quoted proxy may fluctuate for lots of reasons other than uncertainty, instead with their measures they want capture when the economy gets less predictable, and that are attributable to ‘true’ uncertainty shocks. In their measurements, there are fewer uncertainty episodes than suggested by Bloom (2009), but these new proxies estimate more persistent and larger negative effects on real activity where a shock of macroeconomic uncertainty arises. However, even in this paper, there is evidence that a rise in these measures leads to large negative effects on the real activity.

5. UNCERTAINTY AND THE ECONOMIC SCHOOLS OF THOUGHT

The inner working through which an uncertainty shock affects output, consumption, investment and hours worked can be explained using the economic theory. Nevertheless, the results are different applying the Neo-Classical view rather than the New-Keynesian one. This diversity is caused by two factors.

The first difference is linked to the idea of competition in markets. The New-Classical economists set a world where there is perfect competition and economic agents trade at the equilibrium prices only. Therefore, any change in price involves a variation in its equilibrium level, and any change in equilibrium conditions are the only change they convey. The New-Keynesian Theory suggests another market structure with imperfect competition. One of the arguments in favor used by J. Keynes is that investments need this incomplete competition, they will be higher than under perfect competition, and they will be less variable, since their profits are larger and more certain. In presence of imperfect uncertainty, firms have market power and set their own prices, often held constant for some significant period of time.

The second issue are the prices. In the first case, they sustain the flexibility of prices and their changes are essential for the optimality of their outcomes and the economic stability. Instead, according to J. Keynes prices are sticky; their adjustments are slow and their alterations worsen the performance of the system. When they fail to clear the markets at all, there are excess of supply or demand and government intervention is necessary to return the economy to equilibrium. Hence, this has an important consequence and the uncertainty over price is in part negligible.

In the real economy, the evidence demonstrates that prices are not perfectly flexible and it shows their adjustment on the types of goods and services. This suggests that prices are not determined in perfectly competitive markets.

The different results, that these two theories provide supposedly negative uncertainty shocks, can be understood using the following equations: demand equation, aggregate production function and static first order condition of consumption-leisure demand.

The demand function: $Y_t = C_t + I_t$ (1)

In equation (1) the government expenditures on provided goods and services as well as the net exports are excluded, since I consider a closed economy and I recall that the aim of my investigation is to understand the effects of uncertainty shocks on total output *Y*, household consumption *C*, private investment *I*, and worked hours *N*.

The aggregate production function: $Y_t = A_t F(K_t, L_t)$ (2)

In equation (2) the technology level is denoted as *A*, the capital level as *K*, and the labor as *L* and it is obtained by multiplying the worked hours with the number of employees: $L = Z_t N_t$. The production function F(K, L) has constant returns to scale.

FOC consumption-leisure demand: $\frac{W_t}{P_t} U_1(C_t, 1-N_t)=U_2(C_t, 1-N_t)$ (3)

Equation (3) involves the maximization of the utility of a representative individual over two different 'goods', a mix of consumption and leisure time

$$\max_{C_t, N_t} U_1(C_t, 1-N_t)+U_2(C_t, 1-N_t)$$

assuming that utility increases in both consumption and leisure time, for this reason they are normal goods.

His feasible choices depend on his real wage $\frac{W_t}{P_t}$. Therefore, his budget constraint is given by

$$C_t= \frac{W_t}{P_t}$$

In presence of an unforeseen negative shock, economic agents reduce their consumption expenditures so that they could increase their precautionary savings.

Neo-Classical model: in this model, this increase of uncertainty doesn't affect labor demand, since it depends on the technology level and capital one, but it has an effect on labor supply.

Labor demand: $\frac{W_t}{P_t} = Z_t A_t F(K_t, Z_t N_t)$ (4)

The left side of equation (4) is the marginal cost of labor, instead the right one is the marginal product of labor.

By substituting equation (4) in equation (3), I obtain the labor market equilibrium, as represented in the next equation:

$$Z_t A_t F_2(K_t, Z_t N_t) U_1(C_t, 1 - N_t) = U_2(C_t, 1 - N_t) \quad (5)$$

Equation (5) determines employment and real wages and it provides the first result: if economic agents decrease their consumption expenditure, there must be an increase in labor supply.

Moreover, the production function gives a new output level. Equation (2) shows that total output must increase when the worked hours increase. If consumption diminishes and total output grows, investment expenditures have to increase to satisfy the equilibrium in equation (1).

To illustrate this point we can represent these findings using two graphs in which we represent the labor market and the general equilibrium in goods and services market and the money market. **Figure 9** illustrates how, after an uncertainty shock, an increase in labor supply moves his curve outward. In this new equilibrium, real wages fall but worked hours rise. Instead, in IS-LM Model we have two opposite movements in the investment-saving curve. The output is higher than it was before the unforeseen shock, but its composition is different: the consumption level is lower but higher investment maintains the total output.

In the event that economic agents supply labor inelastically, total output doesn't change, since there aren't variations on equation (2). According to equation (1), a positive variation in investment is necessary to balance the reduction in consumption expenditures in order to maintain the total output unchanged.

New-Keynesian model: in this model, instead, an unexpected negative shock and consequently an increase in uncertainty generates a reduction in consumption, worked hours, investment and output. To study the changes of the real variables on my interest after an uncertainty shock in a New-Keynesian model, I have to rewrite the labor demand. Indeed, in an imperfect-competitive economy, firms have some control over their price: this explains the existence of a mark-up μ over marginal cost MC. Under perfect competition, μ is equal to zero.

$$P = (1+\mu)MC \;;$$

Labor demand: $$\frac{W_t}{P_t} = \frac{1}{\mu_t} Z_t A_t F(K_t, Z_t N_t) \tag{6}$$

The existence of a mark-up causes higher prices and lower output and employment, than under perfect competition. The combination of the labor supply condition in equation (3) and the new labor demand from equation (6) provides:

$$\frac{1}{\mu_t} Z_t A_t F_2(K_t, Z_t N_t) U_1(C_t, 1 - N_t) = U_2(C_t, 1 - N_t) \tag{7}$$

After a reduction in consumption expenditures, economic agents are willing to work more and this increase of labor supply reduces real wages. However, in case of predetermined prices, savings on wage costs lead to an increase in the mark-up, which leads to lower wages and higher unemployment. Furthermore, as long as mark-up is higher than its previous level, a contraction in demand for consumption, as especially investment goods, is expected in response. The size of the reduction in these two variables depends on the magnitude of the mark-up. According to equation (1) a reduction in both variables consumption and investment pushes down the aggregate output.

With the help of **Figure 10,** it is possible to look at the adjustment of output, investment, consumption, worked hours after a negative unforeseen shock using a representation of the labor market and IS-LM model in a New-Keynesian framework. An increase in labor supply moves his curve outward, but an increase in mark-up leads to an inward shift of the labor demand curve. Both worked hours and real wages are lower than before the uncertainty shock. Instead, in IS-LM space the new output level is lower after this negative event, since economic agents reduce their consumption and investment expenditures after the increase in mark-up.

This basic explained mechanism employed by the economy in a New-Keynesian model is consistent with the data from the Great Recession. During this period of high uncertainty there was a contraction in Real GDP, Real Gross Personal Domestic Investment and Real Personal Consumption Expenditures. In the same period, the Unemployment Rate doubled. This evidence is in line with the works of N. Bloom. He demonstrates how, in presence of a foreseen shock aggregate output, private consumption, private investment and hiring fall.

To summarize: while in a Neo-Classical model after an uncertainty shock we have a reduction in consumption but an increase in aggregate output, investment and worked hours, in a New-Keynesian model this unexpected event leads to a contraction in aggregate output, consumption, investment and worked hours. Observing the real case of high uncertainty, the second model provides the right results.

6. REAL BUSINESS CYCLE MODEL

How can macroeconomists observe the workings of an economy? Essentially through building and manipulating models. There are two main economic theories, which explain business fluctuations through the following two different economic theories: Neo-Classical and New-Keynesian. There are different ways of analysis as real business cycle (RBC) and dynamic stochastic general equilibrium (DSGE).

Arthur F. Burns and Wesley C. Mitchell (1946) suggested one of the first definition of business cycles. According to their view, business cycles are different from other types of fluctuations. They occur in many activities, have a sequence of phases (expansion, contractions, and revivals) which is recurrent but not periodic, and have varied but somewhat long duration.

However, Robert Lucas (1977) proposed a modern definition of cycles as a joint dynamic behavior of deviations of variables from trend. He wrote:

> *Technically, movements about trend in gross national product in any country can be well described by a stochastically disturbed difference equation of very low order. These movements do not exhibit uniformity of either period or amplitude, which is to say, they do not resemble the deterministic wave motions which sometimes arise in the natural sciences. Those regularities which are observed are in the co-movements among different aggregative time series.*

The newness is the co-movements among the aggregate variables. This is one of the keywords to understand the different views between real business cycle and New-Keynesian theorists. The other main issues of their disagreement are: how to identify shocks, which ones (if nominal or real shocks) explain most of the observed data of a given economy in a given time period and what is the dynamic propagation of shocks in the economy.

A Real Business Cycles model explains the co-movements on the real side of the economy, when aggregate economic variables fluctuate in their trend. The aim of this approach is to understand the internal mechanism after an exogenous disturbance, a real shock. The fluctuations mainly examined are: unemployment, output and its component.

After this introduction, I will begin the analysis of the economic fluctuations due to an unforeseeable event in a competitive economy using Basic Real Business Cycle Model then I will study the behavior of the economy in presence of uncertainty shock in a Basic New

Keynesian model. The guidelines of my investigation are a manual by David Romer (2012) and a paper written by Guillermo A. Calvo (1983).

6.1 Basic RBC Model

The general restrictions in this model are: the absence of frictions or imperfections and symmetry. Therefore, there is perfect competition in all markets (and it is Pareto Optimal), wages are flexible, firms are identical and price takers as well as households are identical, price takers and infinitely lived. However, since it is a real model, there is no role for money or nominal variables. This monetary neutrality feature of the RBC model requires flexible prices. This setting suggests the link with this model and the Neo-Classical view. The characters involved in this analysis are firms and households. By understanding their behaviors, it is possible to understand the effect of an uncertainty shock on the overall economy.

6.1.1 The Firms

During each period firms hire workers at wage w_t and rent capital from the households at a rate s_t. Their production function is a Cobb-Douglass.

$$y_t = A_t k_t^{\alpha} l_t^{(1-\alpha)}, \qquad 0 < \alpha < 1 \tag{1}$$

Here, y_t is the real production and its inputs are: A_t is the stochastic technology process ($A_t > 0$), k_t is the capital stock (predetermined endogenous variable), l_t is the labor. Output is divided between consumption (C) and investment (I). Every period the capital depreciates at the rate δ. Thus the capital stock in period t+1 is:

$$k_{t+1} = I_t + (1-\delta)k_t \tag{2}$$

Firms want to maximize their profits as follow, in a static framework:

$$\max_{\{k_t,\, l_t\}} \left(A_t k_t^{\alpha} l_t^{(1-\alpha)} - w_t l_t - (s_t + \delta)k_t\right) \tag{3}$$

Firms hire new workers until the (real) wage rate is equal to marginal product of labor, instead they rent capital until the (real) rental rate of capital is equal to marginal product of capital. The derivation of marginal product of labor (MPL) and marginal product of capital (MPK) is obtained by profit maximization:

$$\text{MPL:} \qquad (1-\alpha)A_t k_t^{\alpha} l_t^{-\alpha} - \delta = w_t \tag{4}$$

$$\text{MPK:} \qquad A_t k_t^{(\alpha-1)} l_t^{(1-\alpha)} - \delta = s_t \tag{5}$$

6.1.2 The Households

Households have a certain amount of time each period that can be used either to work or as leisure time. They want to maximize the expected value of the intertemporal utility function:

$$\max_{\{c_t,\, l_{t,}\, k_{t+1,}\}} E_0 \sum_{t=0}^{\infty} \beta^t \left[u(c_{t,}) + V(1 - l_t)\right] \tag{6}$$

In this utility function: c_t is the consumption in real term, (1- l_t) denotes the leisure time, β is the time discount factor (the lower its value, the less future consumption and leisure are valued respect to present ones).

Considering households in period t, they earn a salary (w_t) and receive rents (s_t) from firms, but they depend on the technological process. However, households act to maximize their intertemporal utility function subject to their budget constraint:

$$c_t + k_{t+1} = w_t l_t + [s_t + (1-\delta)]k_t \tag{7}$$

To solve the household intertemporal problem, I define the Lagrangian function:

$$L_0 = E_0 \sum_{t=0}^{\infty} \{\beta^t [u(c_t + V(1 - l_t)] + \lambda_t [w_t l_t + [s_t + (1-\delta)]k_t - c_t - k_{t+1}] \tag{8}$$

The first order conditions are given by the first derivatives of L_0 with respect to $c_t,\, l_{t,}\, k_{t+1,}$ equal to zero. They are respectively:

$$\frac{\partial L}{\partial c} = 0,\; \mathrm{u}'(c_t) = \lambda_t \tag{9}$$

$$\frac{\partial L}{\partial l} = 0,\; \mathrm{V}'(1 - l_t) = \lambda_t w_t \tag{10}$$

$$\frac{\partial L}{\partial k} = 0,\; \lambda_t = \beta E_t \lambda_{t+1} (s_t + 1 - \delta) \tag{11}$$

Substituting equation (9) into (10) yields the marginal rate of substitution between consumption and leisure:

$$\frac{\mathrm{V}'(1-l_t)}{\mathrm{u}'(c_t)} = w_t \tag{12}$$

Instead, using equation (9) and (11) I derive the stochastic Euler equation:

$$\mathrm{u}'(c_t) = \beta E_t u'(c_{t+1})\,(s_t + 1 - \delta) \tag{13}$$

An alternative way to write equation (8) is the following:

$$V'(1 - l_t) = u'(c_t)\ [(1-\alpha) A_t k_t^{\alpha} l_t^{-\alpha} - \delta] \quad (14)$$

6.1.3 Results

Because of an uncertainty shock, the household behavior changes and an analysis of these effects can be conducted using the following system of equations:

$$u'(c_t) = \beta E_t u'(c_{t+1})\ (s_t + 1 - \delta) \quad (13)$$

$$V'(1 - l_t) = u'(c_t)\ [(1-\alpha) A_t k_t^{\alpha} l_t^{-\alpha} - \delta] \quad (14)$$

$$k_{t+1} = y_t - c_t + (1 - \delta) k_t \quad (15)$$

Under standard preferences, uncertainty will lead to higher expected marginal utility of consumption, i.e.: $E_t u'(c_{t+1})$ rises. Therefore, households reduce their current consumption, so they can save more money and they are willing to work more, hence labor supply increases, leading to an increase in total output. The explanation of this movement can be observed in equation (14): unless something happens to MPL, consumption and hours of work will move in opposite directions, since they are normal goods.

From equation (15) a higher value of aggregate production triggers more investments and future capital. Therefore, the total GDP doesn't change since the reduction in consumptions is counterbalanced by a positive variation in investments.

After a negative uncertainty shock, the expectations and the news about the future economic trend can help the economy to recover quickly or at the worst they can increase pessimism among consumers. In this last scenario, the effect of negative news about future wealth among households or a negative outlook about future productivity can be studied with the system of equations (13), (14) and (15) with a similar result.

The Real Business Cycles model provides the same result reported in **Figure 9**, again this is in contrast with empirical data. This kind of shock tends to generate the wrong co-movement in this model. A reasonable explanation is that there are some market imperfections missing from our model. For this reason, I want to introduce in my model an economy with imperfect competition among firms and the presence of mark-up.

6.2 Basic New Keynesian Model

This model has a different assumption from the previous one. Business cycles are driven by nominal and real shocks, there is monopolistic competition among firms and/or in labor market, there are nominal rigidities and monetary policy does play a role. As in the basic RBC model, there is not asymmetric information.

In this new setting, there are frictions and imperfections as prices do not adjust instantaneously as well as firms have some market power, but households are identical and so is price-taking as in the previous model.

Conversely, from the previous model the actors in my findings are householders, firms and the central bank. This last character has a central role in reducing economic fluctuations, adopting its monetary policy or through statements.

6.2.1 The Households

Differently from the previous model, I introduce an important assumption: consumers love variety, so goods are no more perfect substitutes as it happens in reality. Therefore, the expected value of the intertemporal utility function is:

$$\max \quad E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, 1 - l_t) \tag{16}$$

where $U(C_t, l_t) = \frac{C_t^{(1-\sigma)}}{(1-\sigma)} - \frac{(1-l_t)^{(1+\theta)}}{(1+\theta)}$ and $C_t \cong \left(\int_0^1 C_t\,(i)^{\left(1-\frac{1}{\varepsilon}\right)} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$ (love for variety).

Since there are several goods in the economy ε represents the constant elasticity of substitution between different goods. The higher degree of substitution, the less market power producers have. Instead, σ is the inverse of the intertemporal elasticity of substitution.

