LUISS

Department of Economics and Finance

Chair: International Finance

# An empirical analysis on the effects of uncertainty in the Italian economy

Prof. Pierpaolo Benigno
Supervisor

Prof. Nicola Borri
Co-supervisor

Carmelo Genovese (ID 691651)
Candidate

Academic year 2018/2019

*Ai miei genitori,*

*che hanno avuto fiducia in me*

*e mi hanno sempre supportato*

# Table of contents

## Introduction

In the last decade Italy faced a recessive economic phase. Two financial crises hit the economy during this phase. Generally, economic downturns are transitory phenomena, but the last two have not been completely absorbed and their consequences still have impacts on the economic activities. Despite all national and international stimuli, GDP is lower than the 2009 level. Moreover, the international scenario is worsening[1], therefore the possibility that another shock hits the weakened Italian system is increasing. How is it possible to explain the current economic phase and the determinants of this phenomenon?

There exists a flourishing literature about the economic effects of uncertainty, but these studies concentrate on the US economy only. This work focuses on Italy and tries to provide an answer to the previous question. The main idea is that these effects persist because last shocks have been combined with the rise of uncertainty. Uncertainty is intended as the condition of being unaware about possible realizations of some contingencies. The increase limited the recovery of the system and had effects on the business cycle. In particular, it is assumed that uncertainty plays a major role in the Italian case because some peculiarity of the economic system. Its deleterious effects were particularly relevant in credit markets, in public bonds markets and in investment decision. An empirical analysis will be conducted to highlight the relationships between uncertainty and other macroeconomic quantities. The quantities will be both financial and real. These results will be interpreted and compared with forecasts based on a theoretical model.

The empirical analysis will be performed estimating a model that captures the relationship between macroeconomic variables and an uncertainty indicator. The chosen model is a vector autoregressive model of order 2. The V.AR.(2) model will include macroeconomic variables and a composed indicator of the uncertainty level in the economy. The macroeconomic variables used are freely available online, while the uncertainty measure will be constructed. The theoretical analysis will be built on a new Keynesian model with nominal rigidities.

[1] For example, in the last months the USA rose the taxation on imported goods and oil price increases because the conflict between USA, Iran and other Arabic oil producers. In Europe the leading economy, Germany, is beginning a recessive phase.

# 1) An econometric analysis on the impact of uncertainty on the economic system

The first part of this thesis contains the empirical analysis. After the description of the dataset and the creation of a new measure of uncertainty, an econometric analysis on the time series will be performed. The following sections are divided in the V.AR. estimation and in the presentation of the impulse response functions.

## *1.1) Literature review*

The study of the uncertainty's effects in economic systems has captured the economists' attention since the early stages of the economic studies[2]. In the second part of the twentieth century the interest on uncertainty increased and the related literature rose. For example, game theorists studied the effects of uncertainty on agents' choices, as in Akerlof (1970)[3] or in Spence (1973)[4]. Other economists began to focus on particular effects of uncertainty, for example Fama (1976)[5] analysed the relationship between uncertainty and inflation rate. Successively, new mathematical and technological tools became available and economists started to study uncertainty in stochastic frameworks. In finance and in financial economics, the necessity to model and control uncertainty increased, leading to the creation of new measures and instruments such as the Volatility index[6].

After the financial crisis of 2009 the interest in uncertainty analysis has increased in other branches of economics. Macroeconomists began to construct models seeking to isolate and capture the effects of uncertainty on the business cycle. In this sense, one of the main articles is ''The impact of uncertainty shocks'' by Bloom[7]. In this article Bloom studies the firms' investment and hiring reactions to an exogenous shock. The author finds that firms react negatively to uncertainty, decreasing investment and hiring. This causes a short run crisis. This article gave the impulse to produce complementary studies on uncertainty shocks. J. Fernández-Villaverde et alt[8]. studied the effects of a shock in a small open economy. Recently, Basu and Bundick[9] published a more exhaustive article on the effect of uncertainty in a production economy. Alternative model specifications have been published, for example by S. Yildirim-Karaman[10], that introduces an OLG model with limited living households. In one of the most recent published articles, C. Bayer et alt.[11] analyse the relationship between uncertainty shocks, monetary policy and asset holding. Another recent econometric study by A. Carriero et alt.[12] focus on the permanent effects that uncertainty shock has on macroeconomic variables.

Some economists, that belong to an alternative tendency, analyse the role of policy risks in uncertain scenarios. For example, Born and Pfeifer[13] or Fernández-Villaverde et alt.[14] studied the effect of uncertainty about fiscal policy on the economy. The uncertainty shock framework supports the idea that uncertainty shocks have strong effects on real variables, while results in the fiscal policy framework are not univocal. The existing literature

---

[2] For example, F. Knight wrote a paper called ''Risk, Uncertainty, and Profit'' in 1921.
[3] G. Akerlof, ''The Market for "Lemons": Quality Uncertainty and the Market Mechanism'', The quarterly journal of economics, 1970.
[4] M. Spence, ''Job market signaling'', The quarterly journal of economics, 1973.
[5] E. Fama, ''Inflation uncertainty and expected returns on Treasury bills'', Journal of Political Economy, 1976.
[6] M. Brenner, D. Galai, "New Financial Instruments for Hedging Changes in Volatility", financial Analysts Journal, 1989.
[7] N. Bloom, ''The impact of uncertainty shocks'', Econometrica, 2009.
[8] J. Fernández-Villaverde, P. Guerrón-Quintana, J. F. Rubio-Ramírez, M. Uribe, ''Risk Matters: The Real Effects of Volatility Shocks'', American economic review, 2011.
[9] S. Basu, B. Bundick, ''Uncertainty shock in a world of effective demand'', Econometrica, 2017.
[10] S. Yıldırım-Karaman, ''Uncertainty in financial markets and business cycles'', Economic modelling, 2018.
[11] C. Bayer, R. Lütticke, L. Pham-Dao, V. Tjaden, ''Precautionary savings, illiquid assets, and the aggregate consequences of shocks to household income risk'', Econometrica, 2019.
[12] A.Carriero, T. E. Clark, M. Marcellino, ''Measuring uncertainty and its impact on the economy'', The review of economics and statistics, 2018.
[13] B. Born and J. Pfeifer, ''Policy risk and the business cycle'', Journal of monetary economy, 2014.
[14] J. Fernández-Villaverde, P. Guerrón-Quintana, K. Kuester, J. Rubio-Ramírez, ''Fiscal Volatility Shocks and Economic Activity'', American economic review, 2015.

regards mainly the US. Apart from A. Anzuini at alt.[15] and J. Crespo Cuaresma, F. Huber, L. Onorante[16] there are not published studies on the Italian case.

### *1.2) Uncertainty measurement*

While uncertainty can be easily defined, it is difficult to find an omni-inclusive measure able to capture all the sources of economic uncertainty. In literature, authors prefer to consider measures that proxy only a part of the uncertainty in the system. In this sense, statistical indicators, such as volatilities, are employed[17]. This method represents one of the two possible alternatives. It consists in inferring the level of uncertainty in the economy analysing the behaviour and the choices of the economic agents. According to the standard economic framework, the agents react to uncertainty and adequate their actions accordingly to their view about future possible contingencies. Agents react to changes in their beliefs, for example reallocating their financial portfolio or their consumption plan. From these changes it is possible to construct measures and to infer uncertainty level's movement. One issue with these indicators is the limited ability to distinguish between the value change due uncertainty and the value change due to other factors.

The alternative method consists of computing statistics and indicators based on surveys or on qualitative data. In general, these surveys are constructed to assess directly the interviewees' beliefs about future economic conditions. Typical interviewed people are either professionals, top managers or households. When these agents state their beliefs about the future, they will be influenced by their view about uncertainty. Most of the surveys are constructed to extrapolate the uncertainty view of each individual and to deduce the general level of uncertainty of the population. A classical uncertainty indicator built on surveys and publicly available is the ''Consumers' confidence level''. This indicator assesses the households' level of confidence about the current economic conditions and their opinion about future economic trends. Although these indicators[18] assess directly the uncertainty level, they may present some issues. For example, they are based on limited samples and the sampling procedure can introduce biases. Additionally, the answers of these interviewees are influenced by their cultural and social identity. Considering the Italian case, ISTAT[19] constructs the consumers' confidence indicator using a sample of 2000 consumers only while the population is above 60 million[20].

In the following empirical analysis several indicators will be considered. The next section is dedicated to the analysis and selection of the uncertainty indicator.

### *1.2) Description of selected indicators*

In the V.AR. model there will only be one measure of uncertainty. Among all possibilities, only indicators whose observation are available at least from the last quarter of 1999 have been considered. Other indicators have been discarded. The survivors have been tested and used to estimate a preliminary V.AR. model. Only two indicators seem to be suitable for the Italian case. The first indicator is the Economic Policy Uncertainty index (EPU). This is a mixed index[21] freely available online[22]. The EPU index is the aggregation of three measures. The first measure is built analysing national newspapers articles. In particular, an algorithm

---

[15] A. Anzuini, L. Rossi, P. Tommasino, ''Fiscal policy uncertainty and the business cycle: time series evidence from Italy'', Bank of Italy, Working paper, 2017.
[16] J. Crespo Cuaresma, F. Huber, L. Onorante, ''The macroeconomic effects of international uncertainty'', E.C.B. working paper, 2019.
[17] A classic example is the VIX index that asses uncertainty through equity prices' fluctuations.
[18] Similar indicators are constructed with samples of business managers, manufacture firms and similar categories.
[19] ''Istituto nazionale di statistica'', the Italian national institute of statistics.
[20] http://dati.istat.it/OECDStat_Metadata/ShowMetadata.ashx?Dataset=DCSC_FIDCONS&Lang=it.
21 Scott R. Baker, Nicholas Bloom, Steven J. Davis, Measuring Economic Policy Uncertainty, *The Quarterly Journal of Economics*, Volume 131, Issue 4, November 2016;
[22] https://www.policyuncertainty.com/;

computes the frequency at which some relevant triplets[23] appears in the articles. The second component of the index is built on the basis of the government reports about temporary tax code provision. Lastly, the authors compute a measure of disagreement about future economic forecasts provided by different professionals. The EPU index is published as a monthly time series. Since the V.AR. is estimated using quarterly data, the series used is the mean of every month realization during each quarter.

The second indicator selected is an indicator of the FTSE MIB volatility. This index belongs to the first category of indicators because it is based on observed market prices. This uncertainty indicator, corresponding to the American VIX index, is the most used in literature. However, the FTSE MIB[24] volatility index, called FTSE MIB IVI, cannot be used since available times series are not long enough. To proxy the FTSE MIB IVI, an historic volatility index has been selected. The series has been downloaded from DataStream.

The two selected indicators have limitations. The EPU index, by construction, cannot be properly replicated in a theoretical model and the relationship between the triplet and uncertainty may be questioned. The historic volatility, contrarily to FTSE MIB IV index, is backward looking, hence it only proxies properly the period level of uncertainty from prices' dispersion, not the expected uncertainty. Since these indicators presents issues, an alternative indicator has been constructed. This new estimator is a linear combination of consumers' confidences, FTSE MIB historic volatility, Euro Stoxx 50 implied volatility and a measure of uncertainty in bond markets. The last component, called $\omega$, is an alternative indicator based on the divergences of the 10Y BTP and 10Y BUND interest rates.

### *1.2.1) The description of the indicator $\omega$*

The new indicator $\omega$ is based on the divergence between the 10Y BTP and the 10Y BUND interest rate. Both BTP and BUND are long term government bonds. The 10Y BUND is amply considered as the European risk-free long-term investment and its rate of return can be used as risk free rate in most of economic and financial models based on European economies. The BTP is the Italian long-term government bond. It can be considered as the Italian riskless long-term investment. However, these securities are highly correlated. The European economic integration, started with the creation of the European Economic Community (ECC) and hastened with the creation of the European Union (EU), increased the cross-country financial integration. Nowadays, the European Central Bank (E.C.B.) takes all monetary policy decisions and has the duty to monitor the European banking system. This increasing economic integration of the European countries implies that also the financial instruments become closely related. Nevertheless, returns of many instruments, for example long term government bonds, are still different because of issuers' economic structural differences. In particular, returns on German government bonds are lower than the returns on Italian government bonds. According to the asset pricing theory, the return of an asset is higher if the risk associated with the asset is higher. Especially for long term bonds, differences come from structural aspect of the economy and from uncertainty about economic stability in unfavourable scenarios. The main idea behind $\omega$ is to infer changes in the uncertainty level from changes in the secondary market rates of return[25].

This can be possible because only professional agents invest in the government bonds' secondary market. Daily, they negotiate government bond, trying to adjust their portfolios to market changes or trying to speculate on bonds' mispricing. Actions of these agents are partly influenced by daily news, new issues, E.C.B. policies, political inference, and other social phenomena. These aspects define and contribute to the level of uncertainty in the economy. The aim of the indicator is to isolate uncertainty dynamic from bonds' rate movements. To

---

[23] The triple must contain the word economy (or similar), the word uncertainty (or similar) and a word regarding economic policy. See the website or the original paper for further details.

[24] The Italian stock exchange.

[25] Government bonds have predetermined returns. The payment structure is determined at the issue date. The rate of returns used in this analysis are the secondary market returns. These returns may differ from the return agreed in the first market.

isolate this effect, daily market rates time series are used. For each series, the daily change is calculated. A new indicator function can be computed using daily changes. This indicator function takes value 0 if the daily changes of the two bonds' return have same sign. If the BTP's return increases while the BUND's return decreases, the indicator function takes value 1. In the opposite case, the indicator function takes value -1. The logic behind this choice is to discard co-movement in returns and assume that divergence is also caused by change in uncertainty[26]. Without further information, if rates move in the same directions, it is not possible to do inferences. Differently, if rates move oppositely, agents are reacting to new information about one of the two economies. Considering German economy as the leading European economy, it is possible to assume that negative news about German economic conditions will directly afflict Italian government bonds. On the other side, since Italy is just the third[27] economy in the EU, it is possible to suppose that negative information about Italian economic conditions afflict mainly Italian bonds and marginally German securities. In this case, the spread between the rates increases if negative information about Italian economy become available, while tighten in case of positive information releases. Therefore, if rates diverge, economic view about the Italian economy worsen and uncertainty may be increasing. In the opposite case uncertainty decreases.

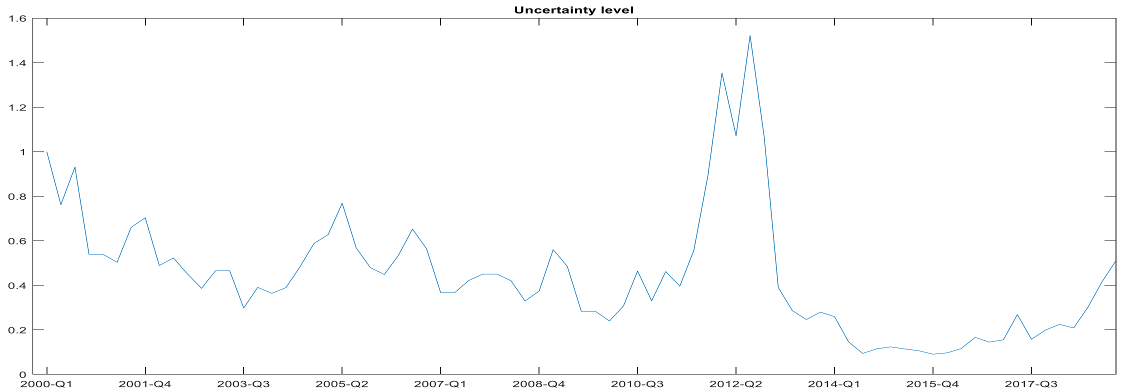
The indicator function takes value -1 if uncertainty decreases, 0 if does not vary, +1 if it increases:

$$f(x) = \begin{cases} -1 & \Rightarrow sign(\Delta ir_{it}) < 0 < sign(\Delta ir_{de)} \\ 0 & \Rightarrow sign(\Delta ir_{de}) = sign(\Delta ir_{it}) \\ +1 & \Rightarrow sign(\Delta ir_{de)} < 0 < sign(\Delta ir_{it)} \end{cases} .$$

The sign of the indicator function can be considered as a proxy for the dynamic behaviour of uncertainty in the economy. This function transforms daily signals in a quarter index. At this point, a measure that includes both prevalent direction of uncertainty changes and frequency of the changes can be constructed. This measure is defined as follows:

$$\omega_{q_t} = \sigma[f(x_t)] * \frac{\sum_t f(x_t)}{10} for\ any\ t \in q_t, where\ q_t is\ the\ quarter.$$

The first term is the standard deviation of the daily signals. This term captures the amount of divergent changes. The second term indicates whether the cumulative uncertainty level increases or not. If the sum is positive, more divergent shocks arose, so uncertainty increased. Contrarily, the sum is negative if uncertainty is diminishing and rates are converging. It is zero when positive and negative shocks balances and it is not possible to conclude anything about uncertainty movements. The graphic representation of the indicator ω is:




[26] This change may be due to policy changes or cycle conditions.
[27] Considering the United Kingdom, Italy would be fourth.

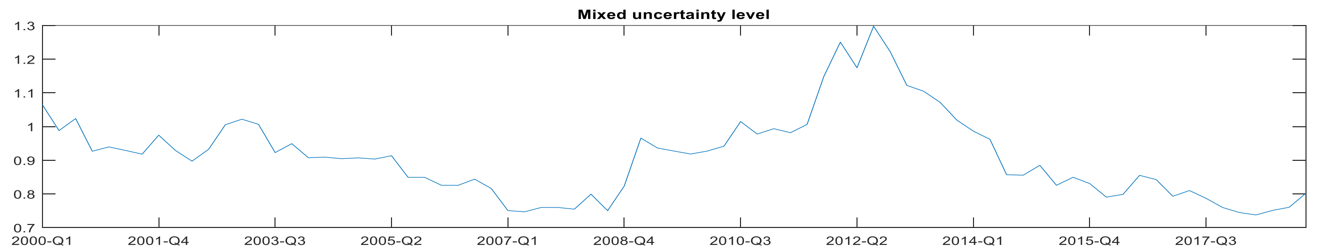
The constructed indicator suggests that uncertainty is decreasing at the beginning of the century. Later, it grew around 2005 and 2008. It is worth noting that the indicator increases but does not peak in 2007-2009 as traditional indicators suggests. This indicates that $\omega$ does not fully capture uncertainty coming from economic downturn caused by the U.S. financial crisis. After the American crisis, the European countries faced another downturn and uncertainty peaked. In particular, from 2010, European countries faced a sovereign debt crisis. Financial investors considered bonds of countries with high debt to G.D.P. ratio, including Italy, highly risky, causing a drop of bonds price and the beginning of a recession period. According to the indicator, this was a period of high uncertainty. From 2013 uncertainty fell, probably because the spread was strongly influenced by the intervention of E.C.B. and by changes in politics and budget spending. However, from the second part of 2017, uncertainty seems to be strongly rising. This may be caused both by international frictions among developed countries and by the change in the domestic politic equilibrium. In appendix A, section 4.1.3, it is possible to find the analysis of the relationship between the indicator $\omega$ and the spread.

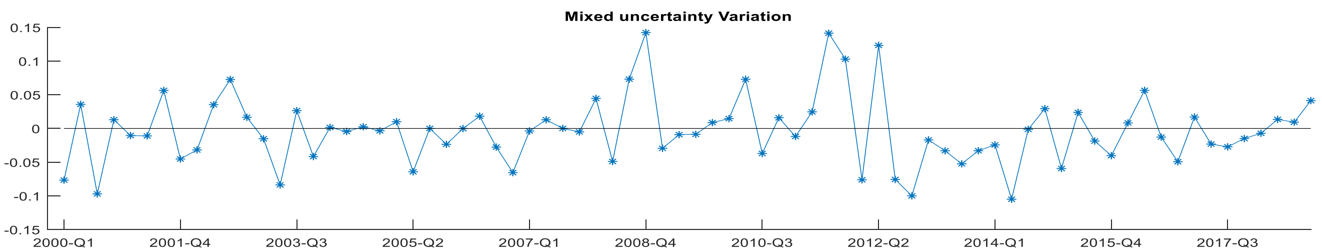
### *1.2.2) Mixed uncertainty indicator U*

Every indicator available has weaknesses and captures only particular aspects of uncertainty. To improve the analysis, it is the case to construct an indicator that comprehends all the previous measures. This indicator includes consumers' uncertainty, signals from Equity markets volatility and signals from long-term public bonds' prices. A possibility to integrate this information is the construction of a linear combination between different measures. To capture consumers' uncertainty[28], consumers' confidence level is used and the indicator $\omega$ will be included to capture signals from the bonds' market. An Equity market signal will be included, but two indicators will be used, the FTSE MIB historic volatility and the Euro Stoxx 50 implied volatility index[29]. It is convenient to include also the Euro Stoxx IV index because it captures changes in uncertainty at European level. The mixed indicator is computed as follows:

$$U_t = 0.425 * \left(\frac{Cons'.conf}{mean(cons'.conf)}\right)^{-1} + 0.075 * \frac{\omega}{mean(\omega)} + 0.35 * \frac{H.V.}{mean(H.V.)} + 0.15 * \frac{E.S.IVI}{mean(E.S.IVI)}.$$

In the next figure it is possible to observe the estimated level of uncertainty and the level movements during the dataset's period:



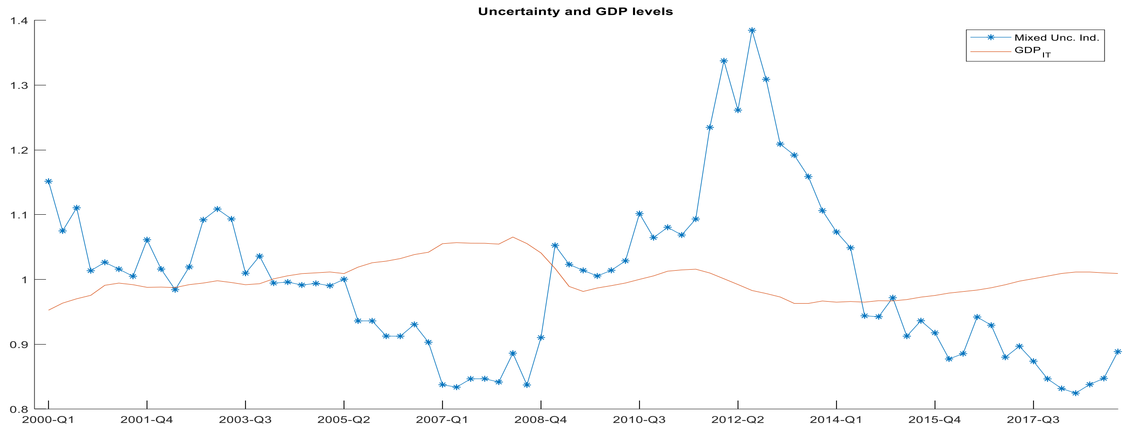




According to the mixed indicator $U_t$ uncertainty is decreasing until 2007. From late 2008, at first for the US financial crisis, then also for the European sovereign crisis, uncertainty strongly increased. After the 2012 the

[28] To describe consumer's uncertainty the inverse of consumers' confidence has been considered.
[29] The Euro Stoxx 50 implied volatility has been downloaded from the Bloomberg platform.

indicator suggests decreasing uncertainty. Analysing the first difference's path it is clear that two main shocks arose in uncertainty during the sample period: 2008 and 2010-2011 crises. However, after the 2008 crisis the uncertainty level did not move back, and it stayed constant for two years. At this point, another shock hit the economy, so the aggregate level reached its peak. This was the period of the feared sovereign default. To avoid the default and to contrasts rising uncertainty, Italian government began restrictive budget policies. When it was clear that Italy would not have defaulted, uncertainty diminished. At this point the economic system started to experience a slightly increasing period, while uncertainty kept decreasing.

To complete the description of the mixed indicator it is the case to study the relationship between the indicator and the GDP and between the different indicators. The correlation between $U_t$ and the GDP is -48%. The behaviour of the time series is represented in the following picture:




The following table contains the correlation coefficients between the various indicators:

Correlation matrix

| | EPU index | Historic volatility | Omega | Consumers' Confidence | Euro Stoxx 50 IVI | Mixed indicator |
|---|---|---|---|---|---|---|
| EPU index. | 1 | 50% | 4% | 17% | 39% | 45% |
| Historic volatility | 50% | 1 | 24% | 22% | 21% | 82% |
| Omega | 4% | 24% | 1 | 32% | 16% | 65% |
| Consumers'. Confidence | 17% | 22% | 32% | 1 | 5% | 57% |
| Euro Stoxx 50 IVI | 39% | 21% | 16% | 5% | 1 | 40% |
| Mixed indicator | 45% | 82% | 65% | 57% | 40% | 1 |

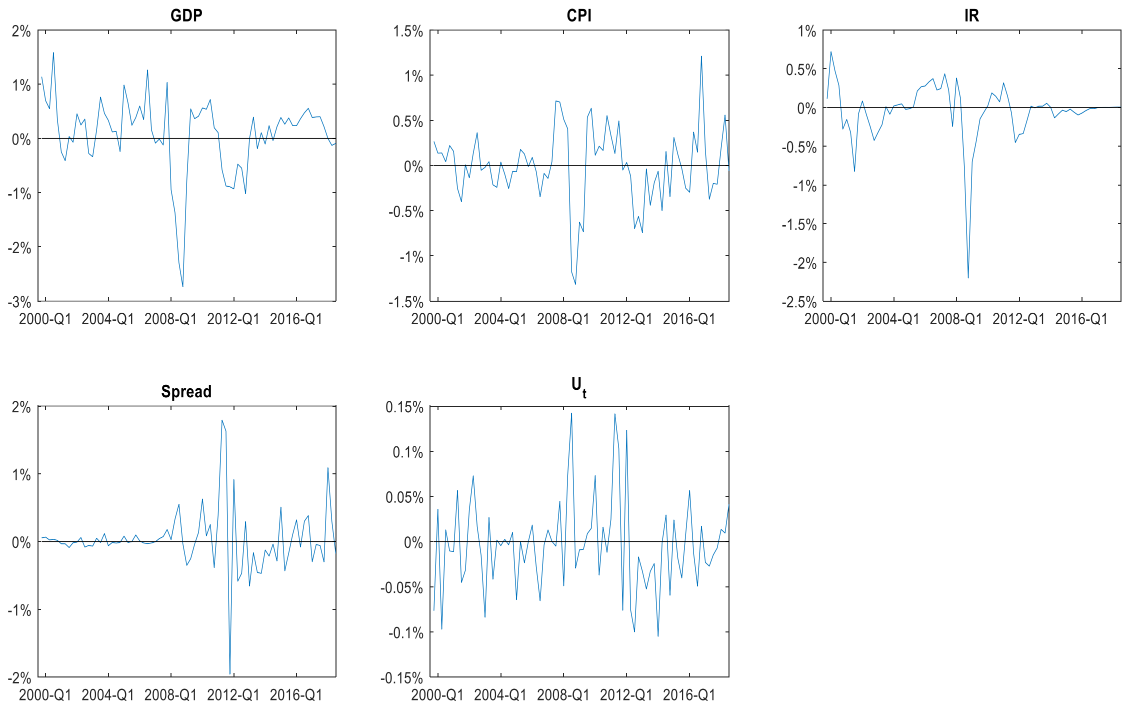
The mixed indicator is highly correlated with all the other considered measures of uncertainty. It is correlated also with the EPU index, which has not been used to construct $U_t$. Even the correlation with $\omega$, which has the lowest weight in the formula, is high. Another relevant information is that the inverse of the consumers' confidence has the second highest correlation with the indicator $\omega$.

## *1.3) Data description and analysis*

The econometric analysis is based on four macroeconomic variables and one uncertainty indicator. The first variable of the model is the Italian gross domestic product percentage change (GDP). The second variable is the consumer price index (CPI). The third variable is the short-term interest rate (IR), annualized. Data of these series are available online on the OECD website[30]. The last variable is the 10Y BTP-BUND spread. This time series has been computed using interest rates available on DataStream.

The uncertainty indicator employed in the V.AR. analysis is the composed indicator $U$. For completeness and comparison, other two V.AR. models will be estimated using the EPU index and the Historic volatility.

The V.AR. model requires stationary data[31]. To check stationarity, the Augmented Dickey–Fuller test and the KPSS test have been performed. These tests evaluate whether the series presents a unit root or not. Both tests indicate that the time series are not stationary[32]. To introduce stationarity, it is necessary to detrend the series. The method used to detrend the series is first difference. The Augmented Dickey-Fuller tests indicates that all series are stationary in first difference. Contrarily, the KPSS indicates that the GDP is not stationary in first difference. Series are all stationary in second difference. Although the KPSS criterion suggests using second difference time series, the final decision is to estimate the model in first difference. The first difference time series are presented in the following figure:




Correlations between variables in first differences are summarized in Table1. Some variables are highly correlated, for example GDP and IR, GDP and CPI or Spread and -U. Other correlations are negligible, for example CPI and U or GDP and Spread.

Since in a V.AR.(p) model each variable depends on the $p$ past realizations of the variables, it is the case to analyse the Autocorrelation and the Partial autocorrelation functions of each series. The ACF function and the PACF function can be used to infer the order of the AR(p) processes[33]. The functions are reported in section 4.2, figure 1 and figure 2. In general, the autocorrelations decay to 0 at high lags and the PACFs are negligible

[30] The GDP series can be found here: https://data.oecd.org/gdp/quarterly-gdp.htm#indicator-chart; The CPI can be download here: https://data.oecd.org/price/inflation-cpi.htm#indicator-chart; The short term interest rate is available here: https://data.oecd.org/interest/short-term-interest-rates.htm.

[31] This is controversy. Some authors argue that stationarity is not required if the variables have the same order of integration and are cointegrated.

[32] Except for the GDP series, which is stationary according to the ADF test, while it is not stationary according to the KPSS test.

[33] The Box Jenkins methodology.

or become negligible after one period. This indicates the possibility to fit an AR(p) model for some of the variables. After the data analysis, it is the case to select the order p of the V.AR. model.

### *1.3.1) V.AR. order decision*

To decide the order p of the V.AR.(p) model two information criteria are considered. The first criterion is the Akaike information criterion (AIC). The second is the Bayesian information criterion (BIC). The latter is closely related to the AIC criterion, but penalizes higher order models. Capping the search field to $p = 6$, the results are summarized in Table2:

Table 2

| Order | AIC | BIC |
|---|---|---|
| 1 | -12,9 | 56,6 |
| 2 | -0,4 | 126,4 |
| 3 | 9,0 | 192,3 |
| 4 | 8,5 | 247,5 |
| 5 | -16,9 | 277,2 |
| 6 | -17,5 | 331,0 |

The order with lower criterion value should be selected. The criteria diverge. The AIC criterion is minimum at order 6. According to the BIC criterion, a V.AR.(1) model should be selected. Because the criteria suggest different orders, a joint minimization approach is used. The V.AR.(2)'s BIC value is the second smallest and not very far from to the V.AR.(1)'s BIC value. The AIC is relatively small at order 1 and order 2. The best candidate would be $p = 1$. However, the order selected is $p = 2$. A one period lag model is simpler to analyse and to deal with. It has a smoother impulse response functions and the shocks' effects expire sooner. But the aim of this work is to analyse real interactions between uncertainty and other macroeconomic variables, hence more complex dynamics are useful. Considering both the desire for more complete impulse response functions and the necessity to build a consistent econometric model, the best choice would be to estimate a V.AR.(2) model. This model have acceptable AIC and BIC values and directly consider changes in macroeconomic variables up to six months.

## *1.4) V.AR.(2) model estimation*

The V.AR. model consists of 5 equations with 10 coefficients each plus the intercepts. The parameters to be identified are 55:

$$y_t = \begin{pmatrix} GDP_t \\ CPI_t \\ IR_t \\ Spread_t \\ \omega_t \end{pmatrix} = \left\{ \begin{matrix} a + a_1 GDP_{t-1} + a_2 CPI_{t-1} + a_3 IR_{t-1} + a_4 Spread_{t-1} + a_5 \omega_{t-1} + b_1 GDP_{t-2} + b_2 CPI_{t-2} + b_3 IR_{t-2} + b_4 Spread_{t-2} + b_5 \omega_{t-2} \\ c + c_1 GDP_{t-1} + c_2 CPI_{t-1} + c_3 IR_{t-1} + c_4 Spread_{t-1} + c_5 \omega_{t-1} + d_1 GDP_{t-2} + d_2 CPI_{t-2} + d_3 IR_{t-2} + d_4 Spread_{t-2} + d_5 \omega_{t-2} \\ e + e_1 GDP_{t-1} + e_2 CPI_{t-1} + e_3 IR_{t-1} + e_4 Spread_{t-1} + e_5 \omega_{t-1} + f_1 GDP_{t-2} + f_2 CPI_{t-2} + f_3 IR_{t-2} + f_4 Spread_{t-2} + f_5 \omega_{t-2} \\ g + g_1 GDP_{t-1} + g_2 CPI_{t-1} + g_3 IR_{t-1} + g_4 Spread_{t-1} + g_5 \omega_{t-1} + h_1 GDP_{t-2} + h_2 CPI_{t-2} + h_3 IR_{t-2} + h_4 Spread_{t-2} + h_5 \omega_{t-2} \\ i + i_1 GDP_{t-1} + iCPI_{t-1} + iIR_{t-1} + iSpread_{t-1} + i_5 \omega_{t-1} + j_1 GDP_{t-2} + j_2 CPI_{t-2} + j_3 IR_{t-2} + j_4 Spread_{t-2} + j_5 \omega_{t-2} \end{matrix} \right\}.$$

The observations are 76 for each variable. The estimation method employed is the maximum likelihood estimator. The MATLAB® software has been used for computation. In particular, parameters and statistics have been estimated using the function ''estimate''. However, it is possible to estimate the model with the ordinary least squares estimator. This is possible because the model is analogous to a seemingly unrelated regressions model (SUR) with the same regressors for each equation[34]. Indeed, the OLS estimation is

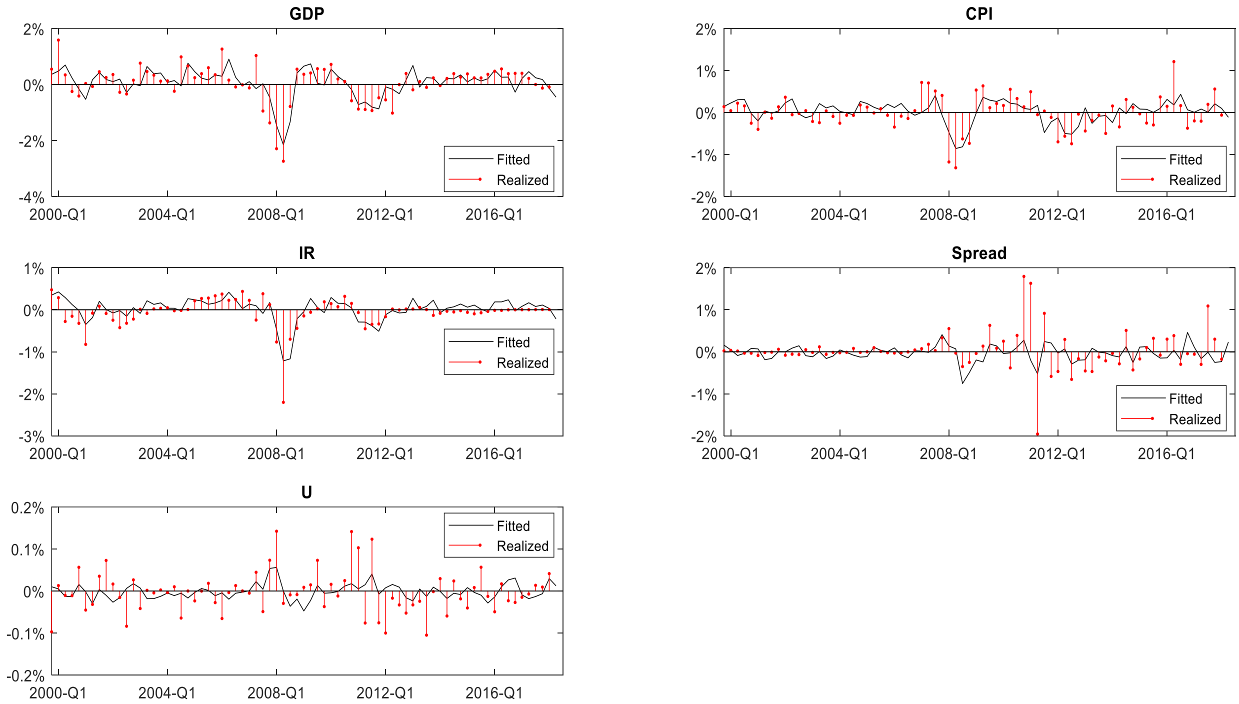
[34]This is one of the two sufficient Zellner's condition. Under this condition, the OLS estimation of the coefficients it consistent and it is possible to estimate the whole system estimating individually each of the equations.