Every period, households can buy one-period riskless bond B_t at a price 1 with an interest yield of R_t . Moreover, they receive the dividends D_t from their firms.

Faced with the following budget constraints, the household acts to maximize the expected utility function. The period budget constraint is:

$$\int_0^1 P_t\,(i)\, C_t\,(i)\, di + B_t = (1 + R_t)B_{t-1} + W_t l_t + D_t \tag{17}$$

To solve the household intertemporal problem, I define the Langrangian function:

$$L_0 = E_0 \sum_{t=0}^{\infty} \{\beta^t \left[\frac{C_t^{(1-\sigma)}}{(1-\sigma)} - \frac{(1-l_t)^{(1+\theta)}}{(1+\theta)} \right] + \lambda_t [(1+R_t)B_{t-1} + W_t l_t + D_t - P_t C_t - B_t] \qquad (18)$$

The first order conditions are given by the first derivatives of L_0 with respect to C_t, $l_{t,}B_t$ equal to zero:

$$\frac{\partial L}{\partial c} = 0, C_t^{-\sigma} = \lambda_t P_t \qquad (19)$$

$$\frac{\partial L}{\partial l} = 0,\ (1-l_t)^{-\theta} = \lambda_t W_t \qquad (20)$$

$$\frac{\partial L}{\partial B} = 0,\ \lambda_t = \beta E_t \lambda_{t+1} \qquad (21)$$

Using equation (19) and (21) I derive the Euler consumption equation:

$$1 = \beta E_t \left(\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \frac{P_t}{P_{t+1}} \right) \qquad (22)$$

Instead using equation (19) and (20) I derive the labor supply equation:

$$(1-l_t)^{-\theta} = C_t^{-\sigma} \frac{W_t}{P_t} \qquad (23)$$

To this end the wage is given, i.e. workers do not have any market power. Instead, $1/\theta$ is the elasticity of labor supply to the wage rate, given a constant marginal utility of consumption.

6.2.2 The Firms

What differentiates monopolistic competition from perfect competition is that a large number of firms sell differentiated products and have some market power. Indeed, in this economy, we have several firms indexed by $i \in [0,1]$, and each one produces differentiated goods. Even though their final product is different, they have the same production function:

$$y_t(i) = A_t k(i)_t^{\alpha} l_t(i)^{(1-\propto)} \qquad (24)$$

As well as all firms face an identical demand schedule and take the aggregate price level and the aggregate demand as given:

$$y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} y_t \equiv Y_t^d(P_t\ ) \qquad (25)$$

Notice that in the equation above the demand for each intermediate goods depends negatively on its related price and positively on total production, since there is not perfect substitutability between goods types. Different prices do not lead to a perfect substitution. In equation (25) the larger y_t, the higher the demand for each variety of goods y_t(i).

6.2.2.1 Optimal price setting with flexible prices and constant mark-up

At this stage, I suppose an economy with flexible prices and constant mark-up. Every firm wants to maximize its profits with respect to labor and price given equation (24) and (25). The lagrangian is:

$$L_t = P_t(i)\, y_t(i) - W_t l_t\,(i) - MC_t^N(i)\left(y_t(i) - A_t k(i)_t^{\alpha} l_t(i)^{(1-\propto)}\right) \qquad (26)$$

Where $MC_t^N(i)$ denotes the Lagrange multiplier (the nominal marginal cost).

At the optimum:

$$W_t = (1-\propto) MC_t^N(i) A_t k(i)_t^{\alpha} l_t(i)^{(-\propto)} \qquad (27)$$

$$P_t(i) = \frac{\varepsilon}{\varepsilon-1}\, MC_t^N(i) \qquad (28)$$

From equation (26) we obtain two important pieces of information: the desired constant mark-up $\frac{\varepsilon}{\varepsilon-1}$ and the real marginal cost $MC_t(i) = \frac{\varepsilon-1}{\varepsilon}$.

6.2.2.2 Optimal price setting with sticky prices and variable mark-up

Conversely, I use Calvo (1983) to show an economy with sticky prices and variable mark-up. In any given period each firm may reset its price with probability (1-ϑ), thus a fraction (1-ϑ) of producers reset their prices, while a fraction ϑ keep their price unchanged. Therefore, the average duration of a price is given by $(1-\vartheta)^{-1}$ and ϑ is an index of price stickiness.

For simplicity, I suppose that all firms resetting prices will choose an identical price P_t^*.

Recalling P_t:

$$P_t = \left[\int_{S(t)} P_t(i)^{(1-\varepsilon)}\, di + (1-\vartheta)(P_t^*)^{(1-\varepsilon)}\right]^{\frac{1}{(1-\varepsilon)}} \qquad (29)$$

where $S(t)$ is the set of firms not reoptimizing their posted price.

Since the distribution of prices among firms not-resetting their prices corresponds to the distribution of prices prevailing in the previous period we have:

$$P_t = \left[\vartheta P_{(t-1)}^{(1-\varepsilon)} + (1-\vartheta)(P_t^*)^{(1-\varepsilon)}\right]^{\frac{1}{(1-\varepsilon)}} \qquad (30)$$

or, alternatively, dividing by $P_{(t-1)}$:

$$\Pi_t^{(1-\varepsilon)} = \vartheta + (1-\vartheta)\left(\frac{P_t^*}{P_{(t-1)}}\right)^{(1-\varepsilon)} \qquad (31)$$

where $\Pi_t = \frac{P_t}{P_{(t-1)}}$. Notice that in a steady state with zero inflation $\frac{P_t^*}{P_{(t-1)}} = 1$.

Log-linearizing around a zero inflation ($\Pi_t = 1$) steadystate implies:

$$\pi_t = (1-\vartheta)(p_t^* - p_{(t-1)}) \qquad (32)$$

Inflation results from the fact that firms setting in any given period choose a price, p_t^*, that differs from the average price in the economy in the previous period, $p_{(t-1)}$. In this economy only a fraction $(1-\vartheta)$ of firms change their price, instead in an economy with flexible prices: $\pi_t = p_t - p_{(t-1)}$.

Under Calvo price-setting structure $\Psi_{t+k}(\bullet)$ is the period t+k cost function, in nominal terms, $Y_{t+k|t}$ is the output in period t+k for a firm resetting its price at time t and $Q_{t,t+k}$ represent a period t stochastic discount factor.

Thus, when a firm has to re-optimize its price in period t it will choose the price P_t^*. In order to maximize the current value of the expected stream of profits generated while that price remains effective:

$$\max_{P_t^*} \quad \sum_{k=0}^{\infty} \vartheta^k E_t\left[Q_{t,t+k}\left(P_t^* Y_{t+k|t} + \Psi_{t+k}\left(Y_{t+k|t}\right)\right)\right] \tag{33}$$

subject to the sequence of demand constraint:

$$Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\varepsilon} Y_{t+k} \equiv Y_{t+k}^d(P_t^*) \tag{34}$$

At the optimum:

$$\sum_{k=0}^{\infty} \vartheta^k E_t\left[Q_{t,t+k}\, Y_{t+k}^d(P_t^*)\left(P_t^* - \frac{\varepsilon}{\varepsilon-1}\frac{\partial \Psi_{t+k}}{\partial\, Y_{t+k|t}}\right)\right] = 0 \tag{35}$$

Reminding how P_t^* is the optimal price, desired markup is $\mathcal{M} = \frac{\varepsilon}{\varepsilon-1}$ and nominal marginal cost is $MC_{t+k|t}^N = \frac{\partial \Psi_{t+k}}{\partial\, Y_{t+k|t}}$. More compactly,

$$P_t^* = \frac{\varepsilon}{\varepsilon-1}\sum_{k=0}^{\infty} E_t\left[w_{t,t+k}\, MC_{t+k|t}^N\right] \tag{36}$$

where $w_{t,t+k} \equiv \frac{\vartheta^k Q_{t,t+k} Y_{t+k}^d(P_t^*)}{\sum_{k=0}^{\infty} \vartheta^k E_t[Q_{t,t+k} Y_{t+k}^d(P_t^*)]}$.

If all firms reset their price in any given period $\vartheta = 0$, $P_t^* = \frac{\varepsilon}{\varepsilon-1}\frac{\partial \Psi_{t+k}}{\partial\, Y_{t+k|t}} = \frac{\varepsilon}{\varepsilon-1} MC_t^N$ as seen above. The markup is a constant and optimal prices are a multiple of the current marginal cost. Instead, when $\vartheta > 0$, the optimal price depends on future expected values of aggregate variables as well as future nominal marginal costs. Put differently, one can see that all the fluctuations in the markup are due to firms being unable to adjust prices.

The optimal conditions can be rewritten as:

$$\sum_{k=0}^{\infty} \vartheta^k E_t \left[Q_{t,t+k}\, Y_{t+k|t} \left(\frac{P_t^*}{P_{t-1}} - \frac{\varepsilon}{\varepsilon - 1}\, MC_{t+k|t} \Pi_{t-1,t+k} \right) \right] = 0 \qquad (37)$$

Where $MC_{t+k|t}$ is the real marginal cost in period t+k for a firm whose price was last set in period, $MC_{t+k|t}$. $MC_{t+k|t} = \frac{\partial \Psi_{t+k}}{\partial Y_{t+k|t}} / P_{t+k}$.

Applying Calvo pricing rule in our model we can determine the nature of inflation modifying the last equation. This approach teaches us how inflation will be higher when firms expect average mark-up M_{t+k} to be lower than at their steady state level M. Having the opportunity to reset their prices, the fraction $(1-\vartheta)$ of the firms in our economy, will choose a price above the economy average price level in order to readjust their markup closer to the desired level M. Therefore, the nature of inflation here results from the price-setting decisions of firms setting their prices in response to current and expected cost conditions.

6.2.3 The Central Bank

The last feature of this model is the introduction of a Central Bank in a cashless economy. This authority conducts monetary policy by following Taylor's rule (1993): it reacts to deviations from the natural level output and from the inflation target setting the net nominal interest rate, according to Taylor's rule:

$$i_t = \pi_t + r_t^* + a_\pi(\pi_t - \pi_t^*) + a_y(y_t - y_t^*) \qquad (38)$$

In equation (38), i_t is the target short-term nominal interest rate, π_t is the rate of inflation, π_t^* is the desired rate of inflation, r_t^* is the assumed equilibrium real interest rate, y_t is the real GDP and y_t^* is the natural GDP. All these variables are expressed in their logarithmic form.

According to Taylor's rule, Central bank raises or lowers the short-term nominal interest rate i_t in response to deviations of inflation and output from their steady-state levels. This rule presumes that this monetary authority chooses its target inflation rate π_t^* and the response parameters a_π, a_y. In particular, a positive response $(a_\pi > 0)$ of the interest rate to movements in inflation ensures that this policy rule remains consistent with the existence of a unique rational expectation equilibrium.

Moreover, changes in the nominal interest rate i_t affect expected inflation and the real interest rate as Fisher's rule describes:

$$i_t = E_t\pi_{t+1} + r_t \qquad (39)$$

6.2.4 Results

Given that, I write down the following system of equations to demonstrate the effects of an uncertainty shock in a New-Keynesian with flexible prices and constant mark-up:

$$(1-l_t)^{-\theta} = C_t^{-\sigma}\frac{W_t}{P_t} \tag{23}$$

$$y_t(i) = A_t k(i)_t^{\alpha} l_t(i)^{(1-\propto)} \tag{24}$$

$$W_t = (1-\propto) MC_t^N(i) A_t k(i)_t^{\alpha} l_t(i)^{(-\propto)} \tag{27}$$

$$P_t(i) = \frac{\varepsilon}{\varepsilon-1} MC_t^N(i) \tag{28}$$

$$k(i)_{t+1} = y(i)_t - c(i)_t + (1-\delta)k(i)_t \tag{15}$$

where (23) is labor supply, (24) is the production function, (27) is labor demand, (28) is the price equation and (15) is the investment capital equation.

As it is known, uncertainty will lead to a reduction in the current consumption and the households are willing to work more, as suggested in equation (23). This increase in labor supply and unchanged labor demand causes a reduction in salary. A higher labor supply not only reduces wages but also the nominal marginal cost faced by the firms.

I recall equation (28) to describe the impact that these lower marginal costs have on the price level. In an economy with constant mark-up and flexible prices, the lowered nominal marginal costs entail a decrease in the current price level.
Moreover, it should not be forgotten that labor supply affects total output, therefore the latter increases as showed in equation (24).

From equation (15) a higher value of aggregate production triggers more investments and future capital. This new investment counteracts the reduction in consumptions maintaining the GDP level unaffected.

The same findings result from a Basic Real Business Cycle model as illustrated in **Figure 9**. As in the previous section I want to lay emphasis on these results. Observing the empirical data, the movement among GDP, consumption, investments hours worked is different. Again, even if I have introduced new assumptions, the model is unable to describe the effects of an uncertainty shock in the real world.

My last attempt to illustrate the effects of an uncertainty shock is a New-Keynesian model with sticky prices and flexible mark-up. I have summarize the model, already described, with the following system of equations:

$$(1 - l_t)^{-\theta} = C_t^{-\sigma} \frac{W_t}{P_t} \quad (23)$$

$$y_t(i) = A_t k(i)_t^{\alpha} l_t(i)^{(1-\propto)} \quad (24)$$

$$W_t = (1{-}\propto) MC_t^N(i) A_t k(i)_t^{\alpha} l_t(i)^{(-\propto)} \quad (27)$$

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \sum_{k=0}^{\infty} E_t \left[w_{t,t+k}\, MC_{t+k|t}^N \right] \quad (36)$$

$$k(i)_{t+1} = y(i)_t - c(i)_t + (1 - \delta) k(i)_t \quad (15)$$

where (23) is labor supply, (24) is the production function, (27) is labor demand, (36) is the price equation and (15) is the investment capital equation.

As in the previous model, also under sticky prices and flexible mark-up, households want to reduce their current consumption after an unforeseeable event. In response to this shock, the households increase their precautionary savings, and they are willing to work more, as can be seen in equation (23). The willingness of the households to increase their hours worked reduces the wages and leads to a lower marginal cost of production.

Conversely, from a Real Business Cycle and a New-Keynesian model with flexible prices and constant mark-up, the aggregate effects are different. In a sticky price economy, this reduction in marginal cost is compensated with a higher mark-up: this relation is demonstrated in equation (36). An increase in the mark-up shifts labor demand down, the compensation becomes even lower and a higher unemployment level follows. Hence, this increase in labor supply involves a totally non-desirable effect: lower salaries and hours worked.

Moreover, this overall effect in labor economy negatively affects the production function represented in equation (24) and the investment in capital stock by firms, see equation (15). The choice of reducing the investment level by firms can be explained with the Real Option Theory.

After this uncertainty shock, the aggregate economy is depressed and there is a co-movement in consumption, investment, hours worked and real wages. These findings match with the empirical data as well as with the graphical representation in **Figure 10**.

The reason why this model is capable of producing a co-movement among the economic variable consistent with the reality is due to the flexible mark-up and its effect on labor demand. In the previous two models, Basic Real Business Cycle and Basic New-Keynesian Model with flexible price and constant mark-up, only the labor supply changes after an uncertainty shock while the labor demand remains unaffected since prices absorb the variation in wages.

6.3 The role of uncertainty shock and the monetary policy

During the Great Recession, one of the most uncertain periods, the US economy dropped. In this situation of crisis, its effects can persist for several years and a period without recovery is costly. Eight years after the sub-prime crisis, few countries have been able to grow at a robust rate. One of them is the US. However, even in this economy its gross domestic product is well below what it hypothetically would have been had the crisis not occurred.

As shown in chapter 9, using the impulse response function I have proved how an uncertainty shock hits consumptions and investment and worked hours declined. The reduction in consumption is due in part to the need for households to maintain their precautionary savings also because many workers lost their jobs. This is expressed in equation (23).

To avoid a long period without growth, the Federal Reserve of the US has lowered its interest rate. That is because to revamp investments, conversely to other countries or areas as the Eurozone, the US bank system supported the recovery. This outstanding FED intervention rescued the US economic future.

How dramatic can the effects of an uncertainty shock be? I will try to explain the worst-case scenario after an uncertainty shock, in order to highlight the role of the FED monetary policy and its effectiveness. As Teulings, and Baldwin (2014) have demonstrated, a country's future capacity to produce and its competitiveness, such as the development of productivity and the stock of capital as well as the size and the level of education depend on its output and economic growth.

In section 6.2.4, using equation (15) and equation (24), I show how the capacity of a country to produce is determined by the level of capital stock, therefore the investment. There is not convenience for a company to increase its production when the demand is low and to invest if there are no profitable returns. In this hypothetical situation, firms may stop to invest in research and development of new products, preventing any new profitable business.

In such destressed situation, there is a credit crunch because of the rise in default risk as a result when banks may lend their money charging higher interest rates, thus deterring new investment.

A low level of investment today will not lead to a higher production tomorrow and it also reduces the number of innovations in an economy, hampering the possibility of creating new job places and discouraging private consumption. This happens because the household wealth declines as well their income. Furthermore, with high unemployment the unemployed people become less qualified to work, thus essentially unemployable. In this extreme case without an intervention of the monetary authority, the recovery is impossible to reach.

Therefore, in absence of the zero lower bound, a monetary policy intervention can stabilize the economy for any given level of uncertainty shock. As mentioned in section 6.2.3, the central bank, managing the nominal interest rate, can also control real interest rates in the short time, thus it can potentially influence the level of output and employment. During the Great Recession, once overnight interest rate accomplished the zero lower bound, the FED started unusual monetary policy interventions in order to get households and firms spending again and banks willing to lend.

7. DATA

Before getting into the model, this section presents information about the data used to conduct my research. I used the following types of data: Real Gross Domestic Product, Personal Consumption Expenditures, Gross Private Domestic Investment, Average Weekly Hours Worked, Consumer Price Index for All Urban Consumers, Federal Fund Rate, VIX and Stock Index (Standard and Poor's 500). The actual releases of macroeconomic variables are used to estimate the underlying model from which I gather the coefficients fit for the purpose to assess the impact of an uncertainty shock in the real economy. In what follows, I describe the details of the data.

The analysis covers the United States economy from January 1964 to the September 2015, but my research is performed using two different end-points: the first case includes the crisis period, instead the second one ends in the last quarter of 2008, because starting from December 2008 the FED funds target rate reached the zero lower bound and the US monetary authority started its first Quantitative Easing program.

First, I want to use those variables that are regarded as the main real activity indicators followed by economists, governments, and central banks as indication of the health of the economy. Second, I choose indicators from the financial markets as VIX and Stock Index to determine a proxy of uncertainty, well known as "implied volatility" or "risk neutral volatility". In this work, I will not consider the role of the government through fiscal policy.

Table 2 recapitulates the indicators, together with their frequency, features, time series and sources. Moreover, it reports the other variables that I will use to conduct my robustness test: Economic Policy Uncertainty Index, 5 year treasury rate and shadow rate. A short description regarding the feature of these variables will be provided in the next sections. The last rightmost column lists the source of the data series that I use to construct my model.

While Real Gross Domestic Product and Gross Private Domestic Investment data are available every quarter, the frequency of the other variables is daily or monthly as indicated in **Table 2**. Therefore, for these indicators I compute a quarterly transformation. Furthermore, I will use the logarithm of the following variables: Personal Consumption Expenditures, Gross Private Domestic Investment, Average Weekly Hours Worked, Consumer Price Index for All Urban

Consumers, VIX and Standard and Poor's 500 (S&P500). I made this decision to reduce skewness.

I collected the macroeconomic data from the Federal Reserve Bank of St. Louis. The only exception is the Average Weekly Worked Hours Worked, since the series comes from the US Bureau of Labor Statistic. The source of the Federal Fund Rate and 5 year treasury rate is the Board of Governors of the Federal Reserve System, while the time series of Standard and Poor's 500 come from the Federal Reserve Bank of St. Louis.

Among the several proxies of Uncertainty list in chapter 4, I choose the VIX. However, the pre-1986 time series of this measure of implied volatility are unavailable. N. Bloom (2009) suggests the following way in order to have a measure of volatility before January 1986. The actual monthly returns volatilities are calculated as the monthly standard deviation of the daily S&P500 index normalized to the same mean and variance as the VIX index when they overlap from 1986 onward. **Figure 11** represents the monthly U.S. stock market volatility. From 1885 to the end of 1985 there is the actual volatility computed as explained above, instead from January 1986 onward there is the implied volatility depicted from VIX index constructed by the Chicago Board Option Exchange (CBOE).

Furthermore, in the second stage of my analysis I replace the VIX with a dummy variable, that takes value 1 when the HP detrended VIX has a standard deviation higher than 1.65 the mean, and 0 otherwise. This design variable was used by N. Bloom (2009), to distinguish the large uncertainty shocks from the smaller one. Using this measure, I can study the response of the economy on really high uncertainty shocks.

I obtained this measure firstly using the Hodrick-Prescott filter (HP) to remove the trend component of my time series from VIX. In **Figure 11** the HP manipulation is plotted, with the trend and the business cycle component. In the second stage, I create a a 0,1 dummy variable. In the sample ranges from January 1964 to September 2015 there are sixteen situations with large significant uncertainty shock.

Each of these sixteen quarters with extremely high volatility is associated with a bad event as war, political issue and stock market shocks. It is noticeable comparing my spikes with the findings of Bloom (2009) that almost all of these peaks are the same. However, in my research the time range period is different as well the periodicity from the sample used by Bloom and this dissimilarity has affected my findings. The reason why the findings are not exactly coincident is due to the smoothing effect of the quarterly transformation and the different standard deviation of my HP detrended VIX sample.

The spikes in my analysis related to war or terrorist events are: in 1966:Q3 Vietnam War, in 1970:Q2 Kent State Shooting and in 2003:Q1 Invasion of Iraq. Instead, the period with sharp peak having reference to political and monetary issues are: in 1974:Q2-Q3 Franklin National Bank Bailout, in 1982:Q4 Reaganomics, in 1987:Q4-1988:Q1 Black Monday Crash, in 2002:Q3-Q4 WorldCom Bubble, in 2008:Q3-2009:Q1-Q2 Financial Crisis, Credit Crunch and Quantitative Easing 1, 2011:Q3-Q4 Treasury Flash Crash and 2015:Q3 Yuan Devaluation.

8. ANALYSIS

An analysis of the immediate effects as well as the duration of the propagation of an uncertainty shock is useful to understand where its effects spread to and how the policyholder can act in order to avoid unpleasant consequences. I am interested in understanding the relationship between a shock of my proxy of uncertainty, the VIX, and the dynamic response of my key macro variables: consumption, investment and worked hours.

With this investigation, the empirical findings can support the predictions of New-Keynesian theoretical models on uncertainty as a negative driving force on consumption, investment and worked hours, demonstrating the slump and the comovements of these three variables after a rise in the VIX.

To investigate the outcomes of uncertainty on economic dynamics in the US, I estimate a Structural Vector Autoregressive Model (SVAR). To sort out the contemporaneous relationships between the variables after the uncertainty shock, I conduct my quantitative analysis using EViews as statistical software.

The data sample available for the US is relatively abundant. I estimate the model with quarterly data starting in 1964 till the third quarter of 2015. The SVAR model contains seven time-series variables: an uncertainty proxy (VIX and dummy of HP detrended VIX), S&P 500, Personal Consumption Expenditures, Gross Private Domestic Investment, Average Weekly Hours Worked, Consumer Price Index for All Urban Consumers, Federal Fund Rate.

To generate my predicted model, in order to gather the effects of an uncertainty shock, I follow the technique recommended by Christopher A. Sims, in one of his most important works *Macroeconomics and Reality (1980)*. The Cholesky decomposition is one method of identifying the impulse–response functions in a VAR; thus, this method corresponds to a SVAR.

The seven variables of my basic VAR are collected in the vector:

$$Zt = [VIX_t, LNSP500_t, LNPCONS_t, LNINV_t, LNWH_t, LNCPI_t, FR_t]'.$$

Thus, I place the uncertainty proxy measure as the first variable in the SVAR model. This Cholesky Ordering implies that this variable does not respond to macroeconomic shocks in the impact period, but the other six variables are allowed to respond to an uncertainty shock. I choose the S&P 500 as second variable, in contrast to the model used by Bloom (2009), because organized in this way I can understand the instant response to uncertainty shock, since this variable is fast-moving. In the subsequent periods, however, uncertainty responds to all shocks through its relation to the lags of the macroeconomic variables as specified in the VAR model.

I consider the following structural VAR:

$$A\ Zt = \Phi\ Z_{t-1} + \varepsilon_t$$

where A is a 7x7 full-rank matrix and $E[\varepsilon_t\ \varepsilon_t'] = I$. The dynamic responses to the structural shocks ε_t. are of particular interest.The reduced-form VAR is estimated first:

$$Zt = B\ Z_{t-1} + C\ \varepsilon_t$$

where B denotes $A^{-1}\ \Phi$ and C denotes A^{-1}. The number of lags included in VARs is chosen with the Akaike criterion.

As last step, the main results are represented in the form of impulse response functions (IFRs) in order to show the dynamic reaction of the variables in my sample to a shock in my proxy of uncertainty. The impulse response functions are shown in **Figures 12-15**. While the blue solid lines are median responses of the endogenous variables to one standard deviation increase in the innovations to uncertainty, the red dashed lines represent the rage of plus minus two times the standard errors confidence band around the point estimates.

9. IMPULSE RESPONSE FUNCTIONS

Sections 9.1.1 and 9.1.2 show the quantitative findings from a VAR model with logarithm of VIX as proxy of uncertainty. Instead, in sections 9.2.1 and 9.2.2 I have reported the quantitative results replacing the logarithm of VIX with a dummy variable called HP VIX. In this last case, I have studied the impact of large uncertainty shocks, excluding the small ones.

9.1.1 VIX proxy of uncertainty: dataset from 1964 to 2015.

The IRFs plotted in **Figure 12** indicate that an exogenous increase of my uncertainty proxy VIX leads to a decline in all my variables: logarithm of S&P 500 (LNSP500), logarithm of consumption (LNPCONS), logarithm of investment (LNINV), logarithm of worked hours (LNWH), logarithm of CPI (LNCPI) and Federal Fund Rate (FR). The dataset ranges from the first quarter 1964 to the third quarter 2015. In this sample, we include the sub-period 2008-2015 in which the FED kept overnight interest rate to zero to encourage a quick recovery. I estimate a quarterly three-lags VAR with a constant and a linear time trend and I identify the shocks recursively.

The selection of the VAR lag order is due to an Akaike information criterion test. This methodology is applied to all my VAR case studies.

The strongest effect of one standard deviation increase in uncertainty hits after three quarters all the variables and after five years some of them do not recover. The IRFs indicate that only worked hours, CPI and Federal Fund Rate show a positive variation in the 5 years following the impact period.

The effect on LNSP500 is grave, in fact this variable for five years does not recover to the pre-shock level. When the shock arises this index loses 4% and after 5 years it is still 2% lower than its original value. Instead, the FR after 9 months from this event loses 20% and it needs other four years to recoup. The response of LNCPI is small, however. It hits the minimum of -0.13% and then it recovers after four years from the shock.

The unexpected increase in VIX leads to a persistent decrease in in logarithm of consumption and investment. An increase in uncertainty about the future decreases immediately these two variables respectively by 0.11% and 0.2%. The decrease in LNPCONS and LNINV remains significant for about 14 quarters, with the peak effect occurring in the third quarter -0.27% and -1.8%. Five years later these two real variables have almost regained the losses.

Heightened uncertainty also leads to a decline in the worked hours, with the peak effect -0.21% occurring roughly three quarters from the impact period. The decline in LNWH becomes significant from the first quarter (-0.05%) and remains significant for about 2 years.

Therefore, the reductions in consumption, investment and worked hours suggest that uncertainty operates like an aggregate demand channel that reduces both economic activity, consumer price index and interest rates. Households reduce their consumptions because they are induced to increase their precautionary savings. Firms invest less because of the lower demand and the higher real option value. Meanwhile, the higher labor supply reduces the labor cost and with sticky prices, the markups raises. This last effect implies that firms will produce less output and requires less capital. With less investment and more saving, the interest rate is lower.

In this first impulse response analysis the empirical data support the New-Keynesian theory at the expense of Neo-Classical economists. Moreover, this first investigation shows a comovement among consumption, investment and worked hours.

9.1.2 VIX proxy of uncertainty: dataset from 1964 to 2008.

In the new analysis, I want to determine if the recent outstanding monetary measure and the consecutive zero lower bound episode bias my IRFs. For this purpose, I will trim the end of the sample from 2015 to 2008. Thus, in **Figure 13**, the sample is from the first quarter of 1964 to the fourth quarter of 2008.

The figure shows the IRFs to a positive one standard deviation increase of VIX in a quarterly four lag VAR. This negative event leads to a significant reduction in S&P 500, consumption, investment, worked hours, CPI and Federal Fund Rate. The first main difference between these two analyses is the response of FR. In this case, the reaction is more severe, the peak is -40% and it occurred in the fourth quarter. The effects of this shock persist for about three years. The response of LNSP500 and LNCPI is roughly similar to **Figure 12**.

The unexpected increase in our proxy of uncertainty causes a decline and a recovery after 8 quarters from the impact period in consumption, investment and worked hours. The peak is the effect occurring about nine months from the shock reaching the minimum values of -0.2%, -1.5% and -0.2% respectively. After five years, LNPCONS and LNINV show a positive variation (0.4% and 1%) compared to the pre-shock levels, instead worked hours are still 0.1% below their original value.

Again, all three main variables in my work (consumption, investment and worked hours) are affected by an uncertainty shock and these responses show a reduction in prices and Federal Fund Rate. This shorter dataset reveals a quickly recovery in consumption, investment and worked hours even if the immediate responses and the peaks are almost the same. A plausible explanation can be the following: in this new sample, I take out 7 years of crisis and have only a soft recovery. Instead, the reason why the Federal Fund Rate in this case is harshly hit from this shock is caused by the absence of a zero lower bound period as in the previous time series.

Overall, again these new IRFs show that an uncertainty shock causes a significant negative reaction in the real economy and it can be compared to a negative aggregate demand shock.

9.2.1 DUMMY HP DETENTRED VIX: dataset from 1964 to 2015.

Figure 14 reports the IRFs derived from a three lag VARs with a sample from the first quarter of 1964 to the third quarter of 2015.

The first dissimilarity between these IRFs and those showed in **Figure 12** is the trend of the variables. Uniquely, in this new model I obtain a rapid drop, rebound in consumption, investment, and worked hours. However, in the medium-long run, these variables return to the trend. Immediately, a positive standard deviation increase of this uncertainty proxy generates a sharp drop in all my variables, as from the fourth quarter there is the recovery.

After this shock, the S&P 500 index has an immediate peak of -2.8%, in the next months it rebounds, even if its value five years after this bad event is slightly lower than the pre-shock level. The FED’s overnight interest rate does not react as instantly as the other variable to the increase in uncertainty. FR hit their minimum (-15%) in the fourth quarter and two years later they restore their pre-shock level.

Conversely, the reaction of CPI is different in the two models compared. In this new IRF, the consumer price index is always lower than the value before the shock with a new peak -0.18% in the eighth quarter.

9.2.2 DUMMY HP DETENTRED VIX: dataset from 1964 to 2008.

The IRFs in **Figure 15** represent the responses of an increase in volatility of my uncertainty proxy in a 3 lag VAR model. In this case as in **Figure 13,** I reduce the range of my sample to the fourth quarter of 2008.

After the initial reduction, **Figure 15** shows a quick recovery in consumption, investment and worked hours compared to **Figure 13**. In this new analysis they recoup in eighteen months after the shock; however, in the medium term their values return to trend.

The effects on S&P 500 of a positive variation of uncertainty comparing the two cases show the same initial effect on S&P 500 (-3%). However, in **Figure 15** the stock market index rebounds one year after the shock. This did not occur in the other IRF. Instead, the negative effect of this shock on the Federal Fund Rate is roughly similar with a peak in the following year and a slow recovery in the third year.

Conversely, as of now the uncertainty shock to the response of CPI is negative with a minimum -0.3% in the eighth quarter. This response is more severe than in **Figure 14**.

9.3 Connection with the existing literature.

In this analysis, I prove that an uncertainty shock has a negative impact on the real economy leading to a comovement among consumption, investment and worked hours as mentioned by New-Keynesian economists.

In my general equilibrium results, households reduce their consumptions and are willing to work more, but they obtain the opposite effect. The worked hours decline, rising the level of unemployment. This effect not only dampens the economy, but it could lower the economic growth in the following years. The decline in economic output leads to a fall in costs and, thus, inflation is reduced.

Firms postpone their investments and, as showed in the previous figures, the investment rate declines. In a situation in which demand is low and in an uncertain economic outlook, companies have a higher interest to hold back their investments. Moreover, external sources of financing are more expensive, banks hesitate to lend money and raise the interest rate on their loans, reducing the realization of new investment projects.

Another important finding is that a standard increase of uncertainty shocks acts like a negative aggregate demand shock. Indeed their effects are recessionary. This leads to a decrease in consumption, investment and worked hours. Moreover, there is a persistent decrease in inflation. The intervention of a central bank is necessary to restore the stability, and the monetary policy reacts to the recessionary effects of uncertainty by lowering the nominal interest rate.

These results are not new in the literature, for instance S. Basu and B. Bundick (2014) demonstrate the comovement among the components of aggregate output. In their general equilibrium, they showed the effects in an economy with rigidities and with full elasticity. In the same paper, they pointed out how this kind of shock has repercussions on the real economy as a negative demand shock. Sylvain Leduc and Zheng Liu (2013) studied and proved the significant recessionary effects of uncertainty and with a transmission mechanism comparable to a negative demand shock. In their work, these oppressive effects are amplified with frictions and nominal rigidities. Through the real option theory, Bloom (2009) illustrated the reason why firms are unwilling to invest and the drop, rebound and overshoot responses of the real variables.