consistent and coincides with the maximum likelihood estimation[35]. The estimated coefficients are presented in Table 3:

Table 3

| | GDP(t-1) | CPI(t-1) | IR(t-1) | Spread(t-1) | U(t-1) | GDP(t-2) | CPI(t-2) | IR(t-2) | Spread(t-2) | U(t-2) |
|---|---|---|---|---|---|---|---|---|---|---|
| GDP(t) | 0,59 | 0,03 | 0,24 | 0,08 | -2,27 | 0,10 | -0,51 | -0,32 | 0,00 | 1,25 |
| CPI(t) | 0,28 | 0,24 | -0,06 | 0,11 | 0,13 | 0,09 | -0,09 | -0,04 | -0,04 | 1,61 |
| IR(t) | 0,15 | 0,12 | 0,33 | 0,06 | -2,16 | 0,10 | -0,16 | -0,12 | 0,02 | -0,07 |
| Spread(t) | -0,05 | -0,03 | 0,20 | -0,22 | 0,67 | 0,03 | 0,40 | -0,07 | -0,24 | 1,11 |
| ω(t) | -0,02 | 0,02 | 0,01 | 0,00 | -0,14 | 0,00 | 0,03 | 0,00 | 0,01 | -0,19 |

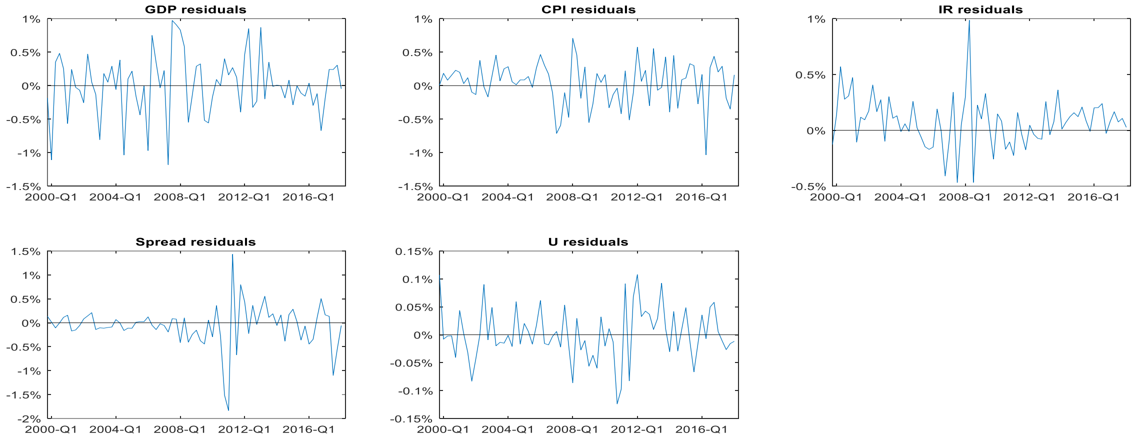
Intercepts have been omitted. Details about intercepts and further statistics about all the coefficients can be found in table 4. The adequacy of the estimated model is summarized in the following figure:




[35]In the MATLAB script the file the OLS estimation has also been coded.

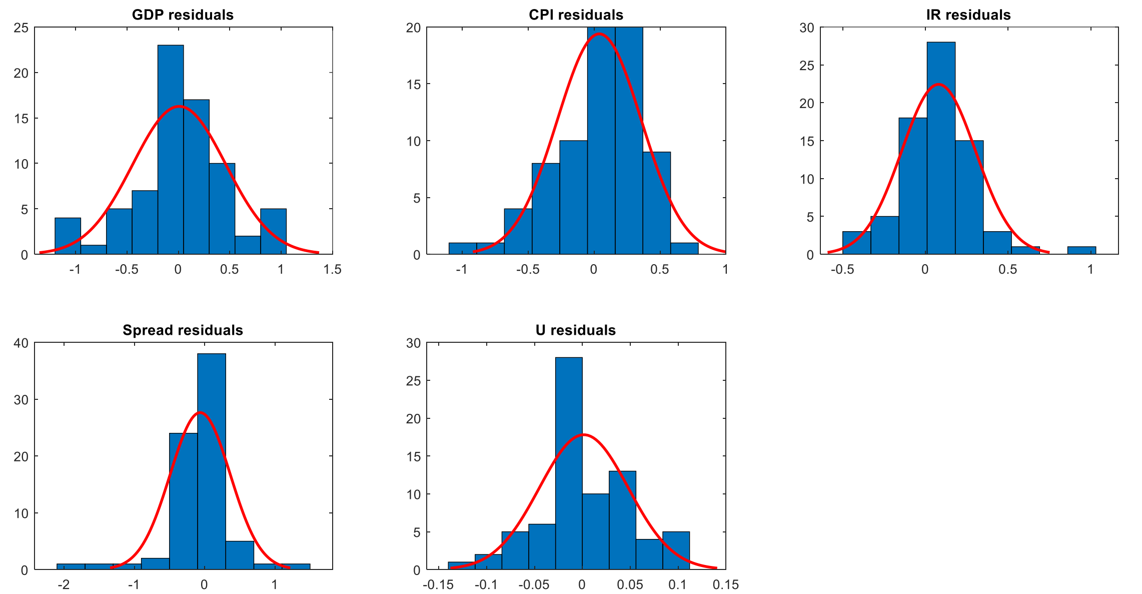
### *1.4.1) Analysis of the residuals*

Since the V.AR. model consists of linear regressions, it is the case to analyse the statistical properties of residuals. In theory, the generating process should be a Gaussian Normal distribution. Under this assumption, the asymptotic distribution of residuals should be normal. However, the dataset used to determine the coefficients has 76 observations, therefore asymptotic properties may not be verified. Additionally, SUR models tolerate correlated residuals at the same point in time, but there should be no correlation among residuals at different time. The residuals are presented in the following figure:



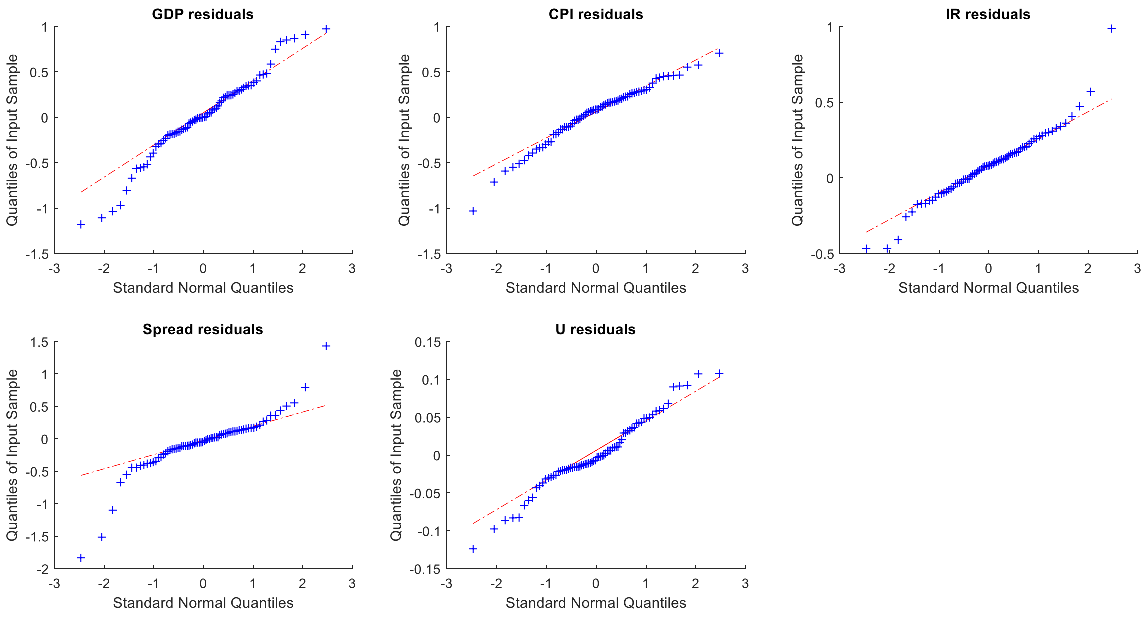

Extreme realizations are present in graph 3 and in graph 4. They are related to the crises. In particular, the residuals of equation 3 (IR) increase during the period of the US financial crisis, while the residuals of equation 4 (Spread) seem to overreact during the European sovereign debt crisis. The presence of extreme realizations suggests that the sample's residuals may be not normally distributed.

To investigate whether residuals' normality is verified or not, it is convenient to plot the histograms of each series:




The equation 4's histogram highlights the presence of non-normal kurtosis. In particular, the distribution seems to be leptokurtic.

Additional information can be derived from the quantile-quantile plot (QQ-plot). The QQ-plots presented below compares the quantiles of the errors' empirical distribution with the quantiles of a normal distribution:




The graphical analysis suggest that CPI's residuals are probably normal. Even residuals of IR and U are probably normally distributed. The GDP's residuals are less fitted then the IR and the U case, but probably them are normally distributed. Spread's residuals may be not normal. It is the case to complete the analysis with a formal test. The chosen test is the Lilliefors test. This test is a non-parametric test used to analyse normality when mean and variance are not known. Performing the test, the null hypothesis that the errors are normally distributed is rejected for equation 4 at 5% confidence level. Since evidence suggests that the estimated model does not satisfy normality of residuals, is it the case to modify the model?

Probably not. Test failure is likely to be caused by sample shortness. Moreover, the sample covers the period from first quarter of 2000 to last quarter of 2018, where two major shocks arose. The presence of two important economic shocks in limited sample caused the extreme realizations and the residuals issues. A larger sample, including economic shocks arose in eighties and in the nineties, would have improved estimation performances. For completeness, the Spread's residuals without extreme realizations[36] have been tested. In this case, the Lilliefors test cannot reject the null hypothesis of normality. It is possible to see the histogram and the QQ-plot of the modified residuals series in Figure 3 of appendix A.

The second part of residuals analysis is about correlation among residuals. In particular, it is the case to verify whether residuals are correlated across time or not. It is possible to verify if residuals' ACF and PACF are relevant. The ACF and PACF are presented in Appendix A, Figure 4 and 5. Analysing the Figures, it is possible to argue that the autocorrelations and partial autocorrelations are not relevant. To complete the analysis, a hypothesis test[37] has been performed. The test confirms the graphic intuition.

Since residuals are not autocorrelated and the Spread's non normality probably comes from the dataset's period peculiarities, the model will be considered valid and confirmed as the empirical baseline model.

[36] The realizations greater than 0.99 have been considered outliers.
[37] The test performed is the Ljung–Box test.

## *1.5) Impulse response functions*

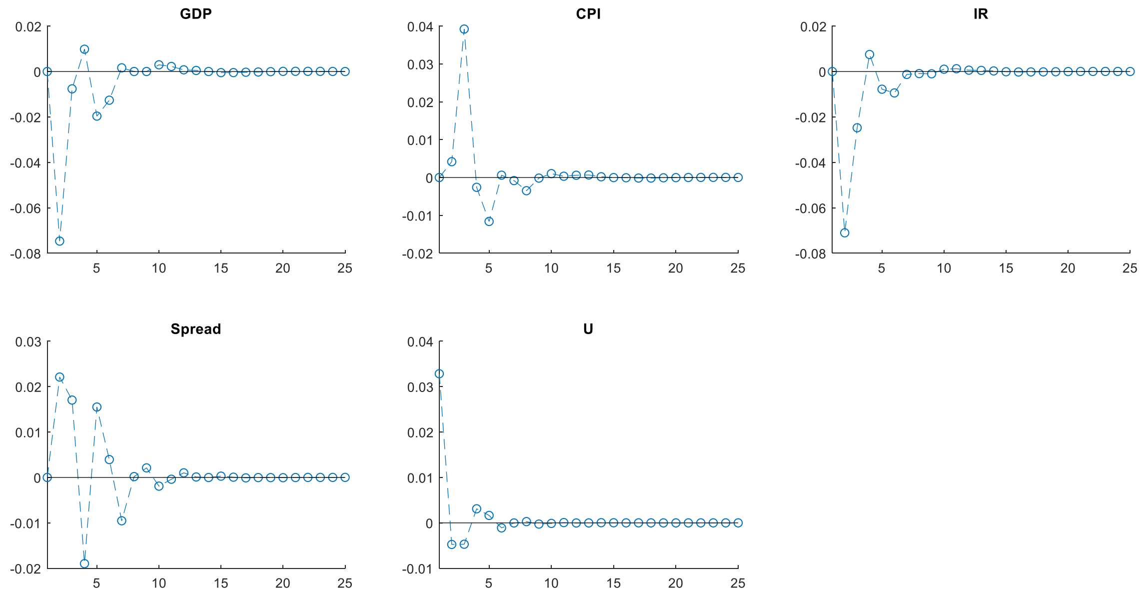
The estimated V.AR. model is useful to simulate the dynamic responses of the economic system to economic shocks. Assuming that the model is in equilibrium, the impulse response functions describe the dynamic behaviour of each variable of the system. When a shock hits one of the variable, it propagates in time to all the others. The effects of the shock's propagation is fully determined by the coefficients. In this analysis, a shock is the unpredicted realization of a variable. Since the model is stationary, the effects of every shock will eventually dry out over time and the system will reach a new equilibrium level. If the system is in equilibrium, all variables are constant. Without loss of generality, it is possible to assume that $y_t = 0$ for any t.

The impulse response functions can be easily calculated. Assume, for example, that an unit shock hits the GDP at time t-1. According to the model, if $GDP_{t-1} = 0 + \varepsilon_{t-1}^{GDP}$, the variables at time t-1 and t will be

$$y_{t-1} = \begin{Bmatrix} GDP_{t-1} \\ CPI_{t-1} \\ IR_{t-1} \\ Spread_{t-1} \\ \omega_{t-1} \end{Bmatrix} = \begin{Bmatrix} \varepsilon_{t-1}^{GDP} \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix}; \; y_t = \begin{Bmatrix} GDP_t \\ CPI_t \\ IR_t \\ Spread_t \\ \omega_t \end{Bmatrix} = \begin{Bmatrix} a_1 GDP_{t-1} \\ c_1 GDP_{t-1} \\ e_1 GDP_{t-1} \\ g_1 GDP_{t-1} \\ i_1 GDP_{t-1} \end{Bmatrix} = \begin{Bmatrix} -0.34\varepsilon_{t-1}^{GDP}, \\ +0.16\varepsilon_{t-1}^{GDP}, \\ +0.06\varepsilon_{t-1}^{GDP}, \\ -0.06\varepsilon_{t-1}^{GDP}, \\ -0.07\varepsilon_{t-1}^{GDP}, \end{Bmatrix}.$$

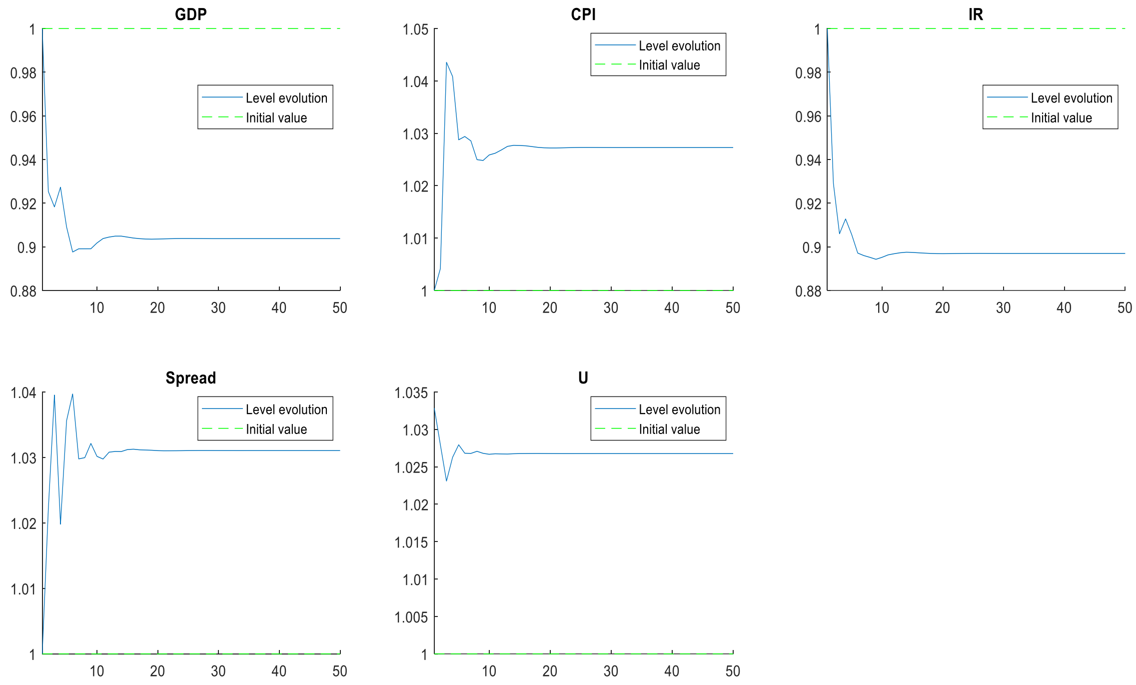
These are the first period impulse response function for a shock that hits GDP. It is possible to substitute $y_{t-1}$ and $y_t$ in $y_{t+1}$to determine the response at time t+1. This procedure can be iterated forward. Eventualy, the impulse responses will approach zero and the effects of the shock will be negligible.