10.ROBUSTNESS

I have shown that my measure of uncertainty has a significant impact on variations in consumption, investment, worked hours, stock market index, CPI and Federal Fund Rate in the US. However, it is possible that my baseline model is too parsimonious, i.e. it falls short of some key variables that may be central to the results. In this section, I consider three changes to the baseline model, which serve as robustness checks: replacing the Economic Policy Uncertainty Index (EPUI) to VIX, changing the rate of interest with the 5 year treasury and shadow rate.

As expected, the impact of uncertainty on my variables is recessionary and they show similarities on their trend compared to the baseline model.

10.1 The Role of Uncertainty Proxy

To show the robustness of the previous findings, in order to prove that the macroeconomic effects of uncertainty shocks are remarkably similar across different proxies of uncertainty, I replace the VIX with another measure of uncertainty, the Economic Policy Uncertainty Index (EPUI). The correlation between these two proxies of uncertainty is almost 40%.

Figure 16 shows the IRFs to a positive one standard deviation increase of EPUI in a quarterly three lag VAR. The sample covers the period from the first quarter of 1985 to the third quarter of 2015, whence it is shorter than the dataset in **Figure 12** but it also contains the zero lower bound period.

These new IRFs show the same tendency with respect to **Figure 12**. All the variables counter the shock negatively: LNSP500, LNPCONS, LNINV, LNWH, LNCPI and FR lose 3.8%, 0.18%, 0.4%, 0.05%, 0.05% and 8% respectively. The stock market index is not able to reach pre-shock level after 5 years as well consumption, investment and CPI. The response of worked hours shows a recovery about 2 years from the impact period, but 3 years later there is not a significant variation with respect to the worked hours before the increase in uncertainty. The Federal Fund Rate, after a peak (-38%) effect occurring roughly 18 months from the shock, recovers to its original level 6 quarters later.

In this new case the comovement among the indicators is confirmed even if a positive one standard deviation increase in my proxy of uncertainty makes the responses of the variables worse. For instance, the minimum consumption is 0.4%, investment -2% and worked hours -0.23%, while in **Figure 12** they are -0.27%, -1.8%, -0.21% respectively.

However, I show that the effects on consumption, investment and worked hours as well as on the stock market, CPI and Federal Fund Rate do not reflect significant variation in their trends to changes in the proxy of uncertainty even if the sample size is different between **Figure 12** and **Figure 16**.

10.2 The Role of the Interest rate

My sample covers the post-2008 period, during which the U.S. central bank, better known as the Federal Reserve, conducted an outstanding monetary policy and the short term interest rate hit the zero lower bound. This constraint affected the possibility for the FED to accommodate the negative effects of uncertainty. In reality however, the FED used unconventional monetary tools after the short-term nominal interest rate reached the zero lower bound. For instance, the Federal Reserve has conducted three rounds of large scale asset purchases (quantitative easing) and provided systematic forward guidance about the future path of the monetary policy. The Fed has pursued these unconventional policy tools to affect long-term interest rates and promote economic recovery.

To prove the robustness of my work I change the Federal Fund Rate with the following two: five year Treasury and the shadow rate.

Five year interest rate. Unlike the overnight interest rate, the five year Treasury yields didn't reach the zero lower bound. Moreover, the use of this longer interest rate allows to catch the consequences of unconventional monetary policy, which is designed to lower yields on long-term securities.

I have conducted the analysis with two datasets, the first sample covers the period from the first quarter of 1985 to the third quarter of 2015, the second one ends with the fourth quarter of 2008, however.

The IRFs in **Figure 17** show the first sample derived from a quarterly four lag VAR. The shape of the responses is similar to that of the baseline model in **Figure 12**, but there are some peculiarities. Interestingly, the peak in the responses for all the variables that I consider is actually almost the same compared to the baseline model. The effect on the 5 year interest rate is lower, however. The peak response of 5 year interest rate following a shock to uncertainty is

-13% percent compared to -23% percent in the baseline case and it happens after 6 months from the shock.

Moreover, in this new model consumption and investment recoup (even though it takes them more than three years) from the initial negative variation, while in the previous model this did not happen. Conversely, the response of worked hours in a period of 5 years from the change of a one standard deviation increase in uncertainty is always negative. Lastly, in this new model the recovery of CPI is quicker than in the previous setting.

Overall, this first test confirms the robustness of my results and it sustains the New-Keynesian theory.

Instead, the new IRFs showed in **Figure 19** are derived by estimating in a VAR model with 4 lags with a shorter data range.

The trend of the IRFs is similar to that of the baseline model. However, the magnitude of the responses for consumption and investment is actually much stronger in this new sample. For instance, the peak response of LNPCONS and LNINV following a shock to uncertainty is -0.25 and -1.8 percent compared to -0.2 and -1.5 percent in the baseline case. On the contrary, the response of 5 year Fund Rate is lower than in the VAR with overnight Fund Rate.

Only the shape of the IRF worked hours is slightly different. This response shows a decline, rebound and one more time decrease.

I have found largely similar results using this medium term interest rate with respect to the overnight interest rate, therefore, again the results are robust.

Shadow rate. Lastly, I investigate the effects of one standard deviation increase in VIX replacing the shadow rate in my model. Short-term interest rates can’t technically be negative, but what if there were a hypothetical, “shadow” short-term rate that could move into negative territory? Fisher Black (1995) proposed this interest rate for the first time.

Lately Jing C. Wu and Fan D. Xia (2014) used the shadow rate to summarize the impact of the Fed actions including quantitative easing during the Great Recession. In their work, they proved that the Fed has used unconventional policy measures to successfully lower the shadow rate in order to boost economic recovery.

I conduct this test of robustness only for the sample with data ending in the third quarter of 2015. The new VAR model contains three lags and its IRFs are showed in **Figure 19**.
In this new figure, the estimated response has a similar tendency to that of the baseline model. The peaks after a standard deviation on uncertainty in this model are roughly the same as in **Figure 12**. The only difference between the two figures is the response of consumption. In this new sample, consumption recovers after sixteen quarters from the shock.

This new analysis leads to two important conclusions: first of all the replacement of the overnight interest rate with the shadow rate does not affect my analysis, maybe because these two rates diverge only for a short period (from January 2009 to September 2015).

Secondly, this last test provides one more time the robustness of my analysis. As in the other two cases, there are not important dissimilarities. As in the baseline model, in all these three samples, I find that a shock that rises uncertainty (measured as VIX or EPUI) has negative effects on consumption, investment, worked hours and CPI. Moreover, there is a drop in stock market (in our case Standard and Poor's 500) and a marked reduction in the interest rate.

11.CONCLUSIONS

In this work, I have investigated the macroeconomic effects of uncertainty shocks. To do so, I have explained their consequences according to economic theory and then by conducting an empirical research estimating a Structural Vector Autoregressive model.

From a theoretical and modeling perspective, only the New-Keynesian Theory is able to clarify the negative effects of uncertainty shocks. Indeed, I have found the empirical inconsistency of a Neo-Classical view, using Real Business Cycle Model, to explain the true transmission channel of an uncertainty shock. Its misleading results have showed an opposite variation between consumption and investment, and as a result, this maintains the aggregate output constant.

Conversely, using a more elaborate model, a Dynamic Stochastic General Equilibrium one, I have demonstrated the ability of a New-Keynesian model with price rigidities to illustrate the consequences of these unpredicted shocks in the real economy. At the beginning, these unforeseen events lead to a reduction in consumption and increase the willingness of work more among the employees. However, it has contractionary effects: lower wages, higher mark-up and so lower labor demand. Moreover, the total output and investment are affected negatively.

This economic view is supported by the consistency of its results with the empirical data, showing the negative responses and the comovement of consumption, investment and worked hours and hence a reduction in GDP.

From an empirical point of view, I have conducted a quantitative analysis on the effects of one of the proxies of uncertainty shocks, the VIX, in U.S. economy with a dataset from 1964:Q1 and two ending points: 2015:Q3 and 2008:Q4. This choice has allowed to show the responses of my variables before including the outstanding FED monetary policy and then excluding it.

Firstly, consumption, investment, worked hours, Standard and Poor's 500, CPI and Fund Rate decrease after these uncertainty shocks. In the larger dataset, consumption and investment do not achieve their pre-crisis levels after 5 years, instead in the other sample after 2 years their variations are positive compared to pre-shock levels. Drops in consumption, investment and worked hours hit their lows roughly three quarters after the shock, with almost the following peaks: -0.2% consumption, -2% investment and -0.2% in worked hours.

Secondly, I have estimated the IRFs to a positive one standard deviation increase of HP detrended VIX. This elaborated proxy considers only the highest spikes in volatility occurred.

Using this measure, I have assessed their impact and the responses are quite similar to the previous case with the VIX as proxy. However, the reactions of consumption, investment and worked hours suggest a rapid drop and rebound during the second quarter, with peaks slightly smaller than those of the VIX.

All things considered, my empirical analysis support the results suggested by New-Keynesian theory. Therefore, I can assert that an uncertainty shock acts as a negative demand shock depressing current consumption, deterring investment, reducing labor demand as well reducing the CPI and hitting the stock markets and Fund Rate.

REFERENCES

Abel, A. B. (1983), “Optimal investment under uncertainty”, American Economic Review, 73(1), pp. 228–33.

Abel, A. B, and Eberly, J. (1996), “Optimal Investment with Costly Reversibility”, Review of Economic Studies, 63, pp. 581-593.

Alexopoulos, M., and Cohen, J. (2009), “Uncertain Times, Uncertain Measures.” University of Toronto, Department of Economics, Working Paper 352.

Amisano, G. and Giannini, C. (1998), “From VAR Models to Structural VAR Models”, Topics in Structural VAR Econometrics – 2nd Edition, pp. 1-28.

Arellano, C., Bai, Y. and Kehoe, P. (2010), “Financial Markets and Fluctuations in Uncertainty”, Federal Reserve Bank of Minneapolis, Research Department Staff Report.

Bachmann, R. and Bayer, C. (2011), “Uncertainty business cycles - really?”, NBER Working Papers 16862.

Baker S. R., Bloom, N., and Davis, S. J. (2013), “Measuring Economic Policy Uncertainty”, Chicago Booth Research Paper 13 (02).

Basu, S., and Bundick, B. (2014), “Uncertainty Shocks in a Model of Effective Demand”, Boston College Working Paper.

Basu, S., and Bundick, B. (2015), “Endogenous Volatility at Zero Lower Bound: Implications for Stabilization Policy”, Boston College Working Paper.

Bernanke, B. S. (1983), “Irreversibility, Uncertainty and Cyclical Investment”, Quarterly Journal of Economics 98 (01), pp. 85-106.

Berger, D., and Vavra, J. (2014), “Measuring How Fiscal Shocks Affect Durable Spending in Recessions and Expansions”, American Economic Review Papers and Proceedings, 104(5), pp. 112.115.

Black, F. (1935), "Interest Rates As Options," Journal of Finance, vol 50 (5), pp. 1371-1376.

Blanchard, O. (2009), “(Nearly) nothing to fear but fear itself”, The Economist.

Bloom, N. (2009), “The Impact of Uncertainty Shocks”, Econometrica, May 77, pp. 623-685.

Bloom, N. (2014), “Fluctuations in Uncertainty”, Journal of Economic Perspectives 28 (2), pp. 153-176.

Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., and Terry, S. J. (2014), “Really Uncertain Business Cycles”, Stanford Working Paper.

Born, B., and Pfeifer, J. (2014). "Policy risk and the business cycle”, Journal of Monetary Economics, vol. 68(C), pp. 68-85.

Burns, A. F., and Mitchell, W. C. (1946), “Measuring Business Cycles”, NBER, pp. 3-22.

Caldara, D., Fuentes-Albero C., Gilchrist S., and Zakrajsek E. (2014), ”The Macroeconomic Impact of Financial and Uncertainty shocks”, Boston University and Federal Reserve Board, mimeo.

Calvo, G. A. (1983), “Staggered Prices in a Utility Maximizing Framework”, Journal of Monetary Economicss 12, pp. 383-398.

Christiano, L., Motto, R., and Rostagno, M. (2014), “Risk Shocks,.American Economic Review”, 104(1), pp. 27-65.

Clarida, R., Gali, J. and Gertler, M. (1999), "The Science of Monetary Policy: A New Keynesian Perspective", Journal of Economic Literature, 37 (4), pp. 1661–1707.

Cooley, T. (1995), “Frontiers of Business Cycle Research”, Princeton University Press.

Eckhard, H. and Engelbert, S. (2011), “A Modern Guide to Keynesian Macroeconomics and Economic Policies”, Edward Elgar Publishing.

Fawley, B. W. and Neely, C. J. (2013), “Four Stories of Quantitative Easing”, Federal Reserve Bank of St. Louis Review, 95(1), pp. 51-88.

Fernandez-Villaverde, J., Guerron-Quintana, P., Rubio-Ramirez, J. F., and Uribe, M. (2010), “Risk Matters: The Real Effects of Volatility Shocks”, NBER Working Paper 148756.

Fernandez-Villaverde, J., Guerron-Quintana, P., Kuester K., and Rubio-Ramirez, J. (2011), “Fiscal Uncertainty and Economic Activity”, University of Pennsylvania Working Paper.

Galí, J. (2008), “Monetary Policy, Inflation and the Business Cycle”, Princeton University Press, pp. 41-70.

Gourio, F. (2012), "Disaster Risk and Business Cycles", American Economic Review, 102(6), pp. 2734-2766.

Hartman, R. (1976), "Factor demand with output price uncertainty", American Economic Review, 66(4), pp. 675–681.

Ireland, P. N. (2004), "Technology Shocks in the New Keynesian Model", NBER Working Paper 10309.

Ireland, P. N. (2010), "A New Keynesian Perspective on the Great Recession", NBER Working Paper 16420.

Johannsen, B. K. (2014), "When are the E¤ects of Fiscal Policy Uncertainty Large?", Finance and Economics Discussion Series 40.

Jurado, K., Ludvigson, S. C., and Ng, S. (2015), "Measuring Uncertainty", American Economic Review, 105(3), pp. 1177-1216.

Keynes, J. M. (1935), "The General Theory of Employment, Interest and Money".

Keynes, J. M. (1937), "The General Theory of Employment".

Kimball M. S. (1990), "Precautionary Saving in the Small and in the Large", Econometrica, vol 58, pp. 53-73.

Knight, F. H. (1921), "Risk, Uncertainty, and Profit".

Krusell, P. and McKay, A. (2010), "News Shocks and Business Cycles", Economic Quarterly 96 (4), pp. 373-397.

Kydland, F. and Prescott, E. C. (1982), "Time to Build and Aggregate Fluctuations," Econometrica.

Leland, H. (1968), "Saving and uncertainty: The precautionary demand for saving", Quarterly Journal of Economics, 82, pp. 465–473.

Leduc, S., and Liu, Z. (2013), "Uncertainty Shocks are Aggregate Demand Shocks", Federal Reserve Bank of San Francisco, Working Paper 2012-10.

Lucas R. (1977) "Understanding Business Cyles", Carnegie-Rochester Conference Series on Public Policy 5: pp. 7-29.

Long, J. and Plosser, C.I. (1983), "Real Business Cycles," Journal of Political Economy.

Orlik, A. and Veldkamp, L. (2014), “Understanding Uncertainty Shocks and the Role of Black Swans”, NBER Working Paper 20445.

Romer, D. (2012), “Advanced Macroeconomics”, McGraw-Hill, 4nd Edition.

Rotemberg, J. J. and Woodford, M. (1997). "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy", NBER 12: pp. 297–346.

Scotti, C. (2013), “Surprise and Uncertainty Indexes: Real-time Aggregation of Real-Activity Macro Surprises”, International Finance Discussion Papers 1093.

Sims, C. A. (1980), “Macroeconomics and Reality”, Econometrica, vol 48 (1), pp. 1–48.

Sims, C. A. (2002), “Structural VAR’s”, Economics 513, Time Series Econometrics.

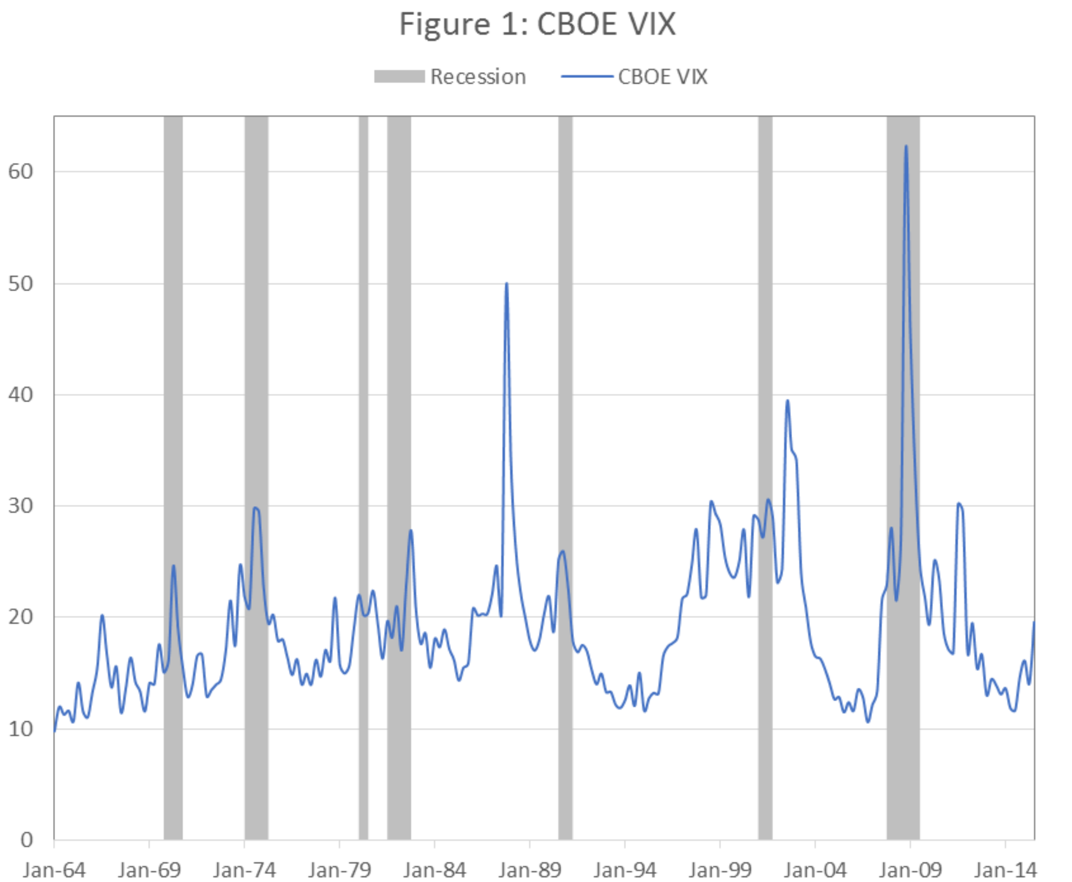
Stock, J. H., and Watson, M.W. (2011), “Additional Topics in Time Series Regression”, Introduction to Econometrics – 3rd Edition, pp. 631-668.

Teulings, C. and Baldwin, R. (2014), “Secular Stagnation: Facts, Causes, and Cures”, CEPR Press.

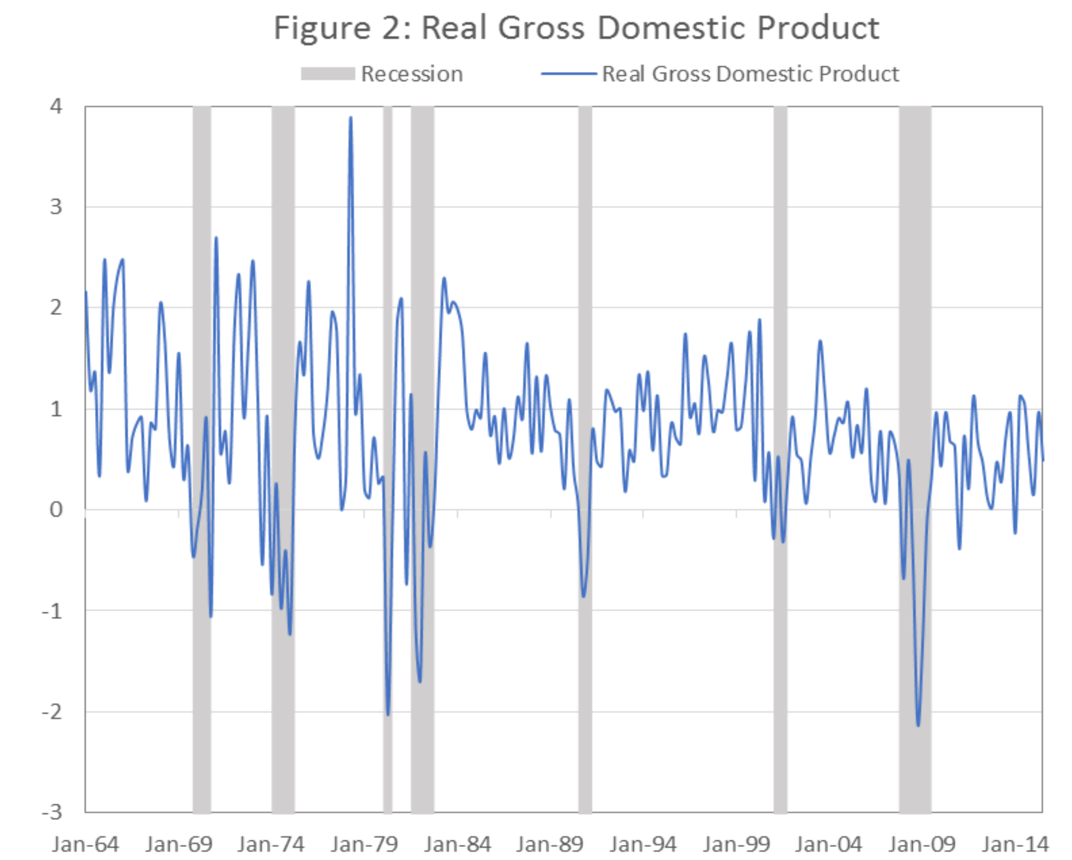
Vavra, J. (2013), “Inflation Dynamics and Time-Varying Volatility: New Evidence and an Ss Interpretation”, NBER Working paper 19148.

Wu, J. C. and Xia, F. D. (2014), "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound," Working paper.

Wickens, M. (2008), “Macroeconomic Theory – A Dynamic General Equilibrium Approach”, Princeton University Press.

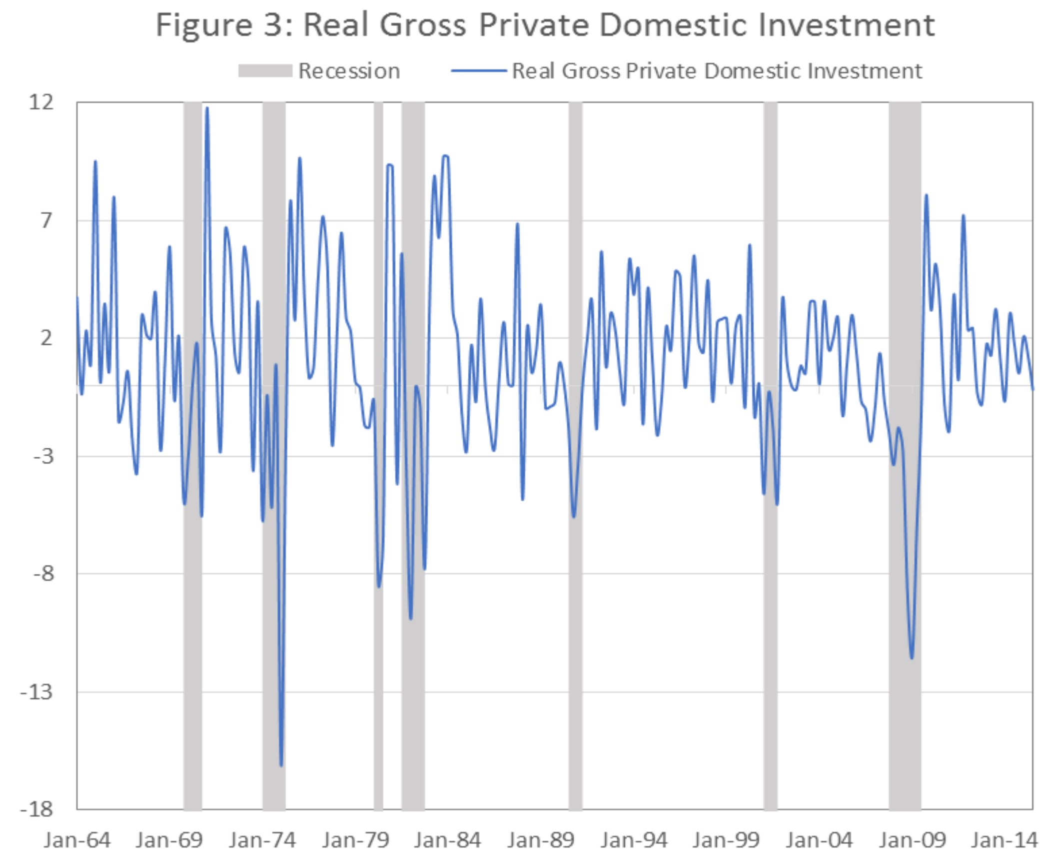


Source: Chicago Board Options Exchange



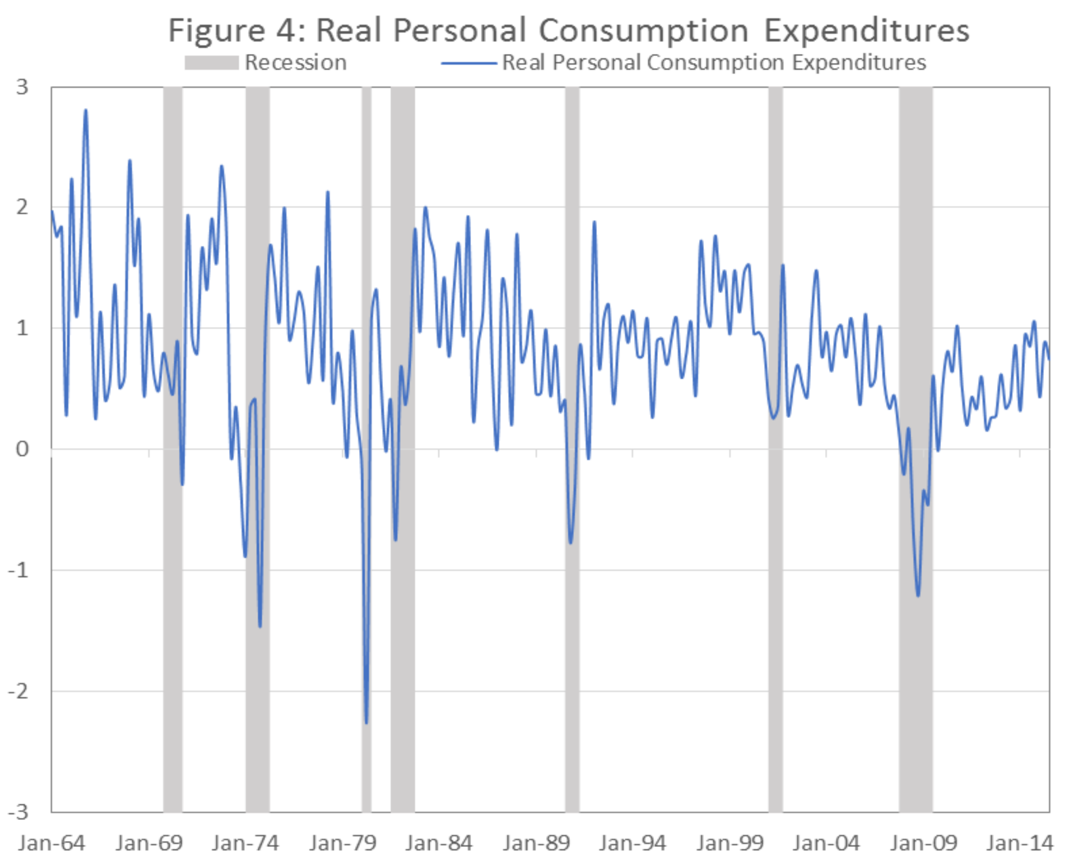
Note: Percentage Change from Previous Period

Source: Fedeal Reserve Bank of St. Louis



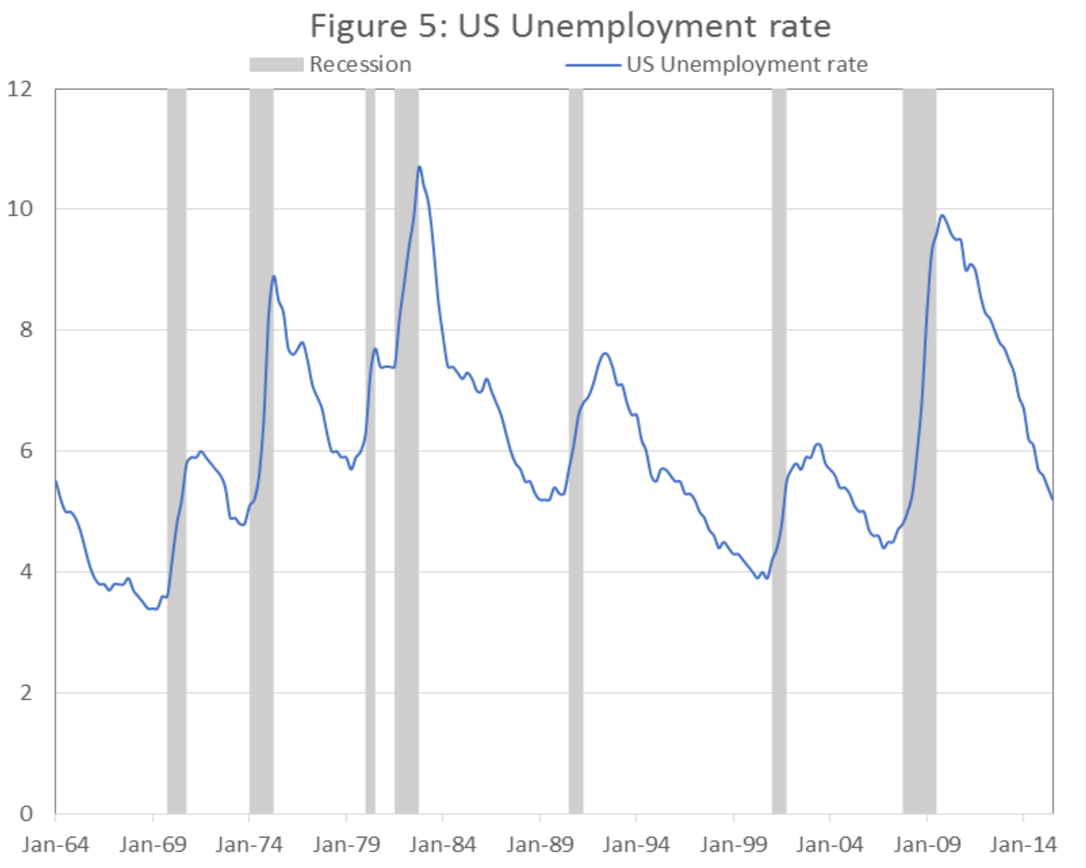
Note: Percentage Change from Previous Period