The main interest is to determine the system's response to an uncertainty shocks. The impulse response to other shocks can be find in appendinx A. The following figure shows the orthogonalized dynamic response to a positive unit shock in the uncertainty level:




The system's response in the first period is negative. Thereafter GDP and IR decrease for several periods. The Spread response is mainly positive but oscillatory. Of course the spread response in negative in economic terms because spread growth implies higher cost of financing. The CPI increases. Even the response of the uncertainty indicator U is positive but dries out quickly.

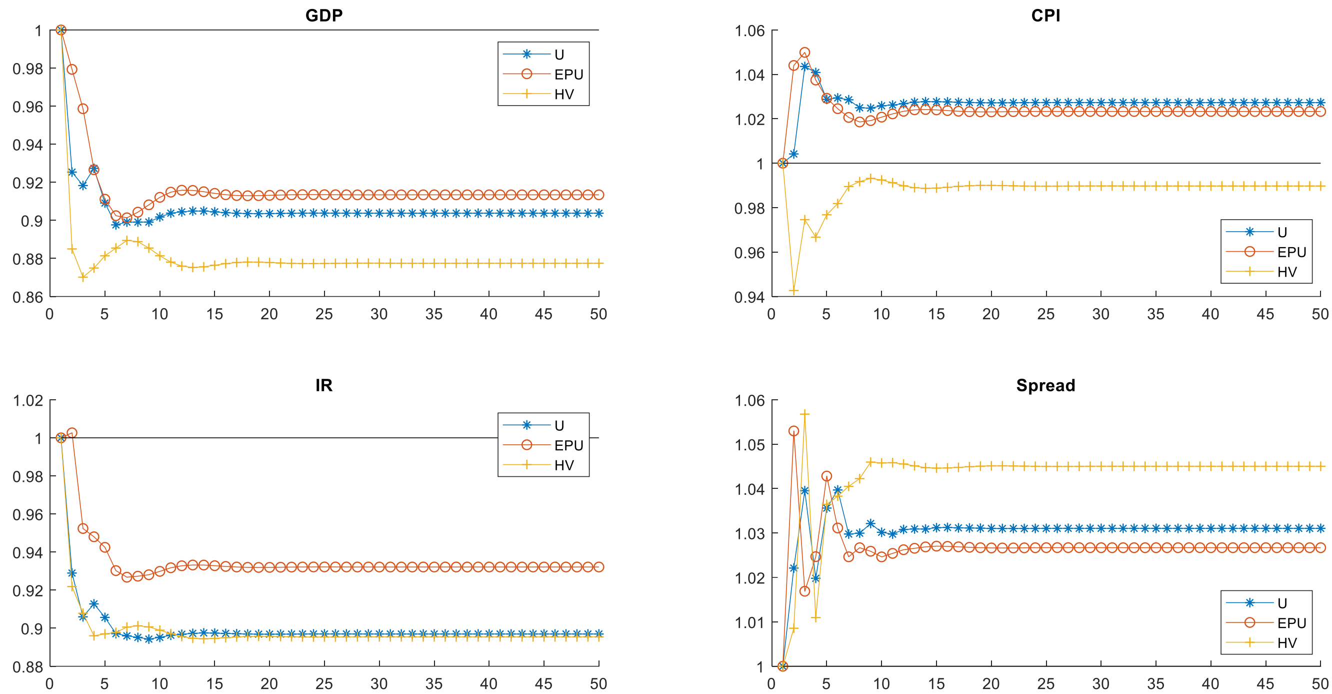
Since the series are in first differences, it is the case to compute the level behaviour of the system to the uncertainty shock. Starting from the equilibrium level $y_t = 1$, the level movements are desribed in the following figure:

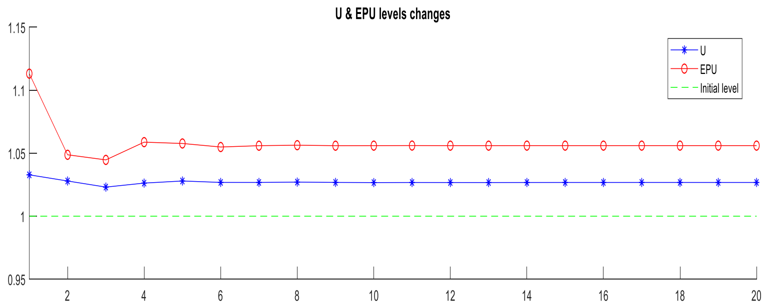


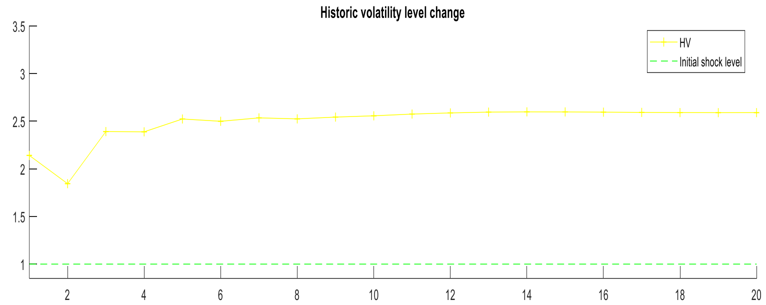

From the levels' changes it is possible to infer the impact that the shock has on the economic system. All quantities have new equilibrium level. The uncertainty level increase. The increase is associated with the decrease of the country production. The GDP has permanetly diminished. The CPI increases despite the crises. This result is affected by the expansive policy. But, if the Fisher equation holds, short term interest rate decrease and the inflation increase imply that the real interest rate must decrease. The incentives to invest are lower and the long term recover may be longer. Additionally, the uncertainty indicator increase the spread. Although the short term dynamic is opaque, the long term increase in long term government bond may undermine the role of the government. If the cost of financing increase the policymaker cannot implement expansive policies and the economic stimuli coming from public spending diminish.

To complete the analysis, the dynamic beaviours of the systems has been simulated using the other uncertainty indicators. The aggregate movements caused by an uncertainty shock are compared in the following figures[38]:

[38] The indicators' impulse response functions are reported separately to simplify graphic analysis. The historic volatility level change is higher, hence in the same figure it would have out scaled the $U$ and EPU changes.




The GDP's responses are similar. The empirical models predict 10% drop in GDP after the shock hit the economy. The historic volatility shock produces an higher drop in output, that recovers for some periods before dropping again to the minimum level. In any case, all models suggest that unexpected uncertainty increase imlpies a permanent decrease in GDP. The CPI behaviour is not univocal. The baseline model, as the V.AR.

model with the EPU index, suggests that inflation rises +6% immediately after the shock and remains +2% higher in the long run. The model with HV predicts a symmetric dynamic behaviour, an initial level drop of 6% is followed by a convergence phase where inflations approch the level 0.99. In the IR case every models predict a permanent level decrease, although the permanent decrease in the EPU case is only 6% while the other predics a 10% permanent fall. The spread's impulse response functions are oscillatory. They converges to higher levels but in the short run their behaviour is not univocal. The oscillations of U and HV are sincronized, while EPU differs. After 5 periods, the EPU model's level converges to the level predict by the indicator $U$, while in the model with historic volatility the level is slightly higher. It is the case to focus on the spread’s short term oscillations. The oscillations may be problematic since they do not indicate a clear path followed by the spread in the short run and may questioned the goodness of the model. Nevertheless, this issue is common in all the estimated model. Since it is a common behaviour to uncertainty shock, the origin of this movement must be found in the dataset. Probably the limited data length entails estimation weakness for the coefficients of the Spread.

Lastly, the uncertainty indicators’s changes are different. After an initial jump due to the positive shock, $U$ and EPU sligthly recover to lower level, while the historc volalitility keep increasing and converges to an higher value. Even if in all the models predicts that an uncertainty shock permanently increase the indicator, the historic volatility seems to overreact.

## 2) A Theoretical analysis on the impact of uncertainty on the economic system

To complete the analysis of the Italian economy's response to an uncertainty shock, it is necessary to compare the empirical findings with the results implied by a theoretical macroeconomic model[39]. In this section the model will be described, solved and impulse response functions will be presented. Finally, differences and similitudes between theoretical and empirical evidences will be discussed.

### *2.1) The description of the model*

Consider a world inhabited by a representative household, a continuum [0,1] of firms that produce intermediate goods, a representative final producer and a neutral government. The household, which is economically rational, consumes, works and owns the firms. Final producer invests in intermediate goods that can buy from each intermediate producer. Intermediate producers are monopolistic competitors and produce using only labour. The government does not act in markets and enforces only an interest rate rule. The interest rate rule depends on inflation, interest rate and output variations.

#### *2.1.1) The household's problem*

The household's decisions regard how much to consume each period, how much labour to supply, and the amount of money to hold. He can also decide to invest in a one period bond market. Through money holding and the bond he can move wealth across different periods. Every period he receives salary for the work supplied, he earns profits from owned firms and pays tax[40]. Assuming that he lives forever, his problem can be formalized as follows:

$$\max_{\{C_t,N_t,M_t,B_{t+1}\}_{t=1}^{+\infty}} \left\{E_0\left[\sum_{t=0}^{+\infty}\beta^t\left[\frac{C_t^{1-\sigma}}{1-\sigma}-\frac{\psi N_t^{1+\eta}}{1+\eta}+\theta\ln\left(\frac{M_t}{P_t}\right)\right]\right]\right\}$$

under the periodical budget constraint

$$P_tC_t+B_{t+1}+M_t-M_{t-1}=W_tN_t+\Pi_t-P_tT_t+(1+i_{t-1})*B_t.$$

The household is assumed to be ''impatient'', because the importance of future consumption, labor and money holding is decreasing over time. In fact, it is assumed that the discount factor $\beta$ is positive and smaller than 1. Moreover, he does not care about money, but about the real money balance.

This problem corresponds to an infinite constrained maximization. It can be solved introducing the correspondent Lagrangian function and maximizing for the choice variables and the Lagrangian multiplier. The problem becomes $\max_{\{C_t,N_t,M_t,B_{t+1}\}_{t=1}^{+\infty}} \Delta(C_t,N_t,M_t,B_{t+1})$, equal to:

$$\max_{\{C_t,N_t,M_t,B_{t+1},\lambda_t\}_{t=1}^{+\infty}} \left\{E_0\left[\sum_{t=0}^{+\infty}\beta^t\left\{\left[\frac{C_t^{1-\sigma}}{1-\sigma}-\frac{\psi N_t^{1+\eta}}{1+\eta}+\theta\ln\left(\frac{M_t}{P_t}\right)\right]-\lambda_t[P_tC_t+B_{t+1}+M_t-M_{t-1}=W_tN_t+\Pi_t-P_tT_t+(1+i_{t-1})*B_t]\right\}\right]\right\},$$

Where $\lambda_t$ is the Lagrangian multiplier.

[39] The theoretical model used is a new Keynesian model. The new Keynesian model were introduced by Smets and Wouters and by Galì and Gertler.

[40] As it would be explained later, because the government is neutral, the household may pay taxes or may receive a transfer from the government. This will depend on the money supply's change.

To find the maximum of the function[41] it is sufficient to consider first order condition with respect variables at time t[42]:

$$\frac{d\Delta(C_t,N_t,M_t,B_{t+1})}{dC_t} = 0 \Leftrightarrow C_t^{-\sigma} = -\lambda_t P_t;$$

$$\frac{d\Delta(C_t,N_t,M_t,B_{t+1})}{dN_t} = 0 \Leftrightarrow N_t^{\eta} = -\lambda_t * \frac{W_t}{\psi};$$

$$\frac{d\Delta(C_t,N_t,M_t,B_{t+1})}{dM_t} = 0 \Leftrightarrow M_t^{-1} = \frac{1}{\theta}(\beta * E_t[\lambda_{t+1}] - \lambda_t);$$

$$\frac{d\Delta(C_t,N_t,M_t,B_{t+1})}{dB_{t+1}} = 0 \Leftrightarrow \lambda_t = \beta(1+i_t)E_t[\lambda_{t+1}];$$

$$\frac{d\Delta(C_t,N_t,M_t,B_{t+1})}{d\lambda_t} = 0 \Leftrightarrow P_tC_t + E_t[B_{t+1]} + M_t - M_{t-1} = W_tN_t + \Pi_t - P_tT_t + (1+i_{t-1}) * B_t.$$

In theory, the function should be differentiated also with respect to the other period variables, however it would be sufficient to differentiate with respect only one variable ahead, for example $C_{t+1}$, to determine the intertemporal relation between variables:

$$\frac{d\Delta(C_t,N_t,M_t,B_{t+1})}{dC_{t+1}} = 0 \Leftrightarrow E_t[C_{t+1}^{-\sigma}] = -E_t[\lambda_{t+1}P_{t+1}].$$

First, combining the derivatives with respect consumption and the derivative with respect bond holding, it is possible to find the following optimality condition[43]:

$$\left(\frac{C_t}{E_t[C_{t+1}]}\right)^{-\sigma} = \beta * (1+i_t) * E_t\left[\frac{P_t}{P_{t+1}}\right].$$

From the derivatives with respect consumption and labour it is possible to determine the labour supply curve:

$$N_t^{\eta} = C_t^{-\sigma} * \psi\frac{P_t}{W_t}.$$

Lastly, the derivative with respect money holding and the derivative with respect bond holding implies that:

$$\left(\frac{M_t}{P_t}\right)^{-1} = \frac{1}{\theta} * C_t^{-\sigma} * \frac{i_t}{1+i_t}.$$

The household problem is synthetized in the conditions above and the budget constraint.

### *2.1.2) The final producer's problem*

The final producer has a constant elasticity of substitution production function that aggregates every intermediate good. The production technology[44] is:

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}}dj\right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

---

[41] This utility function specification implies that the first order conditions are sufficient conditions for the constrained maximum.
[42] $B_{t+1}$ is the decided at time t.
[43] This is the Euler equation, the equation that synthetize the relation between consumption in different periods. Since the household is assumed to be impatient, household would choose future consumptions to be lower than the current level.
[44] It is assumed that ε>1.

The producer sells the final good at price $P_t$ and buys input $Y_t(j)$ at price $P_t(j)$, that is chosen by producer j. Given the prices level, his optimality behaviour is described solving the correspondent static profit maximization problem:

$$\max_{y_t(j)\forall j\in[0,1]} P_t\left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}}dj\right)^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_t(j)Y_t(j)dj.$$

Differentiating for any of the j-th good, the first order condition is:

$$\frac{d\Pi_t^f}{dy_t(j)} = 0 \Leftrightarrow y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} Y_t.$$

This condition, valid for any j, is the final producer's demand for good $y_t(j)$. However, the price level is not determined yet. To derive the price level, consider the nominal output as the sum of nominal value of each intermediate good:

$$P_tY_t = \int_0^1 P_t(j)Y_t(j)dj.$$

$Y_t(j)$ is known from final producer's optimality conditions, therefore it can be substituted. Then, it is be possible to write outside the integral terms that do not depend on j and it is possible to conclude that:

$$P_t = \left(\int_0^1 P_t(j)^{1-\varepsilon}\, dj\right)^{\frac{1}{1-\varepsilon}}.$$

### *2.1.3) The j-th intermediate producer's problem*

The intermediate producers' optimality conditions are needed to solve the model. In theory intermediate producers' problem comes before final producer's one, but they can anticipate the final producer's optimal demand of their product. Furthermore, they cannot freely adjust price each period. They may be obliged to maintain previous period prices with probability ϕ, or, with probability 1- ϕ, they can set the price they prefer. Their problem can be divided into two part. First, they choose the amount of labor needed to produce. This is a static problem. Second, they define a strategy such that if they are able to set their desired price, it should maximize the expected future profits flow. This is a dynamic problem.

The production function of firm j is $Y_t(j) = A_tN_t(j)$, where $A$ is an exogenous productivity shock defined as $\ln(A_t) = \rho_a \ln(A_{t-1}) + a_1\varepsilon_{a,t}$[45]. Prices are sticky, so firm's problem can be solved by the minimization of input cost:

$$\min_{N_t(j)} W_tN_t$$

where $W_t$ is wage. Firm j can anticipate optimal demand from final consumer's problem, then the demand for its good can be considered as a constraint. The constrained problem is:

$$\min_{N_t(j)} W_tN_t(j)\ \ s.t. Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t.$$

To solve this constrained problem, it is possible to define the associated Lagrangian function:

$$\mathcal{L}\big(N_t(j)\big) = W_tN_t(j) + \delta_t(j)\left[\left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t - A_tN_t\right].$$

[45] $A_t$ follows a log AR(1) process with 0 mean. The factor $a_1$ is the component that will be used to introduce second order shock in the simulation with Dynare®.

Differentiating with respect to $N_t(j)$, it is possible to find the following optimality condition:

$$\frac{d\mathcal{L}(N_t(j))}{dN_t(j)} = 0 \;\Leftrightarrow W_t = \delta_t(j)A_t.$$

Knowing the condition that satisfies optimal production choice, it is possible to solve the dynamic price setting problem. The period t profit is by definition:

$$\Pi_t(j) = P_t(j)Y_t - W_tN_t(j).$$

It is possible to substitute optimal $W_t$ and to divide by $P_t$ to express profits in real terms and derive:

$$\Pi_t(j) = \frac{P_t(j)}{P_t} * Y_t(j) - \frac{\delta_t A_t N_t(j)}{P_t}.$$

Calling $\mu_t = \frac{\delta_t(j)}{P_T}$ [46] the real marginal cost of firm j, and by the definition of production function, the period t profit become:

$$\Pi_t(j) = \frac{P_t(j)}{P_t} Y_t(j) - \mu_t Y_t(j).$$

Firm sets its price to maximize this quantity. But it must also consider that with probability ϕ next period it will not be able to reset the price and will be stack with previous period price. This could be the case also two period ahead ,still with probability ϕ, but conditionally to previous period realization. Hence, setting a price at time t implies that this price will be still charged *s* period ahead with probability $\phi^s$. When setting price, firm does not care about the case of future resetting because that contingency does not depend its current action and it will face an identical but independent pricing problem.