Source: Fedeal Reserve Bank of St. Louis

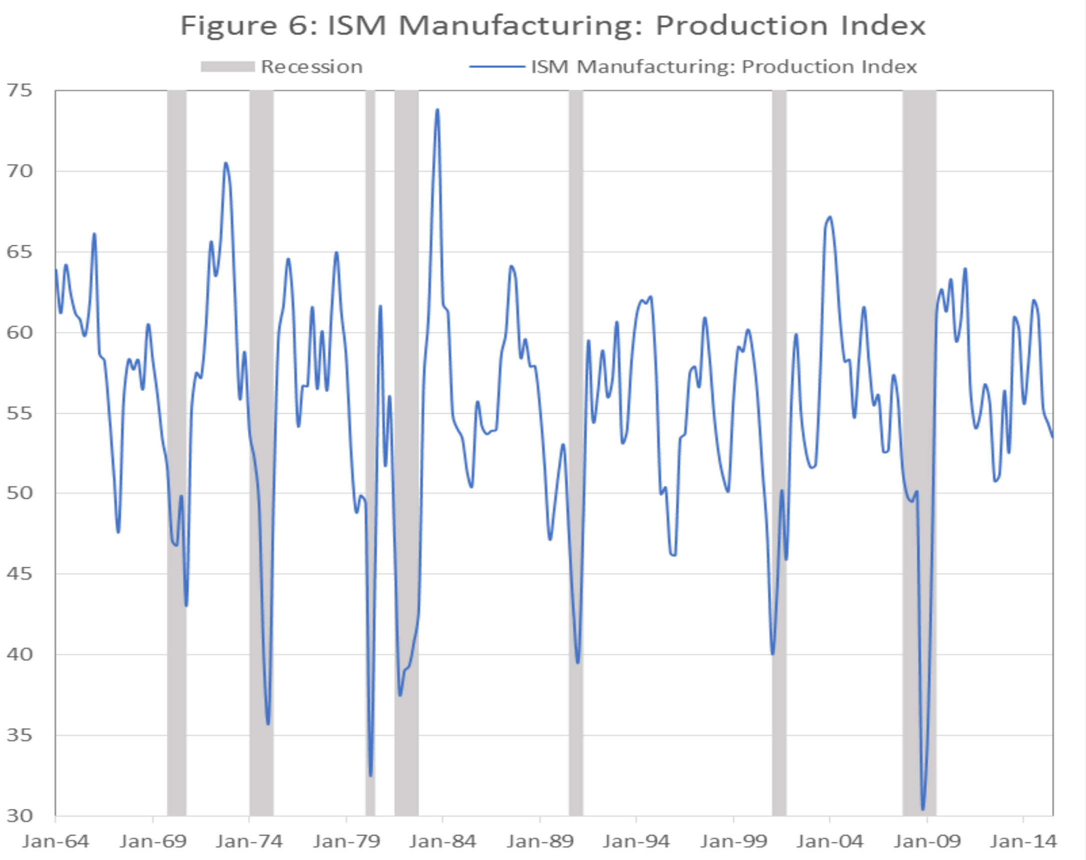


Note: Percentage Change from Previous Period

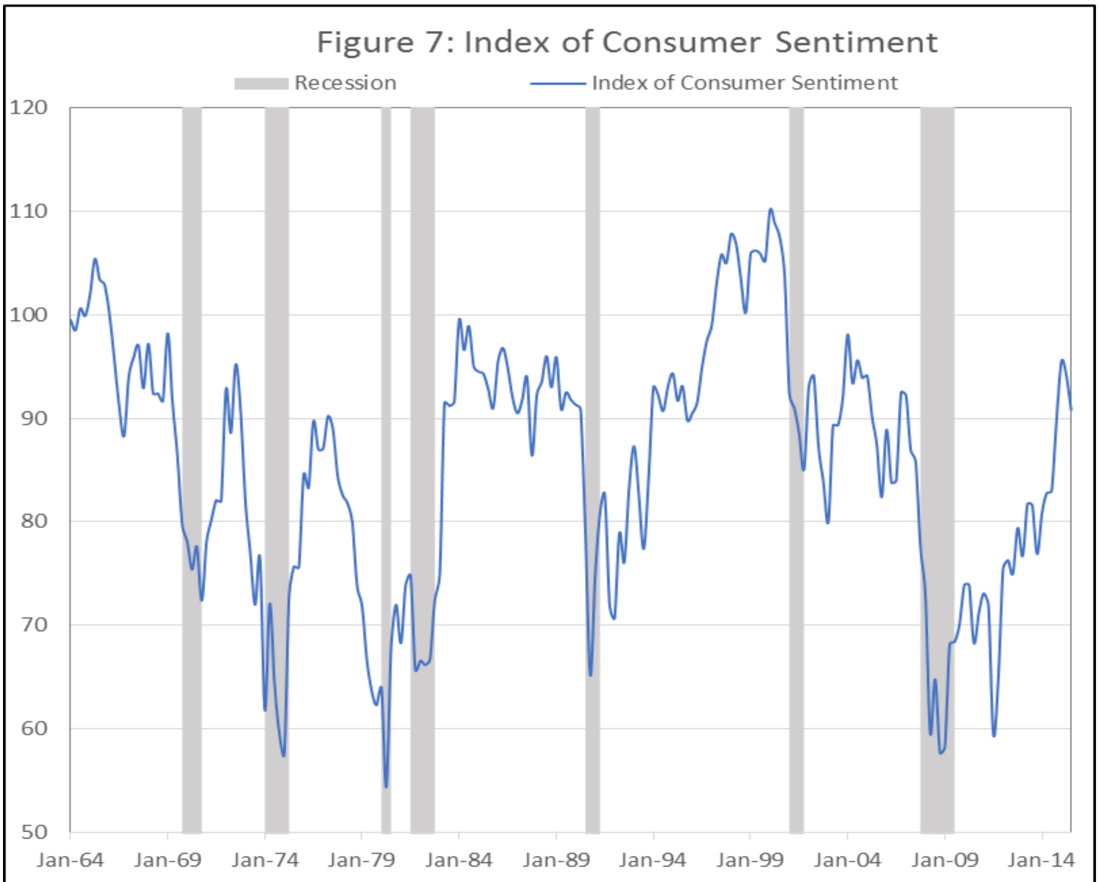
Source: Fedeal Reserve Bank of St. Louis



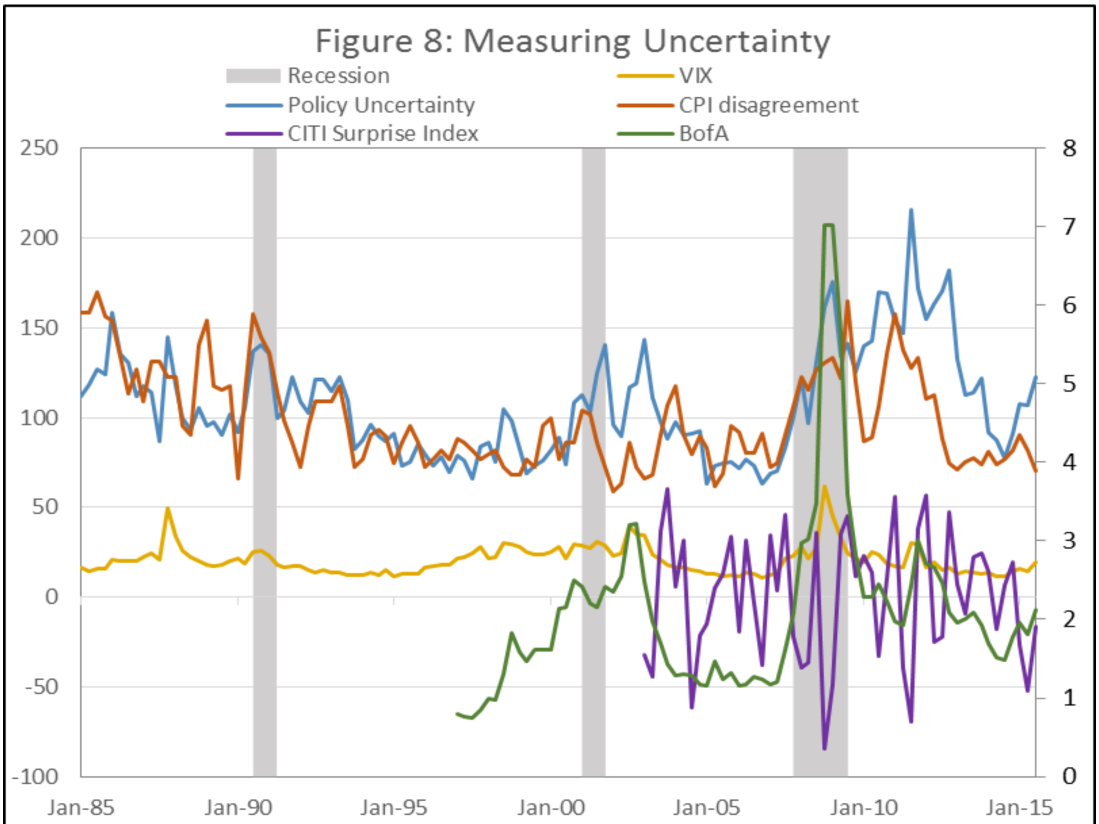
Source: United States Department of Labor



Source: Institute for Supply Management



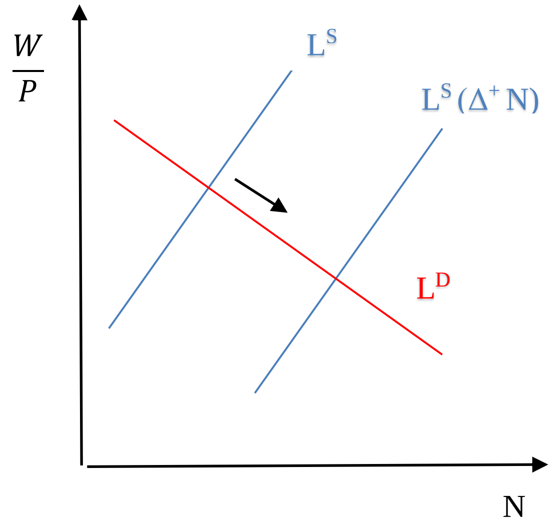
Source: University of Michigan



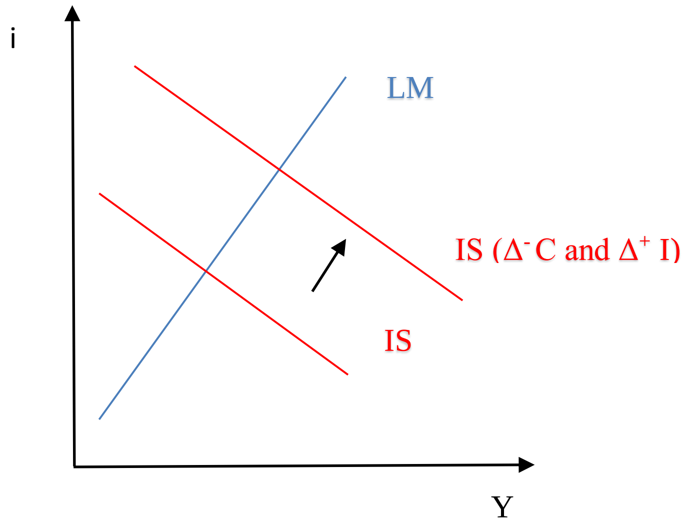
Note: the primary vertical axis is used for CPI disagreement, VIX, CITI Surprise Index, Policy Uncertainy , instead the secondary axis is for BofA.

Source: Fedeal Reserve Bank of St. Louis and Datastream

FIGURE 9: The Dynamic Effect of an Uncertainty Shock in a Neo-Classical Model.

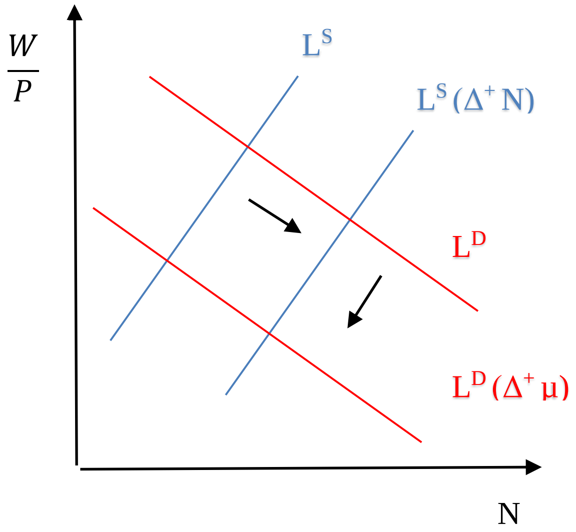


Higher uncertainty reduces consumptions and leads to an increase in labor supply, pushing down the L^s curve. At the new level, the real wages are lower but the worked hours have increased.

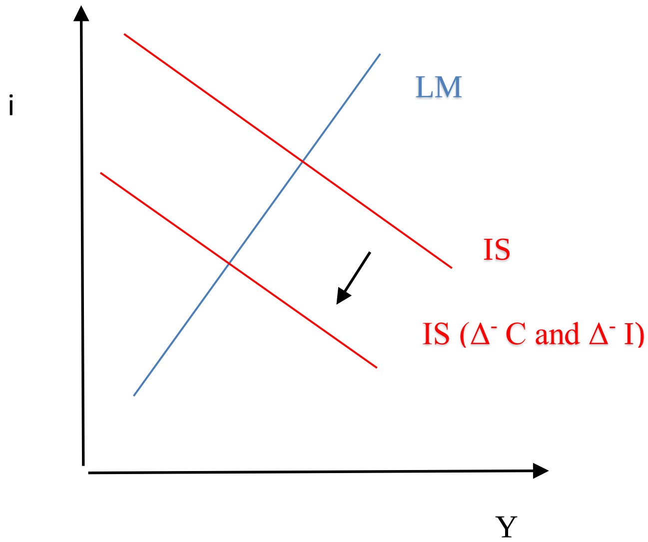


In IS-LM space the new level of aggregate output after an increase in worked hours is shown. The offsetting effect of investment with respect to the lower consumption expenditure leads to a higher output.

FIGURE 10: The Dynamic Effect of an Uncertainty Shock in a New-Keynesian Model.



Higher uncertainty reduces consumptions and leads to an increase in labor supply, pushing down the L^S curve. However a higher mark-up shifts down the L^D curve. At the new level, real wages and worked hours are lower than the starting point.



In IS-LM space the new level of aggregate output after an increase of uncertainty is shown. A higher mark-up depresses real economy through lower investment and consumption expenditure.

Figure 11: Hodrick Prescott Filter

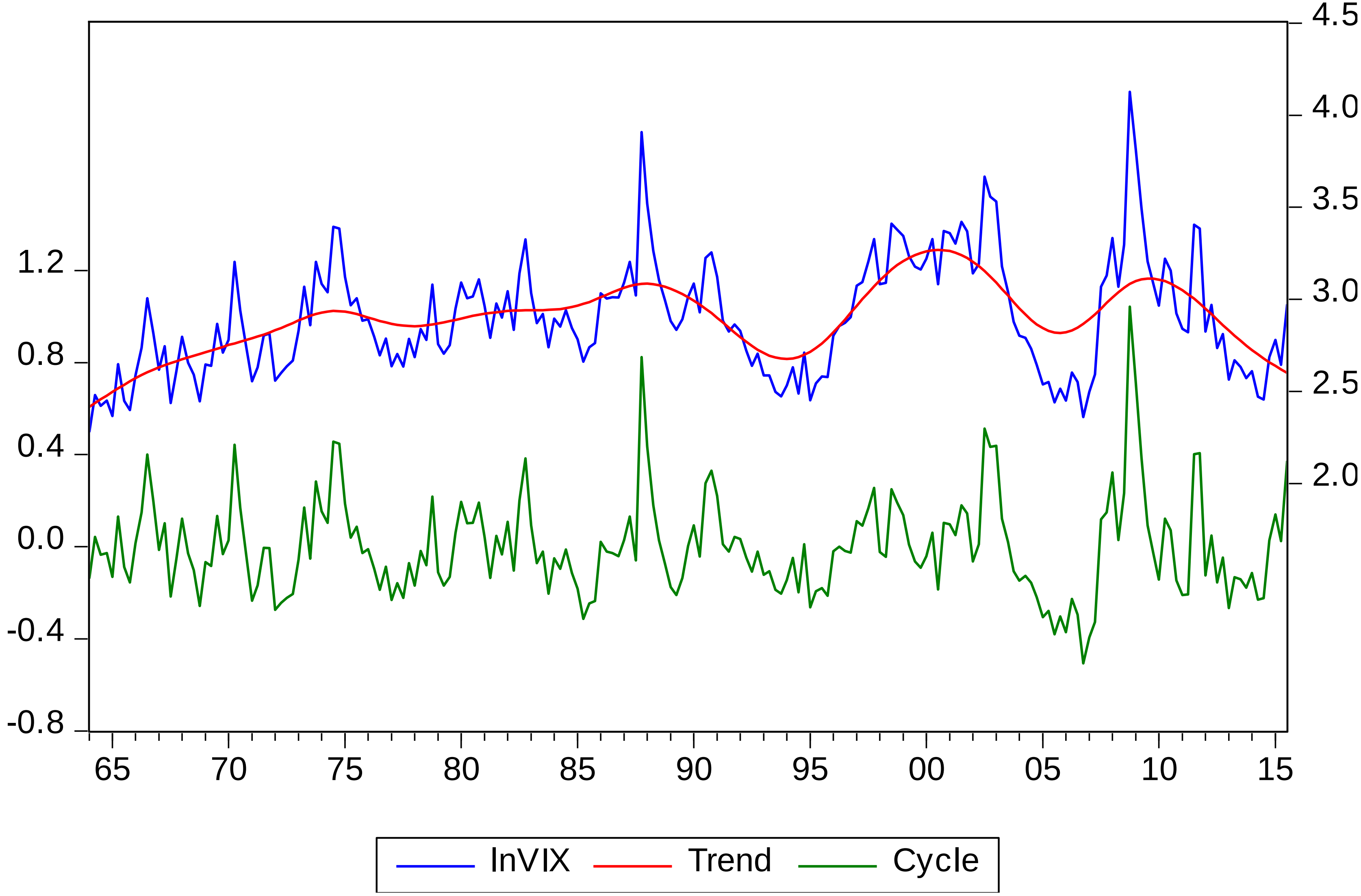


Figure 12. Impulse Responses to a VIX Shock. Period first quarter 1964-third quarter 2015.

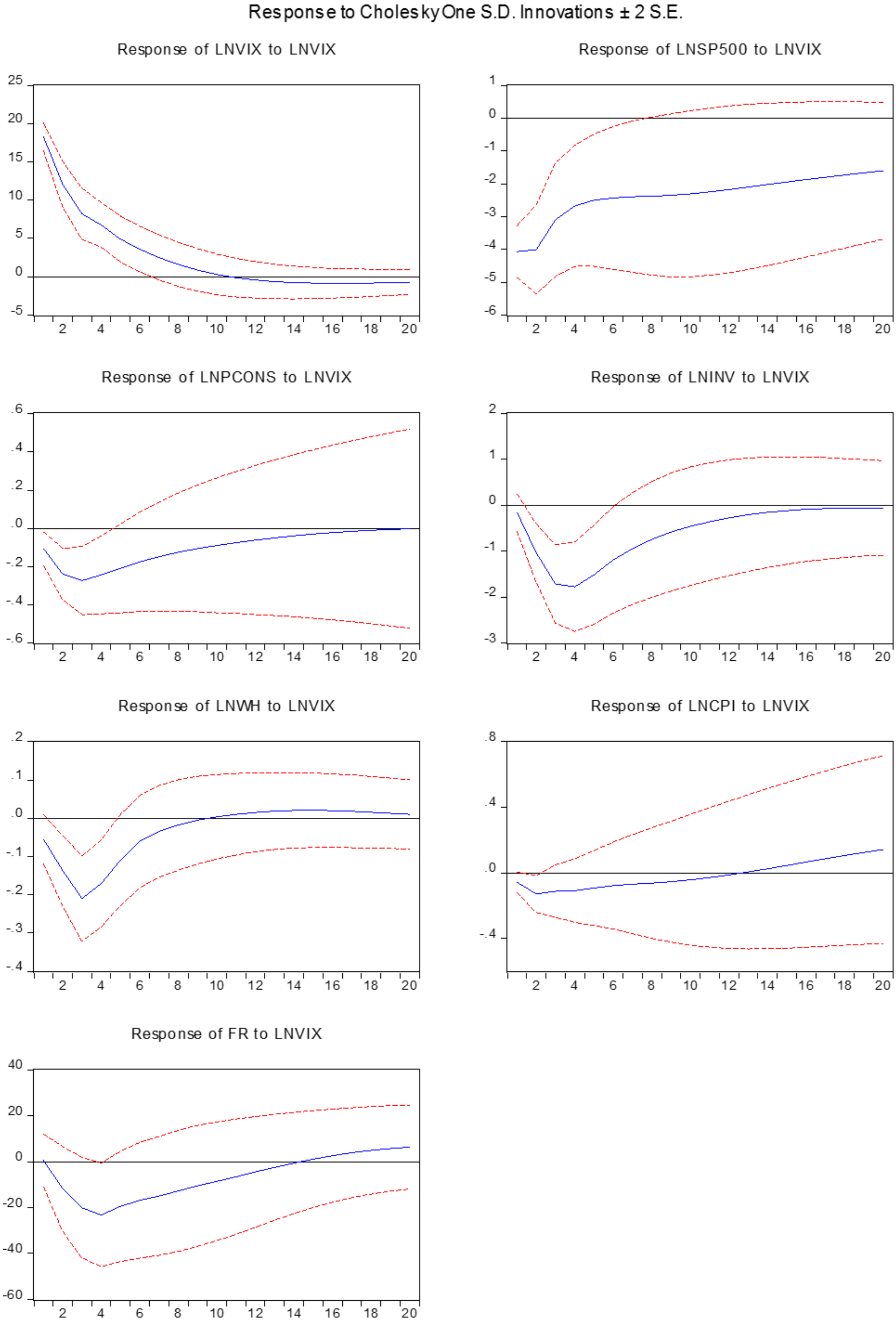


Figure 13. Impulse Responses to a VIX Shock. Period first quarter 1964-fourth quarter 2008.

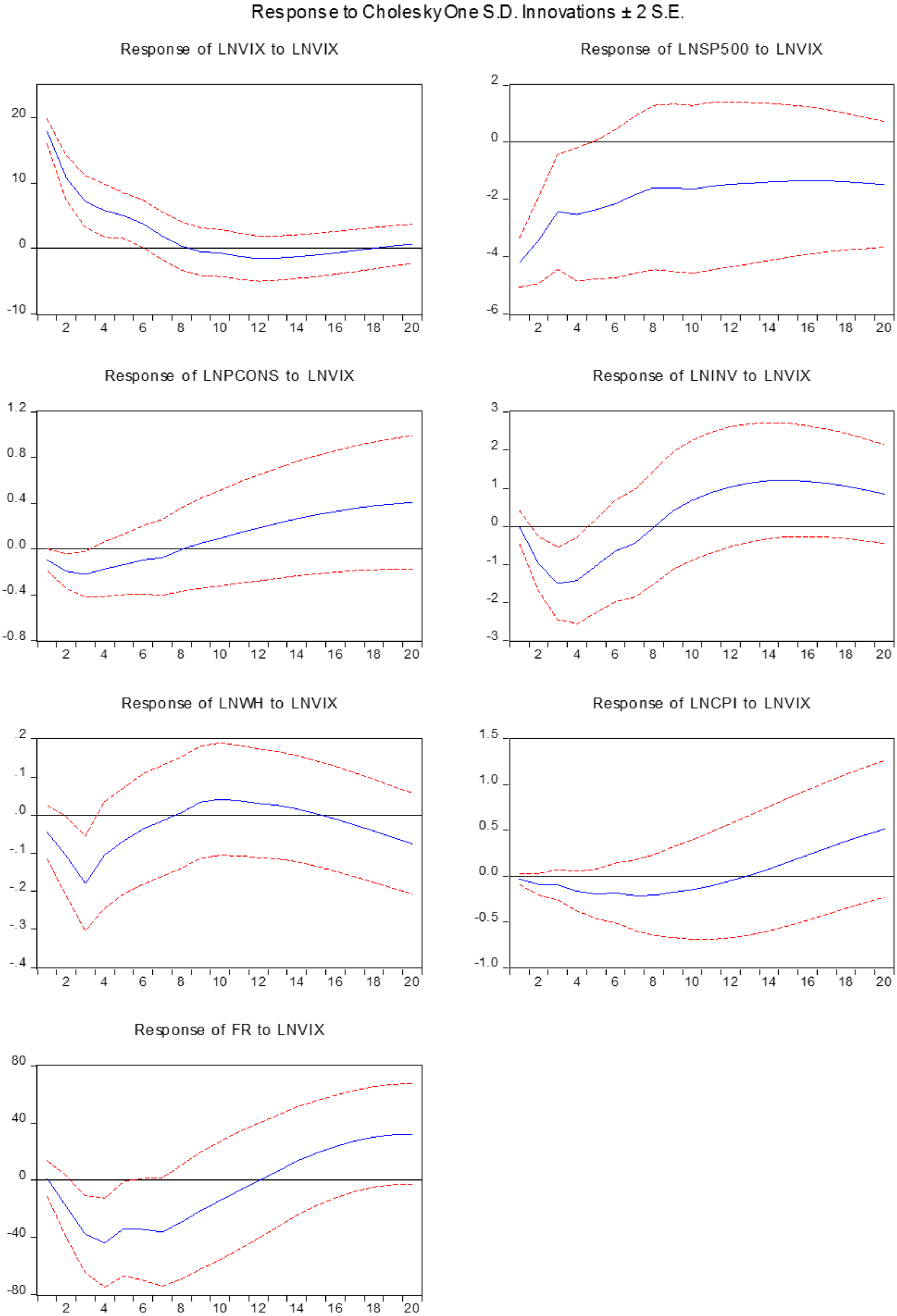


Figure 14. Impulse Responses to an HP VIX Shock. Period first quarter 1985-third quarter 2015.

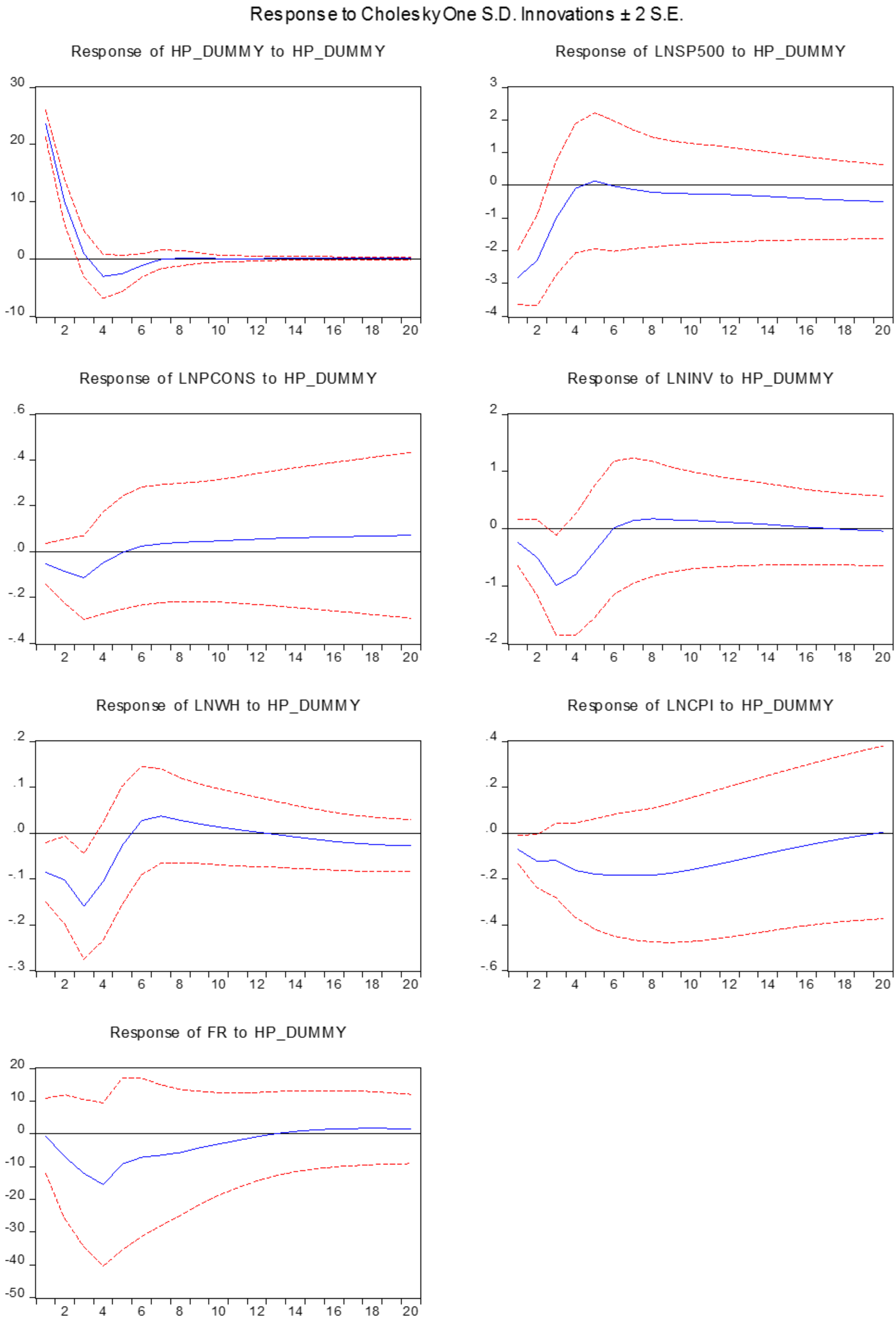


Figure 15. Impulse Responses to an HP VIX Shock. Period first quarter 1985-fourth quarter 2008.

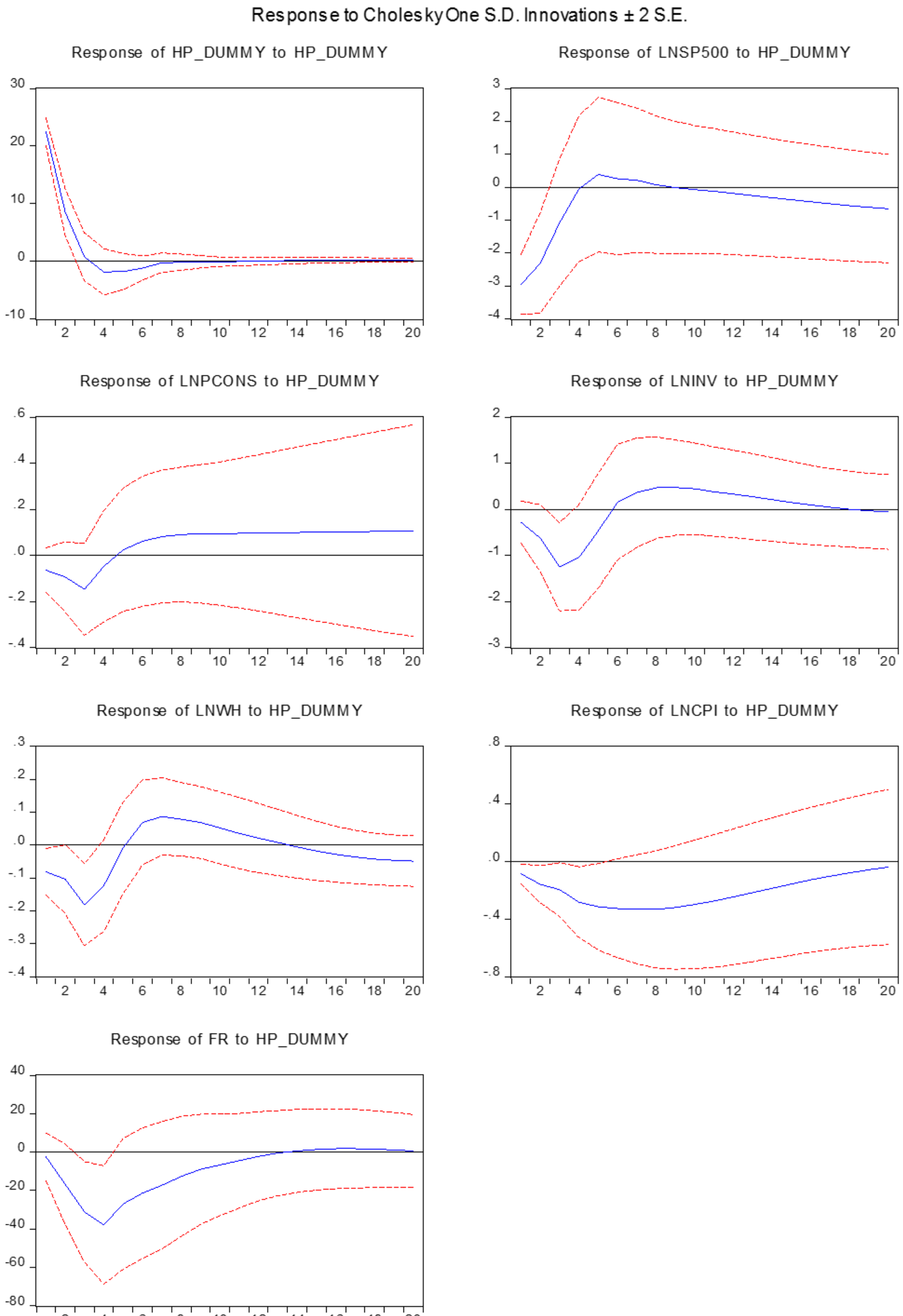


Figure 16. Impulse Responses to an EPUI Shock. Period first quarter 1985-third quarter 2015.