In this economy, given household's preferences, the stochastic discount factor from period n to present is:

$$sdf_{t+n} = \beta^n * \frac{U'(C_{t+n})}{U'(C_t)}.$$

It follows that resetting firm price problem is:

$$\max_{P_t(j)} E_t\left[\sum_{s=o}^{+\infty}\left\{(\beta\phi)^s * \frac{U'(C_{t+s})}{U'(C_t)} * \left[\frac{P_t(j)}{P_{t+s}} Y_{t+s}(j) - \mu_{t+s}Y_{t+s}(j)\right]\right\}\right].$$

Notice that $Y_t(j)$ is known and can be substituted in the problem above, leading to:

$$\max_{P_t(j)} E_t\left[\sum_{s=o}^{+\infty}\left\{(\beta\phi)^s * \frac{U'(C_{t+s})}{U'(C_t)} * \left[\left(\frac{P_t(j)}{P_{t+s}}\right)^{(1-\varepsilon)} Y_{t+s} - \mu_{t+s}\left(\frac{P_t(j)}{P_{t+s}}\right)^{-\varepsilon} Y_{t+s}\right]\right\}\right].$$

Differentiating with respect to price j, it is possible to derive the optimal reset price:

$$P_t^*(j) = \frac{\varepsilon}{1-\varepsilon} * \frac{E_t\left[\sum_{s=0}^{+\infty}\beta^s\phi^s U'(C_{t+s})\mu_t P_{t+s}^{\varepsilon} Y_{t+s}\right]}{E_t\left[\sum_{s=0}^{+\infty}\beta^s\phi^s U'(C_{t+s}) P_{t+s}^{\varepsilon-1} Y_{t+s}\right]}.$$

It is possible to simplify notation introducing two auxiliary variables:

$$V_t = E_t[\textstyle\sum_{s=0}^{+\infty}\beta^s\phi^s U'(C_{t+s})\mu_t P_{t+s}^{\varepsilon} Y_{t+s}],$$

$$Q_t = E_t[\textstyle\sum_{s=0}^{+\infty}\beta^s\phi^s U'(C_{t+s}) P_{t+s}^{\varepsilon-1} Y_{t+s}].$$

[46] Index j can be omitted because each producer has identical technology and faces identical economic conditions, so the marginal cost is common.

Notice that $V_t$ and $Q_t$ does not depend on j. In fact, $P_t^*(j)$ is the price that every firm j would select, thus resetting price at time t for any intermediate producer is:

$$P_t^* = \frac{\varepsilon}{1-\varepsilon} * \frac{V_t}{Q_t}.$$

### 2.1.4) The role of the government

The economy is governed by a neutral government that controls monetary policy and taxes. The government, which neither spends nor participates in the bond market, sets the policy in terms of interest rate.

The interest rate policy adopted by the government is a Taylor type rule:

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\varphi_\pi(\pi_t - \pi) + (1-\rho_i)\varphi_y\left(\frac{y_t - y_{t-1}}{y_t}\right) + a_2\varepsilon_{i,t}$$[47]

Although policy is in interest rate term, there is money in the economy. Money level changes according to money holding demand. When money holding changes, government either earns a revenue or need to collect taxes. Under the assumption that it does not spend neither invest in bond, its period budget constraint is:

$$P_t T_t = M_{t-1} - M_t.$$

In particular, $T_t = \frac{(M_{t-1}-M_t)}{P_t}$ is the quantity transferred to the household. When money holding grows, $T_t$ is negative and the government is transferring its seigniorage revenue to household. Otherwise, government claims back money taxing household.

## 2.2) The equilibrium conditions of the model

In this section the conditions above will be used to derive a system of aggregate equilibrium condition. First of all, it is the case to rewrite the household's budget constraint. $P_t T_t$ is known and can be substituted with $M_{t-1} - M_t$, that is also in the left-hand side, hence they cancel out leaving:

$$P_t C_t + B_{t+1} = W_t N_t + \Pi_t + (1 + i_{t-1})B_t.$$

When the model is in equilibrium, household does not invest in bonds, then $B = 0$ at any time:

$$P_t C_t = W_t N_t + \Pi_t.$$

Profits are also known, in fact $\Pi_t = \int_0^1 \left(P_t(j)Y_t(j) - W_t N_t(j)\right)dj$. Dividing the integral of the sum in the sum of the integrals and substituting the labor market clearing condition[48], profits become:

$$\Pi_t = \int_0^1 P_t(j)Y_t(j)\,dj - W_t N_t.$$

Substituting in the household's budget constraint:

$$P_t C_t = \int_0^1 P_t(j)Y_t(j)\,dj.$$

It is convenient to divide by $P_t$ and to substitute $Y_t(j)$ with final producer's demand:

$$C_t = Y_t \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{1-\varepsilon} dj = Y_t P_t^{\varepsilon-1} * \int_0^1 \left(P_t(j)\right)^{1-\varepsilon} dj.$$

[47] The coefficient $a_2$ will be used to introduce the second moment shock in the simulations.
[48] Total labor used by the firms is equal to the labor supplied by the household $\int_0^1 N_t(j) = N_t$.

$P_t$ is also know, in fact the general price level is $\left(\int_0^1 P_t(j)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$. Substituting $P_t$ in the budget constraint integrals cancels out, then the final condition that is possible to derive from the household's budget constraint is

$$C_t = Y_t.$$

$Y_t$ is not known yet but can be easily found. The final producer's demand for each good j is known, thus it is possible to integrate over j to determine total final output:

$$\int_0^1 Y_t(j)dj \; = \; \int_0^1 A_t N_t(j)dj \; = \; \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t dj \, .$$

$A_t$ is the productivity shock and does not depend on j, $\int_0^1 N_t(j)dj = N_t$, therefore:

$$A_t N_t = Y_t \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} dj \, .$$

Calling $\gamma_t = \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} dj$ to simplify notation, final output is equal to:

$$Y_t = \frac{A_t N_t}{\gamma_t}.$$

The full set of conditions derived in section 2.1 and in this section are sufficient to solve the model. However, because some conditions depend on j, model has heterogeneity. Moreover, equilibrium conditions depend on prices, that are not stationary by construction[49]. To avoid these issues, it is possible to pass from prices to inflation rate, that is stationary, and to consider some variables in real terms. In the following equations cursive letters means that the variable is in real term[50]. By definition, inflation is:

$$\pi_t = \left(\frac{P_t}{P_{t-1}} - 1\right).$$

Starting from household's problem optimality conditions, The Euler equation should be rewritten to transform prices ratio into level inflation:

$$\left(\frac{C_t}{E_t[C_{t+1}]}\right)^{-\sigma} = \beta * (1 + i_t) * E_t\left[\frac{P_t}{P_{t+1}}\right] \; = \beta * \frac{(1+i_t)}{E_t[1+\pi_{t+1}]}. \text{ (a)}$$

The labour supply curve should be written in real terms and becomes:

$$N_t^{-\eta} = -C_t^{\sigma} * \psi(w_t)^{-1}. \text{ (b)}$$

Likewise, money holding should be expressed in real money balance terms:

$$m_t^{-1} = \frac{1}{\theta} * C_t^{-\sigma} * \frac{i_t}{1+i_t}.$$

The price level is function of single heterogenous price. However, the Calvo's pricing assumption[51] allows to simplify the model and to eliminate prices' heterogeneity.

[49] The monetary policy implies that mean inflation is different from zero and equal to $\pi$.

[50] for example: $g_t = \frac{G_t}{P_t}$.

[51] From G. Calvo, ''Staggered prices in a utility-maximizing framework,'' Journal of Monetary Economics, September 1983.

Each period, there will be $1-\phi$ firms that will reset their price, while the remain ϕ firms will be stacked with $P_{t-1}(j)$. The reset price $P_t^*$ does not depend on j, so it is a constant in the integral. It means that:

$$P_t^{1-\varepsilon} = \int_0^1 P_t(j)^{1-\varepsilon}\, dj = \int_0^{1-\phi} P_t(j)^{1-\varepsilon} dj + \int_{1-\phi}^1 P_t(j)^{1-\varepsilon} dj = (1-\phi) * (P_t^*)^{1-\varepsilon} \ + \int_{1-\phi}^1 P_{t-1}(j)^{1-\varepsilon} dj.$$

Under Calvo's pricing assumption $\int_{1-\phi}^1 P_{t-1}(j)^{1-\varepsilon} dj = \phi * \int_0^1 P_{t-1}(j)^{1-\varepsilon} dj = \phi * P_{t-1}^{1-\varepsilon}$. The previous claim holds because updating firms are randomly chosen and they are infinitely many. In particular, the former integral is proportional to the integral over the entire set [0,1] and to the proportionality coefficient is $\phi$.

The price level is then:

$$P_t^{1-\varepsilon} = (1-\phi) P_t^{*1-\varepsilon} + \phi P_{t-1}^{1-\varepsilon}.$$

This equation can be easily expressed in terms of inflation[52] dividing both sides for $P_{t-1}^{1-\varepsilon}$:

$$(1+\pi_t)^{1-\varepsilon} = (1-\phi)(1+\pi_t^*)^{1-\varepsilon} + \phi. \text{ (d)}$$

Using the same logic, it is possible to derive $\gamma_t$ in term of inflation:

$$\gamma_t = (1-\phi)\left[\frac{(1-\pi_t)}{(1-\pi_t^*)}\right]^{\varepsilon} + \phi(1-\pi_t)^{\varepsilon}\gamma_{t-1}. \text{ (e)}$$

Optimal reset price $P_t^*$ is in function of future prices. It is possible to express it in terms of inflation dividing $V_t$ by $P_t^{\varepsilon}$ and $Q_t$ by $P_t^{(\varepsilon-1)}$. The ratio $\frac{V_t}{Q_t}$ becomes $\frac{v_t}{q_t} P_t$[53]

It follows that:

$$v_t = C_t^{-\sigma}\mu_t Y_t + \beta\phi E_t[(1+\pi_{t+1})^{\varepsilon} v_{t+1}], \text{ (f)}$$

$$q_t = C_t^{-\sigma} Y_t + \beta\phi E_t[(1+\pi_{t+1})^{\varepsilon-1} q_{t+1}]. \text{ (g)}$$

Optimal reset price is

$$P_t^* = \frac{\varepsilon}{\varepsilon-1} * P_t * \frac{v_t}{q_t},$$

In terms of inflation becomes:

$$(1+\pi_t^*) = \frac{\varepsilon}{\varepsilon-1} * (1+\pi_t) * \frac{v_t}{q_t}. \text{ (h)}$$

The last condition to be transformed in real terms is the optimality hiring condition for intermediate firms. Dividing both hand sides by price, it follows that:

$$\frac{W_t}{P_t} = w_t = \mu_t A_t. \text{ (i)}$$

[52] $\pi_t^*$ refers to the optimal resetting price inflation.
[53] A clarification on notation: In this case cursive letters does not mean that the original variables are divided by price level, but by the price elevated to the respective power.

In conclusion, the full set of equilibrium conditions, expressed in real term, is:

$$\left(\frac{C_t}{E_t[C_{t+1}]}\right)^{-\sigma} = \beta * \frac{(1+i_t)}{E_t[1+\pi_{t+1}]} \text{ (a)}$$

$$N_t^{\eta} = C_t^{-\sigma} * \frac{w_t}{\psi} \text{ (b)}$$

$$m_t^{-1} = \frac{1}{\theta} * C_t^{-\sigma} * \frac{i_t}{1+i_t} \text{ (c)}$$

$$(1+\pi_t)^{1-\varepsilon} = (1-\phi)(1+\pi_t^*)^{1-\varepsilon} + \phi \text{ (d)}$$

$$\gamma_t = (1-\phi)\left[\frac{(1-\pi_t)}{(1-\pi_t^*)}\right]^{\varepsilon} + \phi(1-\pi_t)^{\varepsilon}\gamma_{t-1} \text{ (e)}$$

$$v_t = C_t^{-\sigma}\mu_t Y_t + \beta\phi E_t[(1+\pi_{t+1})^{\varepsilon} v_{t+1}] \text{ (f)}$$

$$q_t = C_t^{-\sigma} Y_t + \beta\phi E_t[(1+\pi_{t+1})^{\varepsilon-1} q_{t+1}] \text{ (g)}$$

$$(1+\pi_t^*) = \frac{\varepsilon}{\varepsilon-1} * (1+\pi_t) * \frac{v_t}{q_t} \text{ (h)}$$

$$w_t = \mu_t A_t \text{ (i)}$$

$$C_t = Y_t \text{ (j)}$$

$$Y_t = \frac{A_t N_t}{\gamma_t} \text{ (k)}$$

$$\ln(A_t) = \rho_a \ln(A_{t-1}) + a_1\varepsilon_{a,t} \text{ (l)}$$

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\varphi_\pi(\pi_t - \pi) + (1-\rho_i)\varphi_y\left(\frac{y_t - y_{t-1}}{y_t}\right) + a_2\varepsilon_{i,t} \text{ (m)}$$

### *2.3) Analysis of the system's reaction to shocks*

The last part of the theoretical consists of the analysis of the model's impulse responses to shocks. In this model specification, the economy can be hit by two shocks, productivity shocks $\varepsilon_a$ and interest rate shocks $\varepsilon_i$. The model's impulse response analysis consists in the study of the dynamic response to the system hit by a shock while it is in equilibrium. As a starting point, it is necessary to define an equilibrium point for the economy. A classical choice for stochastic dynamic systems is the non-stochastic steady state.

#### *2.3.1) The economy's non stochastic steady state*

Model's non-stochastic steady state is defined as the equilibrium state of the system without uncertainty about future variables. In this state there are not shocks and the stationary variables do not evolve over time.

If there are not shocks, it follows that productivity is constant, then it is possible to assume that $A = 1 \ \forall \ t \in T$. Inflation will be at the targeted level $\pi$.

If consumption is constant over time, the Euler equation (a), becomes:

$$(1+i) = \frac{1}{\beta}(1+\pi).$$

This is the Fisher equation that relates nominal interest rate, real interest rate and inflation rate. This implies that $\frac{1-\beta}{\beta}$ is the real interest rate of the economy.

To find the other equilibrium values it is necessary to determine steady state inflation path, because both $w_t$ and $\mu_t$ depends on inflation and $\gamma_t$. From equation (d) it is possible to derive steady state inflation of reset price:

$$(1+\pi^*) = \left[\frac{(1+\pi)^{1-\varepsilon}-\phi}{1-\phi}\right]^{\frac{1}{1-\varepsilon}}.$$

Now, from equation (e) it is possible to derive steady state γ:

$$\gamma = \frac{\varepsilon-1}{\varepsilon}\left(\frac{1-\pi}{1-\pi^*}\right)^{\varepsilon}\frac{1}{1-\phi(1-\pi)^{\varepsilon}} .$$

The auxiliary variables $v_t$ and $q_t$ becomes:

$$v = \frac{C^{-\sigma}\mu Y}{1-\phi\beta(1+\pi)^{\varepsilon}},$$

$$q = \frac{C^{-\sigma}Y}{1-\phi\beta(1+\pi)^{\varepsilon-1}}.$$

Their ratio is:

$$\frac{v}{q} = \mu\frac{1-\phi\beta(1+\pi)^{\varepsilon-1}}{1-\phi\beta(1+\pi)^{\varepsilon}}.$$

From equation (h):

$$\frac{v}{q} = \frac{1+\pi^*}{1+\pi} * \frac{\varepsilon-1}{\varepsilon} .$$

It follows that steady state μ is:

$$\mu = \frac{1+\pi^*}{1+\pi} * \frac{\varepsilon-1}{\varepsilon} * \frac{1-\phi\beta(1+\pi)^{\varepsilon}}{1-\phi\beta(1+\pi)^{\varepsilon-1})}.$$

From equation (i), given $A = 1$, it is possible to conclude that:

$$w = \mu.$$

Equation (j) implies:

$$C = Y.$$

Equation (k) becomes:

$$Y = \frac{N}{\gamma}.$$

It is possible to derive N from labor supply (b):

$$N = \left(\frac{1}{\psi}\gamma^{\sigma}\mu\right)^{\frac{1}{\eta+\sigma}}.$$

Real money holding is:

$$m = \theta Y^{\sigma}\frac{1+i}{i}.$$

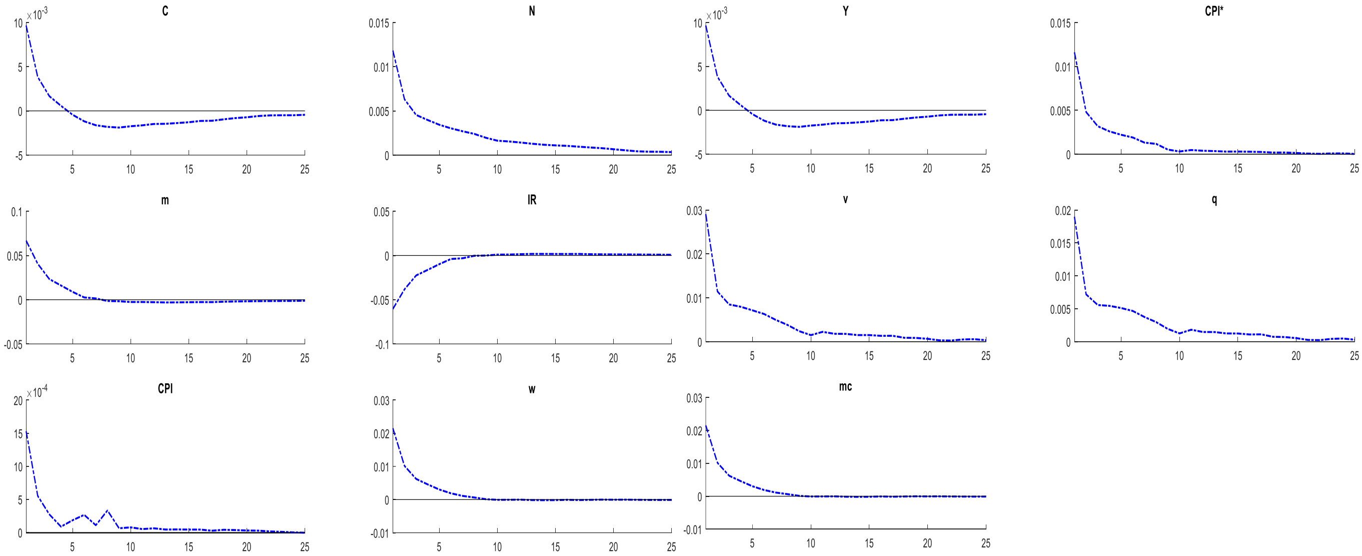
The values determined in this section can be calculated because they depend only on the model's parameters.

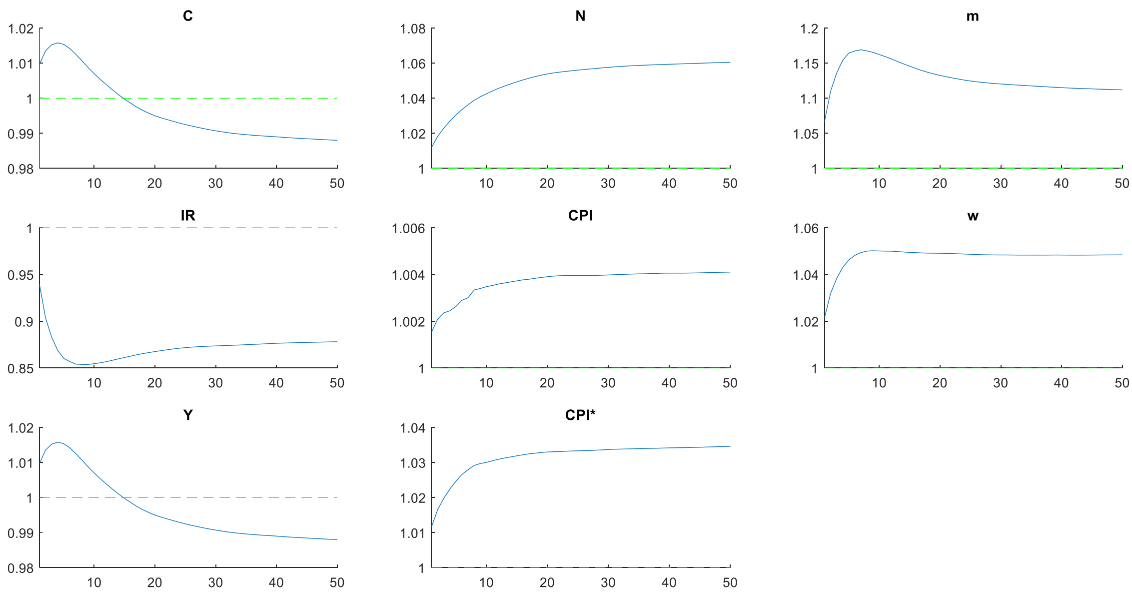
## *2.3.2) The system's dynamic response to an interest shock (first moment only)*

Starting from the steady state, it is possible to determine the system's dynamic response to an unexpected monetary shock. The software Dynare® has been selected to compute the following impulse response functions. At least a third order approximation is needed to simulate second moment shocks. Both dynamic responses to first and second moments shocks will be simulated. In particular, functions below are computed given the following parameters' calibration:

| $\sigma$ | $\eta$ | $\theta$ | $\varepsilon$ | $\rho_a$ | $\rho_i$ | $\pi$ | $\psi$ | $\phi$ | $\beta$ | $\varphi_\pi$ | $\varphi_\pi$ | i |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.99 | 1.01 | 1 | 10 | 0.9 | 0.7 | 0.0199 | 1 | 0.7 | 0.965 | 2 | 3 | 0.05 |

Impulse response functions to a first moment shock in interest rate are:



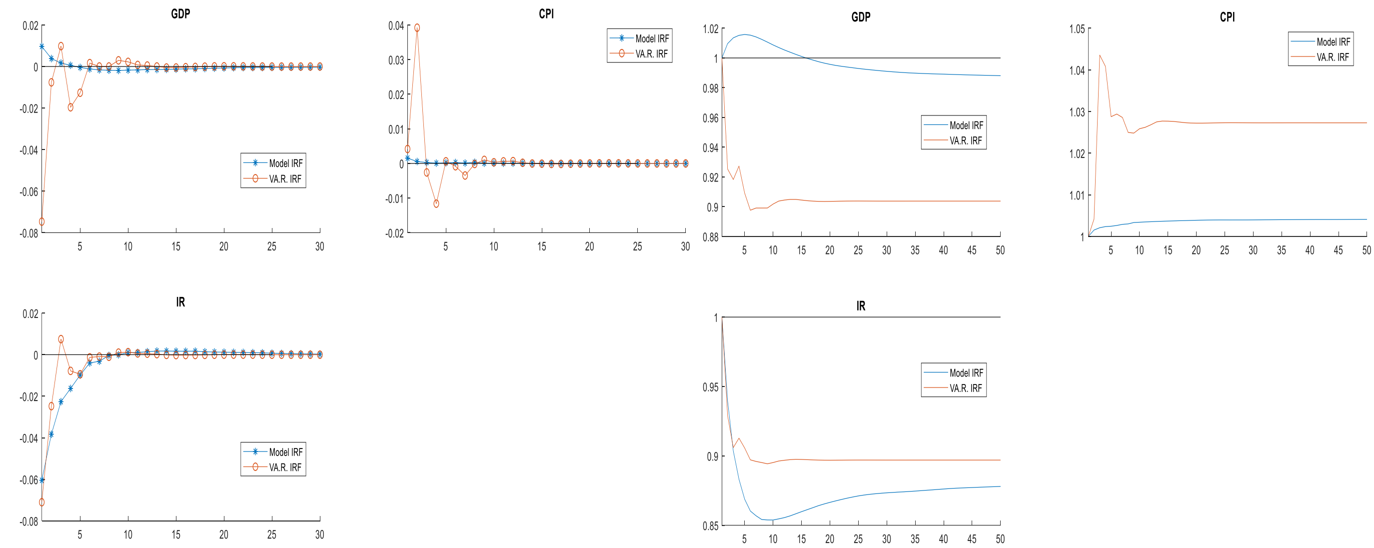

In the previous figure the shock $\varepsilon_i$ is negative. This corresponds to an unanticipated drop in interest rate. It is possible to divide each impulse response function into two parts, the short term response and the long term convergence. For all of the variable the convergence trend follows the short term variation movements, except for the GDP that reverts the trend. These variables increase in the short run, but in the transition phase they slowly start to decrease, converging to a lower value. This difference is given by the different growth rates of labor force and gamma. Some variables, such as IR, wages, and real money balances, invert their trend during the transition between short and long terms. Initially, the IR steeply falls, then it begins to recover slowly. Wages and real money balance, instead, increase after the shock and start decreasing back towards their initial value. Finally, N, CPI and CPI* keep increasing in all periods, but at strongly declining rate in the long run.

### *2.3.2.1) Impulse response functions similarities and differences*

In this section the impulse response functions to the interest rate shock will be compared with the impulse response functions to the uncertainty shock. Before comparing these impulse response functions, it must be clarified why, and to what extent, it is possible to compare the responses to shocks of different nature. Is it possible that an interest rate unexpected decrease is consistent with an uncertainty increase?

It is possible, especially during the period of the dataset. As already mentioned, dataset encompasses two financial crises. During these financial crises, the European central bank strongly decreased interest rate to stimulate the economy. Moreover, as all uncertainty measures indicate, uncertainty level has always increased as a crises' consequence. The interest rare level, contrarily, has always decreased. In this case, an unexpected interest rate movement may be consistent with an increased uncertainty level. This relationship is strengthening if GDP's recession and uncertainty shock are highly correlated. Evidence supports this conjecture because during both crises, GDP and $U$ strongly comoved. Additionally, because E.C.B. policy decisions have been driven by GDP's performances and perspectives, the GDP change has been included in the interest rate rule. This formulation has been chosen to capture the role that GDP and uncertainty changes have in policy decision.

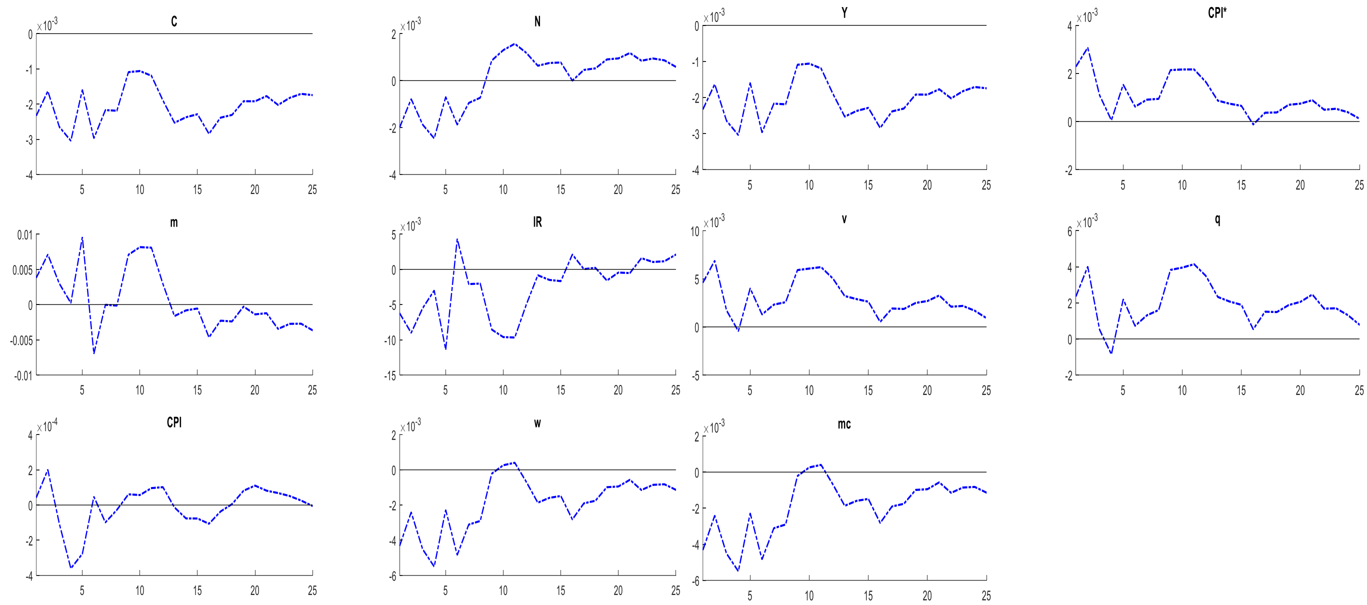
The impulse response functions of the V.AR. model and of the theoretical model are presented in the figures below:



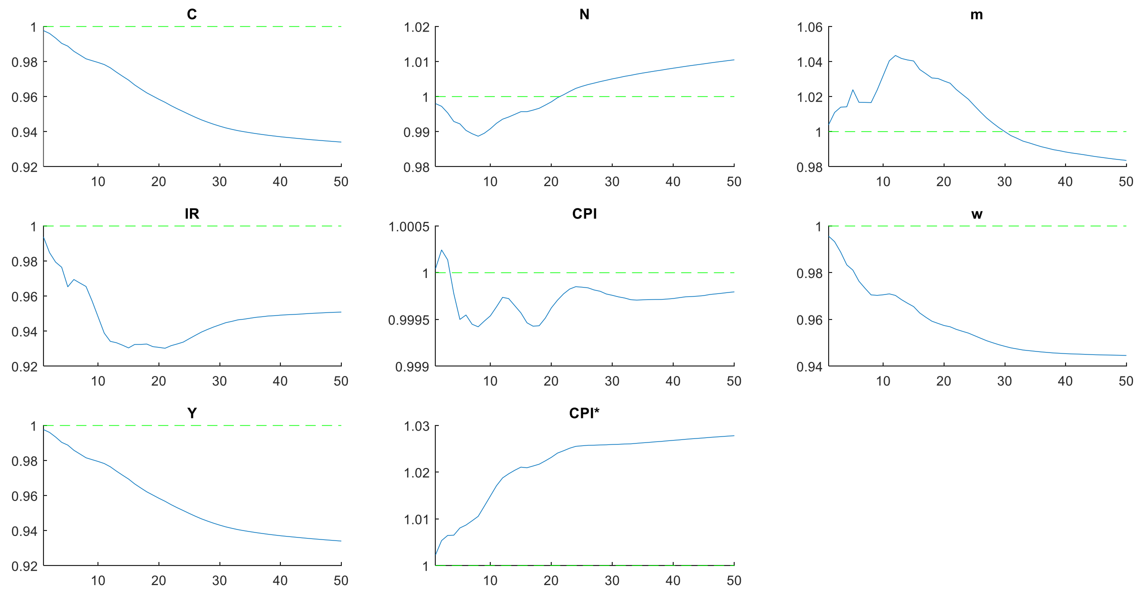

GDP's responses are different in short run. According to the theory, the decrease in IR should enhance GDP growth. This increase is consumption driven. It is not consistent with empirical response, which highlights a reduction in GDP. In this case the interest rate rule shock does not capture the downturn in economic activity. However, in the long run model forecast declining GDP, but the decline is not comparable with the empirical decline because short run differences. Inflation and Interest rate responses are similar. In CPI case, the initial shock is followed by an improvise increase in inflation, that converges to a higher value after few periods. Model's CPI dynamics is smoother. CPI converges slowly, instead V.AR.'s CPI increases suddenly and then slightly converges to the long term level. This is due to price stickiness, that limits the growth of aggregate inflation. In fact, the level change for $CPI^*$ is similar to the CPI empirical forecast. IR decreases similarly in both models, but negative effect dries out earlier in the empirical case. In the long run, when empirical IR is already stationary, the theoretical IR keep increasing and converging to the empirical value.

### *2.3.3) The system's dynamic response to an interest rate shock*

In this section the impulse response functions will be constructed considering a second moment shock. Second moment shock has effects on the variance of the unexpected component of the inter rate. The increase on the volatility of the unexpected component may be directly interpreted as a positive uncertainty shock. The impulse response functions are presented in the following figure:



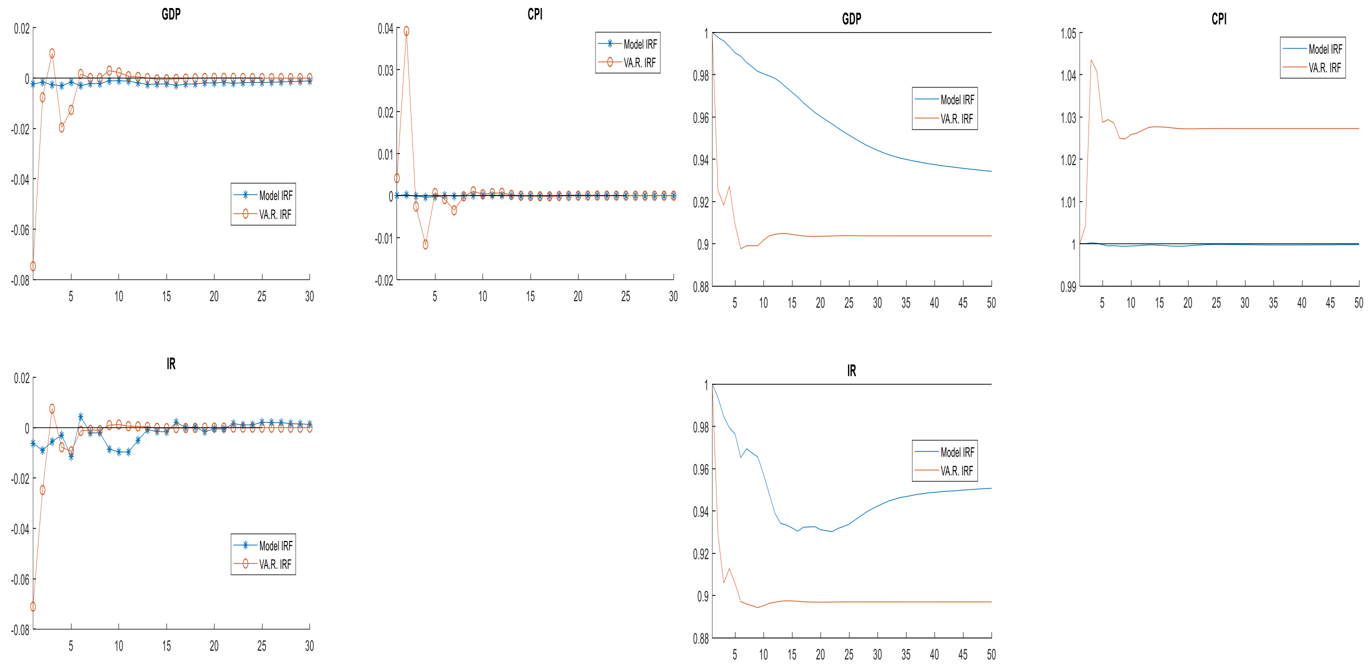

The dynamics are more indented. This because variance of the unexpected component varies every period, influencing interest rate and the behaviour of the component of the system. The level change is reported in the next figure:




In the second moment case GDP decreases. The decrease is smooth and the long term value is about 5% lower than the initial level. Interest rate is decreasing in the short run. Decrease is not marked as much as in first moment case. Moreover, in the second moment set up interest rate slightly recovers during the transition phase, approching a level only 5% lower that the initial value. CPI's response is ambiguous. During the initial phase CPI increases, but after 3 periods faces a decrease. In the transition period the value slowly revovers. Ambiguity comes from the different path of reset price's inflation. CPI* starts a slow increase phase. In the first periods, as in CPI case, the increase is relevant. During the transition period, when CPI falls, CPI* is stable. The following path is increasing with another steady phase. In general, when CPI* is not clearly increasing, CPI decreases and, when CPI* is really increasing, CPI converges back to the initial value. Additionally, notice that changes in CPI are almost negligible in value. This fact and the fact that this is a third order approximation are enough to conclude that the general CPI level is not really effected by the shock, and that changes are only noise. It is also the case to discuss the dynamics of labour and real money holding. Initially, labour is negatively affected by the shock and occupation decrease. In the second phase labour force starts increasing, approching a final level higher than the initial benchmark. Real money holding has opposite dynamic. The first period is characherized by a strong increase in money holding. In the second period money holding decreases, but the transition period is longer than in the labour chase. Finally, wages are constantly diminishing, with a first phase caracherized by a sharp decrease followed by a slow convergence to level 0.94, implying a 6% value drop after the shock. It is possible to find a comparison with first moment shock impulse response functions in appendix section 4.2.