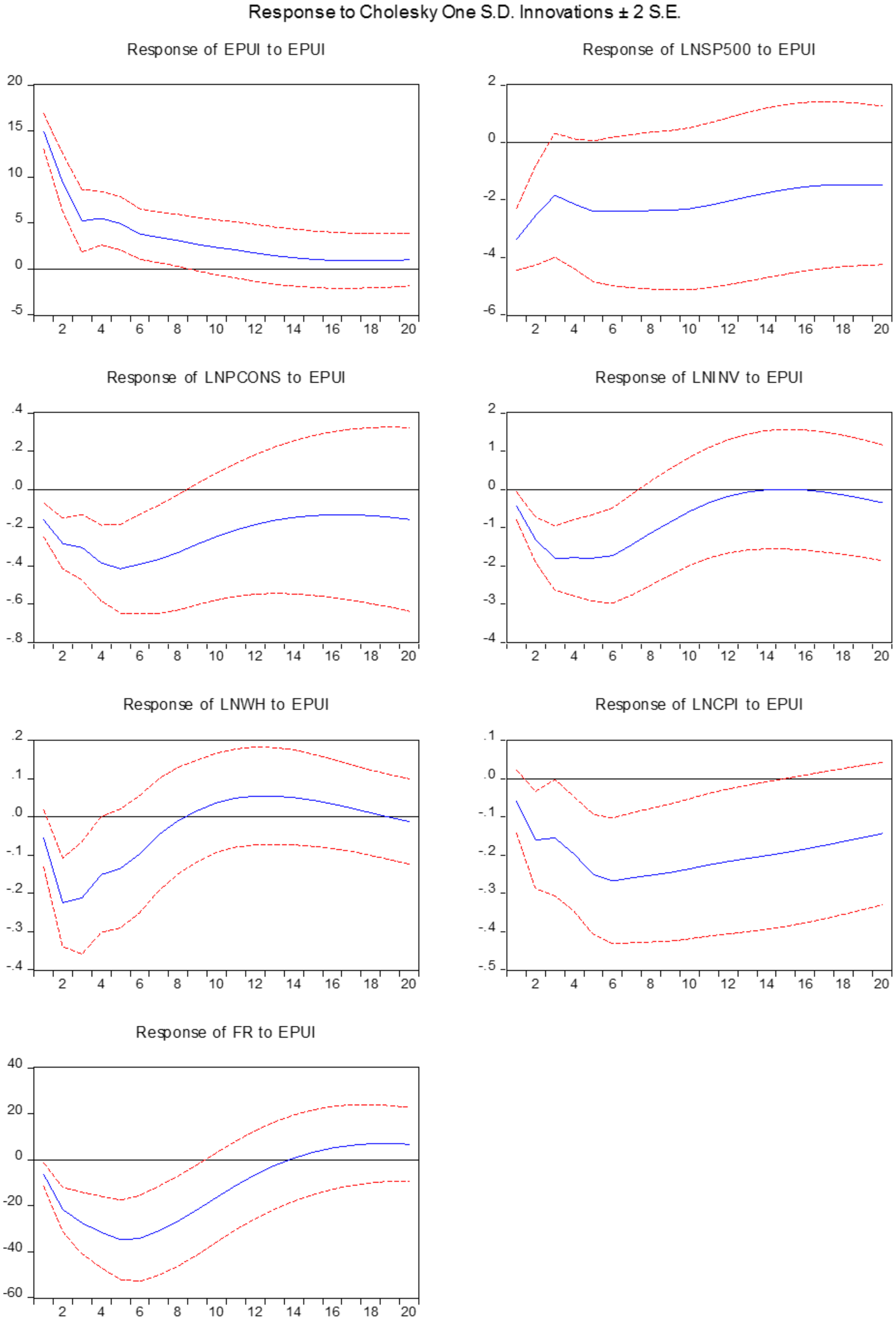


Figure 17. Impulse Responses to a VIX Shock. Period first quarter 1964-third quarter 2015.

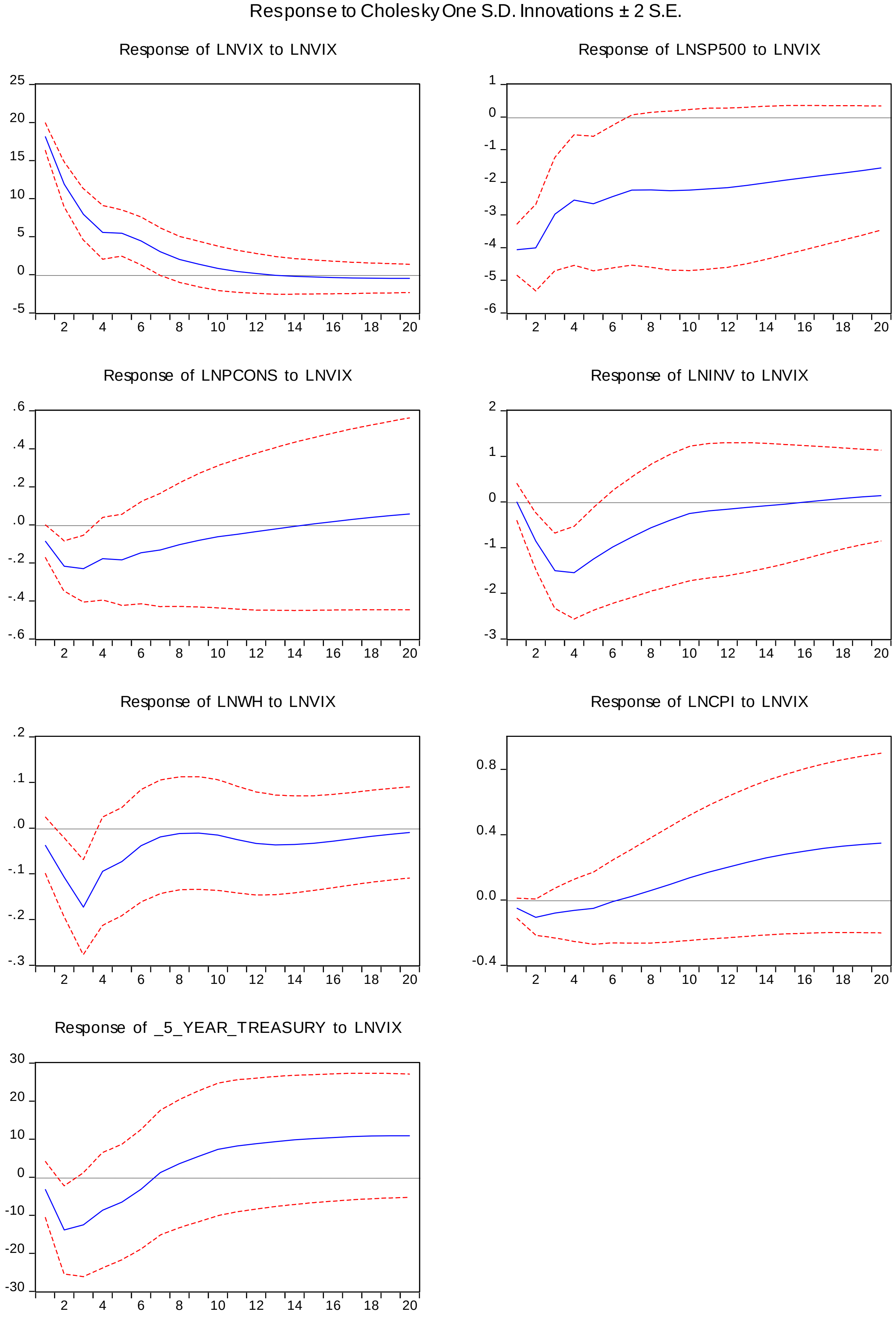


Figure 18. Impulse Responses to a VIX Shock. Period first quarter 1964-fourth quarter 2008.

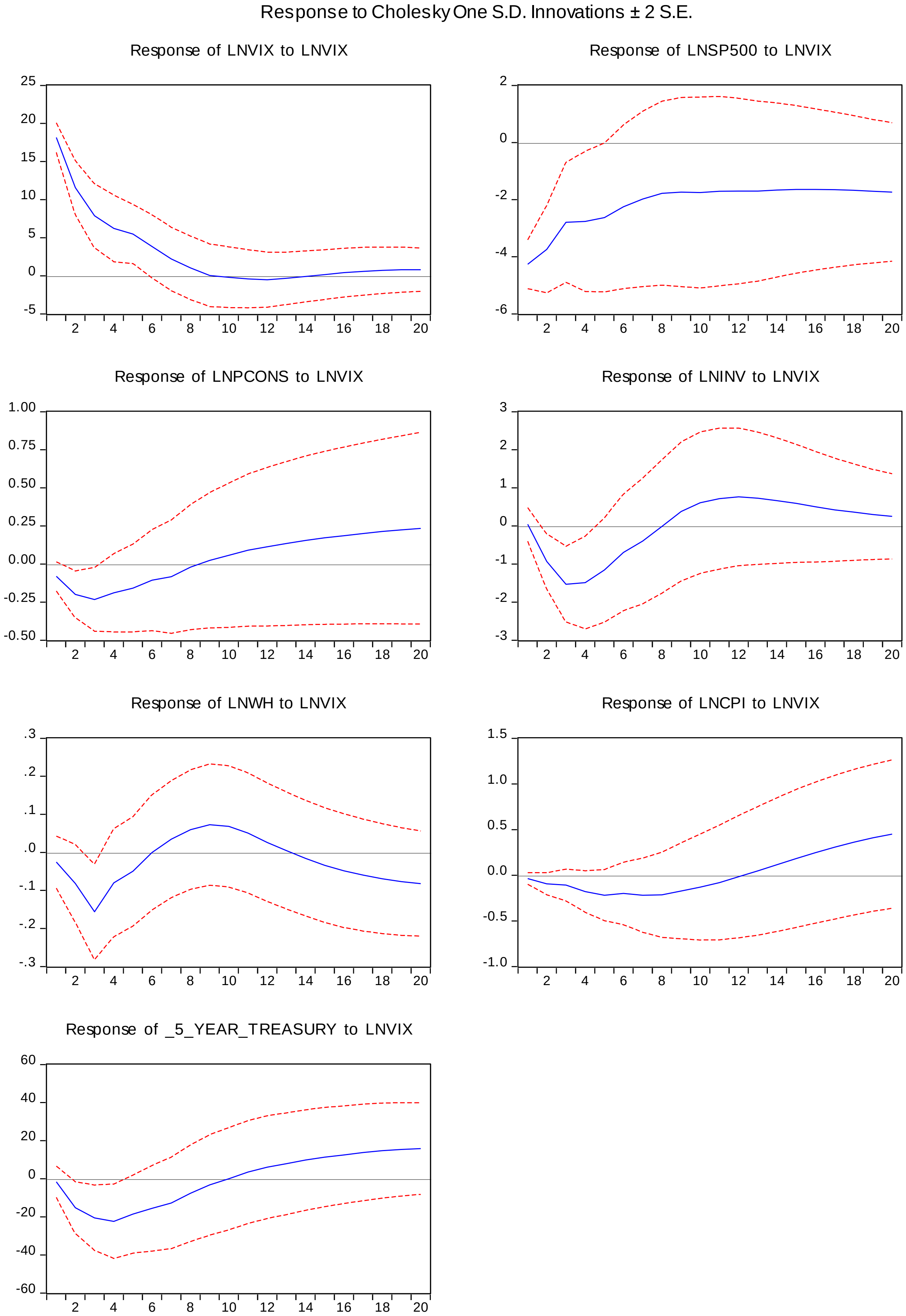


Figure 19. Impulse Responses to a VIX Shock. Period first quarter 1964-third quarter 2015.

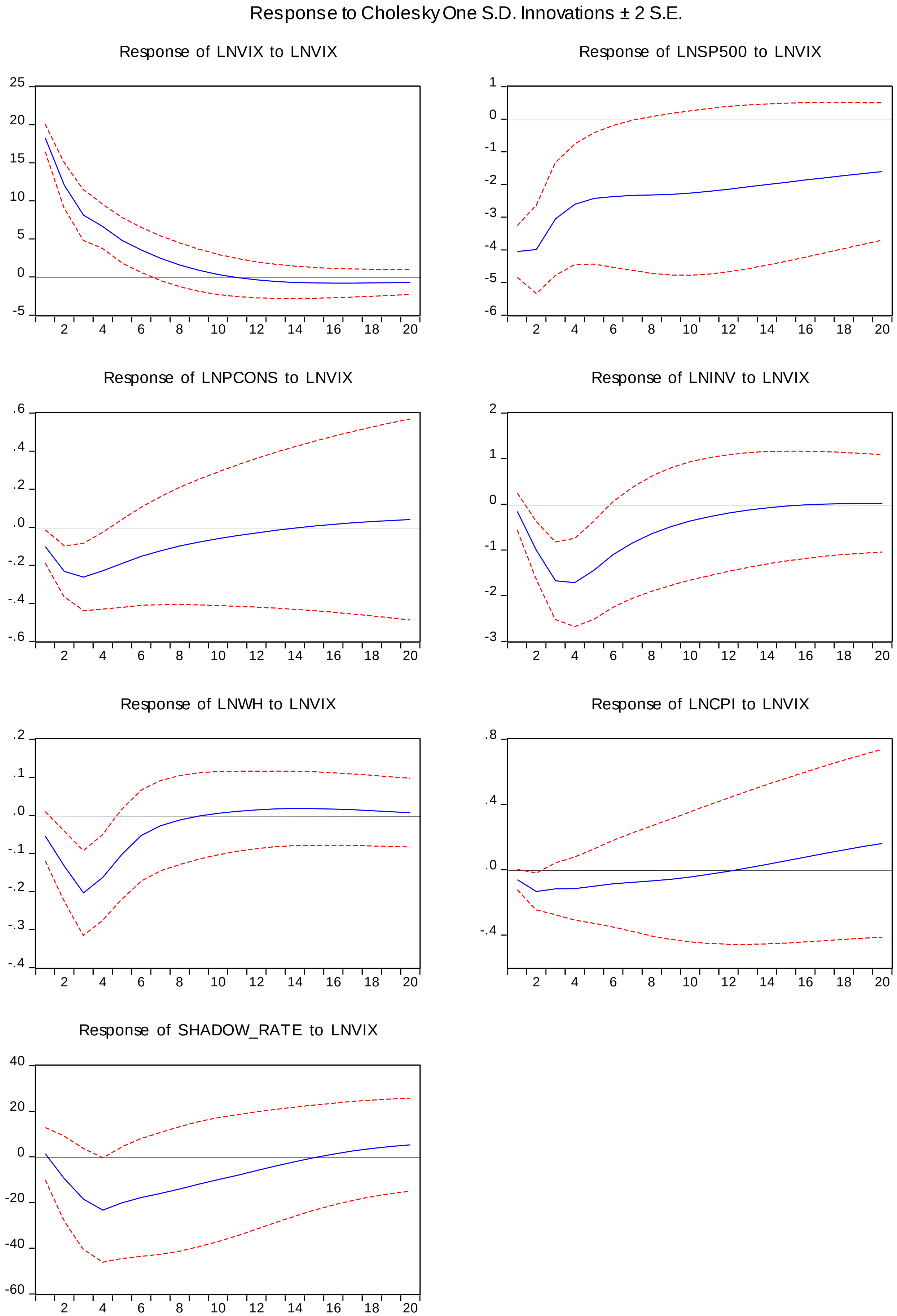


Table 1: Maximum VIX VALUE from1998 to 2015

VIX RANK	CRISIS	YEAR	MAX VIX	MAX 20d HV	VIX vs. HV
1	2008 Financial Crisis	2008	89.53	85.19	5.1%
2	Long Term Capital Management	1998	49.53	45.27	9.4%
3	9/11 World Trade Center Attacks	2001	49.35	32.39	52.4%
4	Asian Currency Crisis	1997	48.64	37.67	29.1%
5	Dotcom Crash	2002	48.46	48.17	0.6%
6	Greek Government Debt Crisis	2010	48.20	33.10	45.6%
7	Italian Government Debt Crisis	2011	48.00	46.00	4.3%
8	Flash Crash	2010	42.15	27.05	55.8%
9	Yuan Devaluation	2015	40.74	28.38	43.5%
10	Bear Stearns Collapse	2008	35.60	30.09	18.3%
11	Fukushima Nuclear Meltdown	2011	31.28	17.84	75.3%
12	Treasury Flash Crash	2014	31.06	24.64	26%
13	Spanish Economic Crisis	2012	27.73	26.71	3.8%
14	Y2K	1999	26.15	14.55	79.7%
15	Fed Tapering	2014	21.48	18.99	13.1%
16	Hurricane Katrina	2005	14.41	9.48	52.0%

Note: this table reports the maximum values (MAX VIX) reached during the negotiation days by VIX index from 1998 to August 2015. Instead, 20d HV is the highest value reached in the 20 days before the maximum VIX.

Source: Chicago Board Options Exchange

Table 2: Data description and source.

VARIABLE	DESCRIPTION	SOURCE
VIX	Index, Daily, Close, Not Seasonally Adjusted; from 02/01/1986 to 30/09/2015	Chicago Board Options Exchange
EPUI	Index, Montly, Not Seasonally Adjusted; from 01/01/1985 to 01/10/2015	Economic Policy Uncertainty
Real Gross Domestic Product	Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted; from Q1/1947 to Q3/2015	Federal Reserve Bank of St. Louis
Personal Consumption Expenditures	Billions of Dollars, Monthly, Seasonally Adjusted; from 01/01/1959 to 01/10/2015	Federal Reserve Bank of St. Louis
Gross Private Domestic Investment	Billions of Dollars, Quarterly, Seasonally Adjusted; from Q1/1947 to Q3/2015	Federal Reserve Bank of St. Louis
Consumer Price Index for All Urban Consumers	Index 1982-1984=100, Monthly, Seasonally Adjusted; from 01/01/1947 to 01/10/2015	Federal Reserve Bank of St. Louis
Average Weekly Hours Worked	Hours, Monthly, Seasonally Adjusted; from 01/01/1964 to 01/10/2015	US. Bureau of Labor Statistics
Federal Fund Rate	Percent, Monthly, Not Seasonally Adjusted; from 01/07/1954 to 01/10/2015	Board of Governors of the Federal Reserve System
Five Year Treasury Rate	Percent, Monthly, Not Seasonally Adjusted; from 01/07/1954 to 01/10/2015	Board of Governors of the Federal Reserve System
Shadow Rate	Percent, Monthly, Not Seasonally Adjusted; from 01/01/2009 to 01/10/2015	Wu and Xia (2014)
Stock Index	S&P500 index, daily, from 17/02/1885 – 1/10/2015	Federal Reserve Bank of St. Louis

Notes: All series were downloaded from the cited sources in December 2015.