### *2.3.3.1) Impulse response functions similarities and differences*

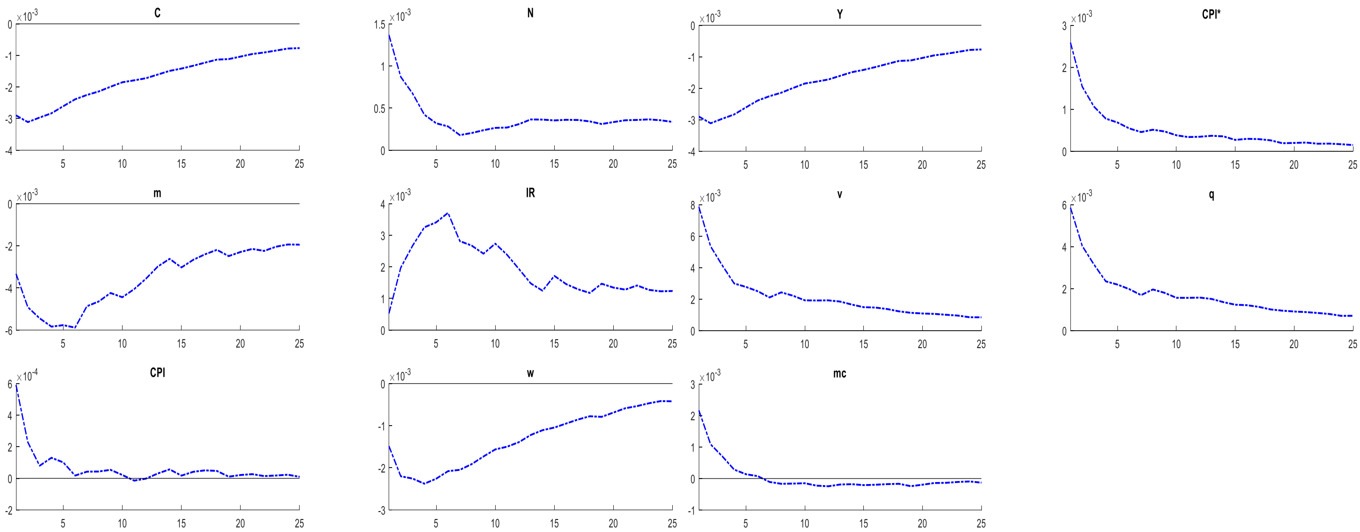
The impulse responses functions are compared with empirical findings in the following figures:

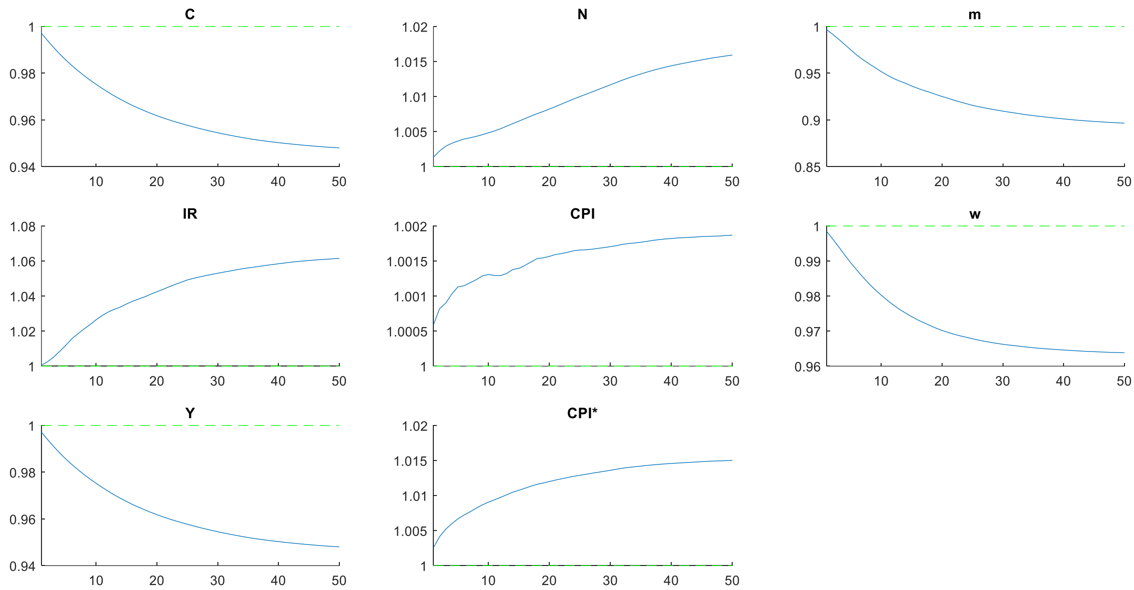



GDP's responses are similar. Both models predict decrease during short run and stabilization during the transition phase. The decrease in the empirical scenario is stronger in the short run and the effects vanish earlier. Model's reaction is minor but more persistent. Notice that in this case, contrarily to first moment shock case, GDP does not respond positive in the short run and approaches a higher long run value. As argued in the previous section, GDP response is negligible. Even in this case the empirical dynamic is similar to CPI*, but the aggregate inflation level is not comparable. Finally, interest rates dynamics are similar, especially in the early stages. Both models predict decreasing interest rates, but, contrarily to first moment case, the variable underreacts. In the long run IR should slightly recover and will approach level 0.95, while empirical evidences suggest no recover and 0.90 long run value.

*2.3.4) The system's dynamic response to a productivity shock (first moment only)*

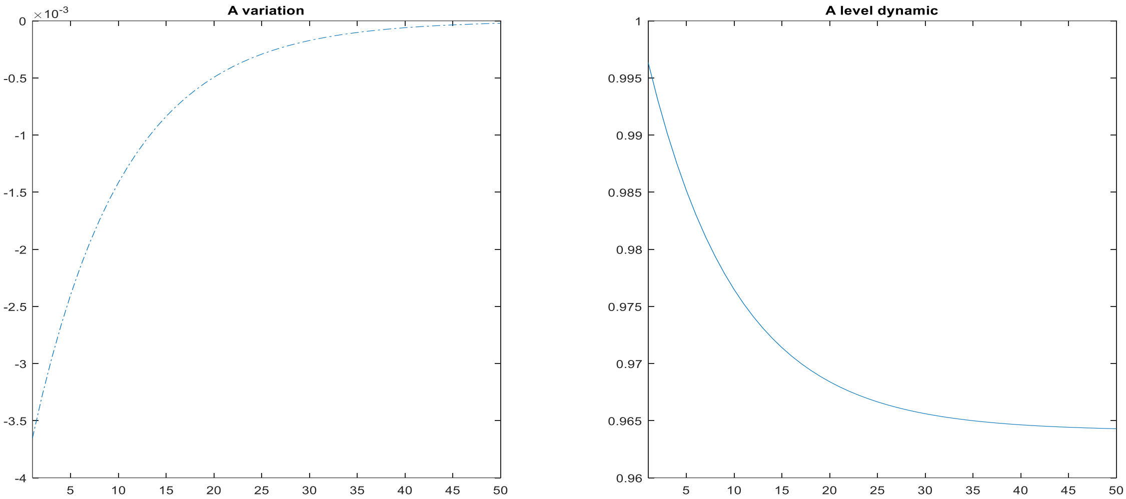
The second alternative to channel an uncertainty shock in the economy is through productivity. A sudden negative variation in the technological level ($\varepsilon_a$) is consistent with an uncertainty shock in the economy. The following figures show impulse response functions and the equivalent levels' movements due to a negative productivity shock:




The technological downturn decreases production. The shock implies a fall in GDP's level, that keep diminishing at a decreasing rate. The long term effect is a 5% drop. CPI and labor force increase after the shock. In particular prices of updating firms increase significantly, while effects on total price level are negligible. Interest rate level is increasing. This increase in interest rate level implicates that money holding decreases. Wage level decrease and approach a 4% lower level.

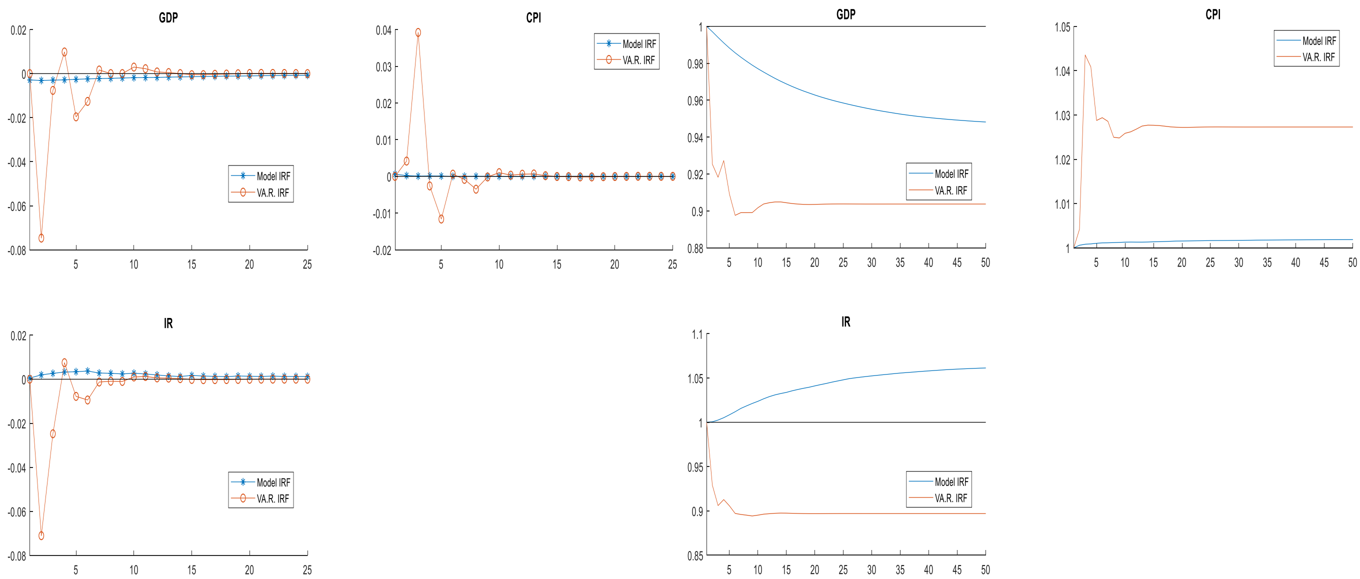
Finally, it is the case consider the productivity's dynamics:




After the shock the productivity level keep decreasing and does not recovers to the initial value. The persistent negative effect in productivity impedes the GDP to recovers to pre-crisis level. This deleterious effect is increased by price's divergence. After the shock, updating firms will adequate their price, in particular $P^*$ increases, while the majority of the firms will be stuck at previous level price. This, by definition, increases $\gamma$, and decreases $y$ because they are inversely proportional. In conclusion GDP fall is mostly caused by the persistent decrease in productivity and by the pricing frictions in intermediate markets. This has negative effect on consumption, that is equal to $y$. Moreover, $N$ is inversely proportional to $C$, therefore labor supply increases. Considering the causes of these dynamic movements, it is possible to compare the model's impulse response function with the empirical results.

### *2.3.4.1) Impulse response functions similarities and differences*

The impulse response functions of the two model are reported in the following figures:



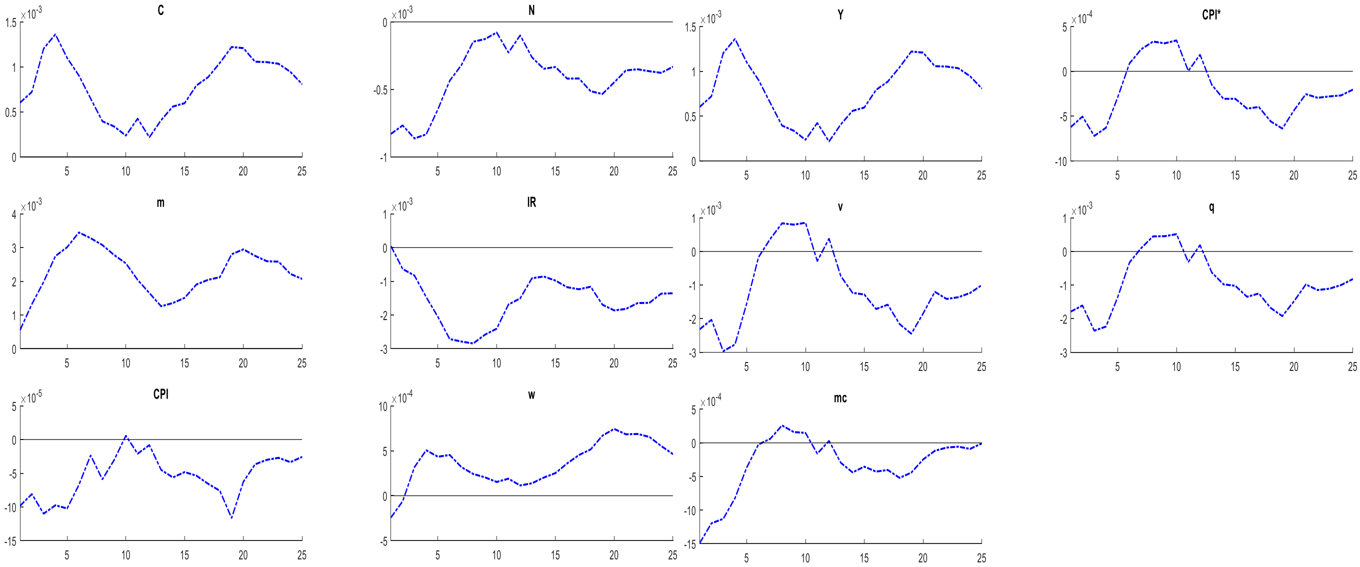

From percentage changes it is clear that the main movements in the V.AR.'s impulse response functions are characterized in the short run, while model's impulse response functions caused by $\varepsilon_a$ are smoother, persists in the transition period and does not change direction[54]. Both models predict decreasing GDP, but V.AR. predicts a sharp initial drop while model's GDP decrease is slower, even if it converges to similar levels. The

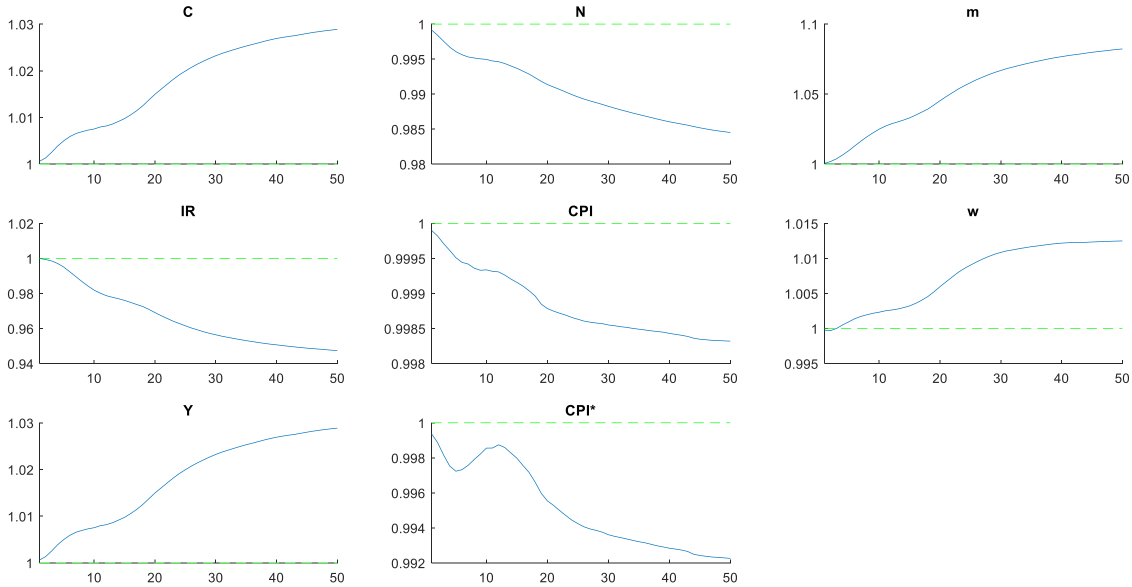
[54] This was not the case in the impulse response functions caused by the interest rate shock.

considerations for CPI are similar to the interest rate shock case, since price stickiness limits CPI growth in the theoretical model. Finally, IR's dynamics are opposite. In the empirical case the level diminishes, while the theoretical model suggest that interest rate should increase after the productivity fall. In this case, the different nature of the shock causes divergence in forecasts.

### *2.3.5) The system's dynamic response to a productivity shock*

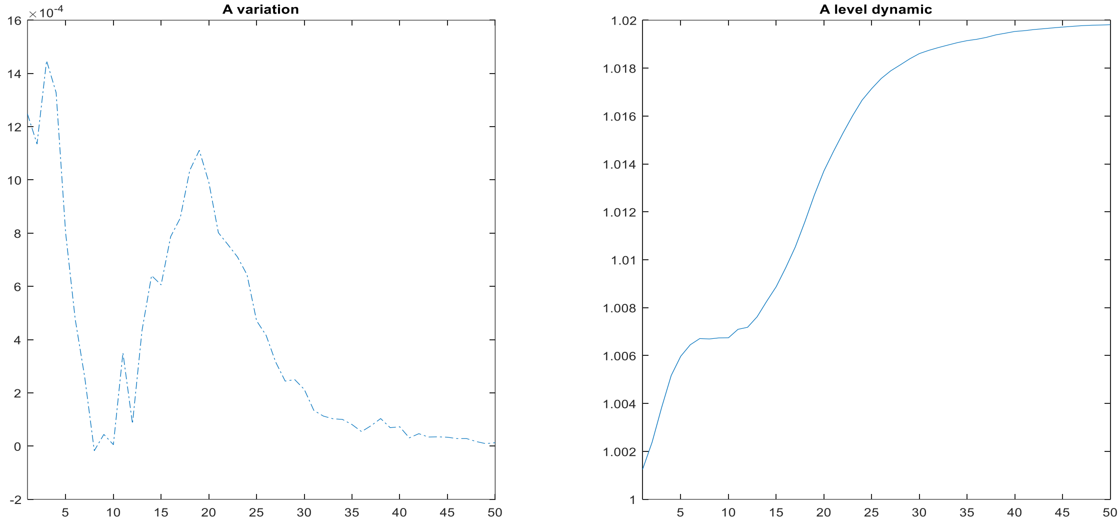
In this final section of chapter 2 it is possible to find the impulse response functions to a second moment shock in productivity. In this chase uncertainty is caused by the increased variance of technological variations. The following figures show the percentage deviation from the steady state and the cumulative movements for relevant variables:



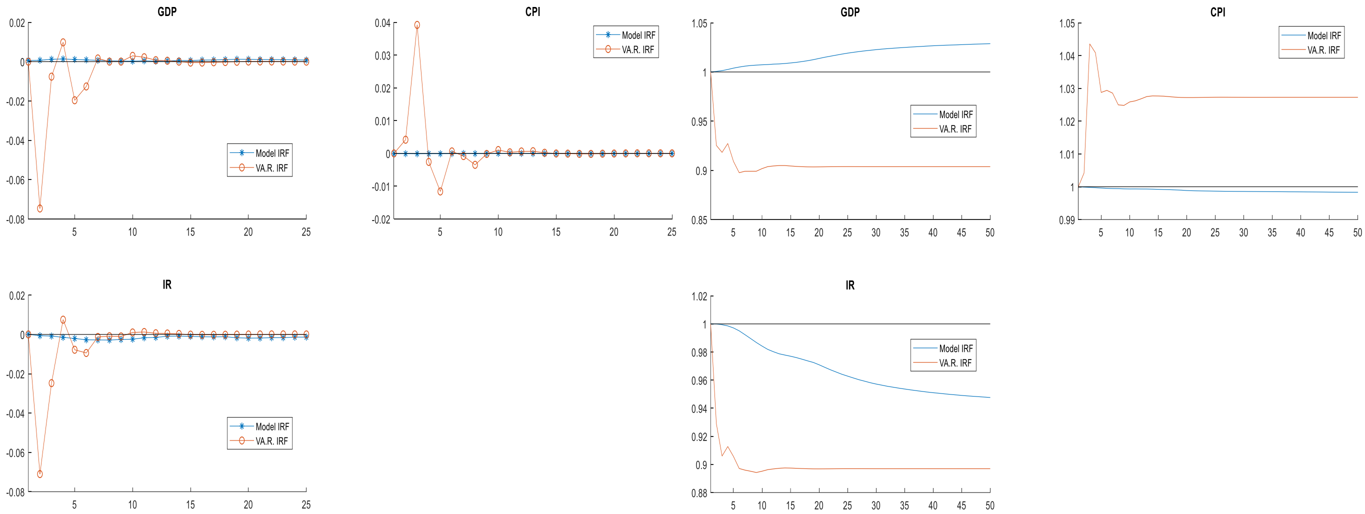

Model's response to a second moment shock is positive. The higher variance of the exogenous shock increases productivity. This increase in productivity depresses interest rate and inflation. Even in this case effects on total CPI are marginal. Labour force decreses while real money holding and wages increases.

The technological level changes are reported in the following figure:




After the second moment shock hits the productivity process, *A* keep increasing over time. The initial boom period is followed by a slowing phase, then process resumes to increase strongly and growth decays when the level approaches value 1.02.

### *2.3.5.1) Impulse response functions similarities and differences*




In this last case the second moment shock provoked a positive effect on productivity. This implies that GDP grows, but the magnitude is lower than in the empirical case. Even CPI's changes differ although the theoretical impulse response function is negligible. IR's impulse response functions are comparable, but the level dynamic in the theoretical case is characterized by lower decreasing rate and the decrease persists for several periods. The dynamics caused by the second moment changes fails to mimic empirical movements. It would have been possible to force productivity to follow a negative path after the second moment shock. This would have implied decreasing GDP and increasing IR. The CPI effect would have been positive but negligible. These results are presented in appendix A chapter 2 alongside with comparison between the and second moment shocks. Even under ''forced'' regime impulse response functions do not capture all aspects of V.AR.'s impulse response function. Their behaviour is similar to the first moment shock in productivity discussed previously.

## 3) Final comments and conclusion

The main purpose of this thesis is to study the Italian economy's response to an uncertainty shock. In the majority of the literature, uncertainty is treated using just one measure. However, despite some recent attempts[55], An unique measure that can capture all possible sources of uncertainty does not exists. For the desire to not limit the analysis to only part of uncertainty, especially not only financial uncertainty, a mixed indicator has been constructed. This indicator attempts to proxy uncertainty from different drivers. The empirical analysis produces interesting results. The first result is a strong negative relationship between GDP and uncertainty. This result was expected since the sample correlation between the variables is negative. However, the consequences of one standard deviation shock are notable because they cause a 7% sudden fall and a 10% persistent decrease.

The financial market variables suggest that the shock causes even structural effects on the economy. The spread's response indicates that the investors require higher premium to hold the long term bond. Higher interest rates for long term government bonds are a symptom of increased riskiness, caused by the increasing possibility of public default.

Another interesting effect appears on the real interest rate. Since the short term interest rate falls and the inflation increases, the real interest rate has a strong decrease. Additionally, the nominal rate is currently at the zero bound, hence the shock may cause real interest rate to be negative. Negative real interest rate discourages investments.

The GDP results are in line with the main findings in Bloom (2009) and in Basu, Bundick (2017). However, in Bloom[56] the long term effect is controversial because a mixed moment shock implies an economic overshot in the long run, while the model converges smoothly to lower level with a first moment shock, as in the Italian case[57] and in Basu, Bundick. The main difference with their findings is the persistency of the negative growth, since in both papers the responses remain negative for several periods[58], while in the model estimated in section 1 the response is negligible after 6 periods. In their paper Bayer et alt. used a different econometric technique to estimate the impulse response functions. Their findings are in line with Bloom because in their model GDP overshot in the long run. The findings on interest rate are similar to the prediction of Bloom, especially the short run response. In the long run Bloom's findings imply that the interest rate recovers, as in Bayer et alt., while in this analysis the level remains lower. Basu and Bundick do not report empirical results neither on interest rates nor on inflation. Even in Bayer et alt the latter is not treated. The results on inflation are different from Bloom findings. In Bloom inflation initially decreases, successively recovers, while, in the V.AR. model, shock increases the CPI in the short period and the value stagnate around the short term level in the long period. Results are in line with the empirical findings reported by Cuaresma, Huber and Onorante and by Carriero, Clark, Marcellino.

The relationship with the policy risk literature is not univocal. Considering the results by Fernandez-Villaverde et alt., their empirical findings differ partially. They forecast a short term GDP decrease followed by an overshoot in the long run, while the empirical evidence on Italy suggests a permanent decrease. The IR's dynamic is similar, but their level converges to the starting level in the long run. CPI differs because reacts negatively to the policy risk shock. Their results differ because they estimate the VAR model with additional variables, such as investment and consumption, and since their dataset starts in 1970.

[55] The EPU index for example.
[56] The analysis in bloom is based on monthly data.
[57] In his analysis Bloom finds similar result considering a first moment shock only.
[58] In Bloom the GDP keeps decreasing over time, while in Basu and Bundick the change is negligible after 12 periods.

Although they focus on other aspects than uncertainty itself, it is possible to compare results with the study on Italy by Anzuini, Rossi and Tommasini. In their analysis, they construct a fiscal policy uncertainty indicator and estimate the impulse response functions to a shock on that index. They find similar dynamics for the GDP but different for investment and inflation. In their analysis inflation first reacts negatively and then converges to a higher level. Their interest rate impulse response function, instead, is increasing at decreasing rate. Even in this case differences probably come from the dataset selection. Their dataset spans between 1981 and 2014, so it comprehends the transition period from high inflation[59] to the 2% level and misses the current period characterized by stagnation and by the Quantitative easing.

In the second section of the thesis the empirical findings are compared with the theoretical results of a new Keynesian model. The model appears to capture some of the main facts. In particular, the impulse response functions to a first moment shock and to a second moment shock in interest rate capture the long term effects and part of the short term dynamics. In the case of a productivity shock the model responses are not totally coherent with the model, especially because the interest rate has opposite dynamics. In this sense, the model fails to match the forecast of the econometric analysis. The comparison suggests that the theoretical model fails to fully replicate economic performances of the analyzed period, characterized by unconventional monetary policy and slow recover.

In conclusion, it is possible to state that uncertainty shocks have deleterious effects on the Italian economy. The GDP's reaction is particularly negative. There exist several interpretations to explain these effects. One of the main ideas is that rising uncertainty causes contraction in financial activities, in particular in the credit market. If borrowing conditions worsen, the economic activity wanes and the GDP contracts. But this is just one aspect. For example, the analysis above suggests that the increasing spread plays an important role during the downturn. The spread has an indented increase during a crisis. The agents, or part of them, may become doubtful about future stability of the system and demand higher returns to finance public expenditures. This spread effect is particularly important in Italy. Public spending policy has been focal in the Italian system, but, when cost of financing increases, the budget constraint becomes tighten. Assuming that the government budget policies are believed to be stabilising, the uncertainty shock increases the cost of finance and dwindles the stabilising role of the government[60]. This may cause another uncertainty shock and the cycle repeats. Moreover, the recent spread's movement suggest that the level changes are highly influenced by the government's spending intentions[61]. This create a major friction between the government, that attempt to stimulate the economic system with expansive policies, and the agents, that are not willing to finance these policies. The uncertainty's rise depresses GDP and increase financing cost, stoking the spread effect.

Another result that the V.AR. analysis suggests is the interest rate level fall under rising uncertainty. As already pointed out, this mechanics has been important during the crises. The extraordinary expansive monetary policy adopted by the E.C.B. limited the growth of the spread and has increased financial market capitalization. It has partially worked against the credit crunch. The V.AR. captures these policy movements, but the long run responses suggests that the effect is to stabilize the system, not to reduce the uncertainty increase generated by the crisis, and not to enhance the recover. Thus, these types of measures are not sufficient to reduce the

[59] Their sample begin with 20% inflation level that keep decreasing for several periods until reaching the 2% target in 1996.

[60] Press usually refers to the spread as the differential in secondary market interest rate. This differential does not affect directly the titles because the interest regime is predetermined at issuance and does not vary according to the spread. However, the spread influences new issuance because new issued bonds must be marketable.

[61] In the last months the spread has struggled when the government tried to plan expansive policies and strongly soften when the fear of such policies vanished. Some press articles explain these movement: https://www.reuters.com/article/us-eurozone-bonds/italian-bonds-suffer-worst-day-in-more-than-25-years-idUSKCN1IU16G; https://www.reuters.com/article/eurozone-bonds/update-4-italian-german-bond-yield-spread-reaches-widest-since-2013-idUSL8N1VL235; https://www.ilsole24ore.com/art/conti-pubblici-vale-20-miliardi-l-eredita-lasciata-tria-gualtieri-ACrDRHi?fromSearch.

level of uncertainty. Moreover, the E.C.B. cannot keep decreasing the rates and, eventually, it will have to stop this expansive policy[62].

The possibility that a new shock hits the economy must be feared, because the previous crises' effects have not completely vanished yet. The policy maker should not just pay attention to stabilizing the system, but also in mitigating the persistency of the uncertainty shocks and in enhancing the absorption ability. The monetary policy responses may stabilize the economy, but it does not appear to be effective against uncertainty.

[62] In a recent interview, the outgoing E.C.B. president Mario Draghi states his beliefs about the current economic conditions. He affirms that monetary policy is not enough and should be integrating with fiscal policies. https://www.ft.com/content/b59a4a04-9b26-11e9-9c06-a4640c9feebb.

# Appendix A

## *4.1) Chapter 1*

### *4.1.1) Tables*

Table1

| | GDP | CPI | IR | Spread | U |
|---|---|---|---|---|---|
| GDP | 1 | 39% | 59% | -8% | -23% |
| CPI | 39% | 1 | 48% | 26% | 14% |
| IR | 59% | 48% | 1 | 12% | -3% |
| Spread | -8% | 26% | 12% | 1 | 64% |
| U | -23% | 14% | -3% | 64% | 1 |

Table 4

| Equation | Variable | Coefficient | Standard error | T statistic | P value |
|---|---|---|---|---|---|
| 1 | Intercept a | -0,008 | 0,059 | -0,142 | 88,7% |
| 1 | GDP(t-1) | 0,594 | 0,113 | 5,256 | 0,0% |
| 1 | CPI(t-1) | 0,025 | 0,175 | 0,144 | 88,6% |
| 1 | IR(t-1) | 0,240 | 0,238 | 1,010 | 31,2% |
| 1 | Spread(t-1) | 0,078 | 0,161 | 0,486 | 62,7% |
| 1 | U(t-1) | -2,274 | 1,506 | -1,510 | 13,1% |
| 1 | GDP(t-2) | 0,103 | 0,129 | 0,804 | 42,2% |
| 1 | CPI(t-2) | -0,512 | 0,167 | -3,063 | 0,2% |
| 1 | IR(t-2) | -0,324 | 0,209 | -1,552 | 12,1% |
| 1 | Spread(t-2) | 0,004 | 0,159 | 0,027 | 97,8% |
| 1 | U(t-2) | 1,254 | 1,595 | 0,786 | 43,2% |
| 2 | Intercept c | -0,039 | 0,042 | -0,950 | 34,2% |
| 2 | GDP(t-1) | 0,281 | 0,080 | 3,523 | 0,0% |
| 2 | CPI(t-1) | 0,242 | 0,123 | 1,963 | 5,0% |
| 2 | IR(t-1) | -0,062 | 0,168 | -0,367 | 71,3% |
| 2 | Spread(t-1) | 0,113 | 0,113 | 0,998 | 31,9% |
| 2 | U(t-1) | 0,127 | 1,061 | 0,120 | 90,5% |
| 2 | GDP(t-2) | 0,088 | 0,091 | 0,973 | 33,1% |
| 2 | CPI(t-2) | -0,091 | 0,118 | -0,775 | 43,8% |
| 2 | IR(t-2) | -0,037 | 0,147 | -0,249 | 80,3% |
| 2 | Spread(t-2) | -0,036 | 0,112 | -0,318 | 75,0% |
| 2 | U(t-2) | 1,611 | 1,124 | 1,433 | 15,2% |
| 3 | Intercept e | -0,079 | 0,029 | -2,729 | 0,6% |
| 3 | GDP(t-1) | 0,147 | 0,056 | 2,633 | 0,8% |
| 3 | CPI(t-1) | 0,115 | 0,086 | 1,335 | 18,2% |
| 3 | IR(t-1) | 0,331 | 0,117 | 2,817 | 0,5% |
| 3 | Spread(t-1) | 0,062 | 0,079 | 0,778 | 43,7% |
| 3 | U(t-1) | -2,163 | 0,743 | -2,912 | 0,4% |
| 3 | GDP(t-2) | 0,100 | 0,063 | 1,579 | 11,4% |
| 3 | CPI(t-2) | -0,163 | 0,082 | -1,971 | 4,9% |
| 3 | IR(t-2) | -0,120 | 0,103 | -1,162 | 24,5% |
| 3 | Spread(t-2) | 0,017 | 0,079 | 0,215 | 83,0% |
| 3 | U(t-2) | -0,074 | 0,787 | -0,094 | 92,5% |
| 4 | Intercept g | 0,063 | 0,056 | 1,134 | 25,7% |
| 4 | GDP(t-1) | -0,047 | 0,106 | -0,441 | 65,9% |
| 4 | CPI(t-1) | -0,030 | 0,165 | -0,184 | 85,4% |
| 4 | IR(t-1) | 0,204 | 0,224 | 0,911 | 36,2% |
| 4 | Spread(t-1) | -0,225 | 0,151 | -1,486 | 13,7% |
| 4 | U(t-1) | 0,673 | 1,419 | 0,475 | 63,5% |
| 4 | GDP(t-2) | 0,033 | 0,121 | 0,274 | 78,4% |
| 4 | CPI(t-2) | 0,399 | 0,157 | 2,536 | 1,1% |
| 4 | IR(t-2) | -0,073 | 0,197 | -0,371 | 71,1% |
| 4 | Spread(t-2) | -0,235 | 0,150 | -1,567 | 11,7% |
| 4 | U(t-2) | 1,107 | 1,502 | 0,737 | 46,1% |
| 5 | Intercept i | -0,002 | 0,006 | -0,251 | 80,2% |
| 5 | GDP(t-1) | -0,022 | 0,012 | -1,884 | 6,0% |
| 5 | CPI(t-1) | 0,022 | 0,018 | 1,208 | 22,7% |
| 5 | IR(t-1) | 0,014 | 0,024 | 0,579 | 56,3% |
| 5 | Spread(t-1) | 0,000 | 0,016 | 0,002 | 99,8% |
| 5 | U(t-1) | -0,145 | 0,154 | -0,939 | 34,8% |
| 5 | GDP(t-2) | -0,004 | 0,013 | -0,305 | 76,0% |
| 5 | CPI(t-2) | 0,027 | 0,017 | 1,598 | 11,0% |
| 5 | IR(t-2) | -0,003 | 0,021 | -0,123 | 90,2% |
| 5 | Spread(t-2) | 0,012 | 0,016 | 0,741 | 45,9% |
| 5 | U(t-2) | -0,186 | 0,163 | -1,140 | 25,4% |

### 4.1.2) Figures

Figure 1

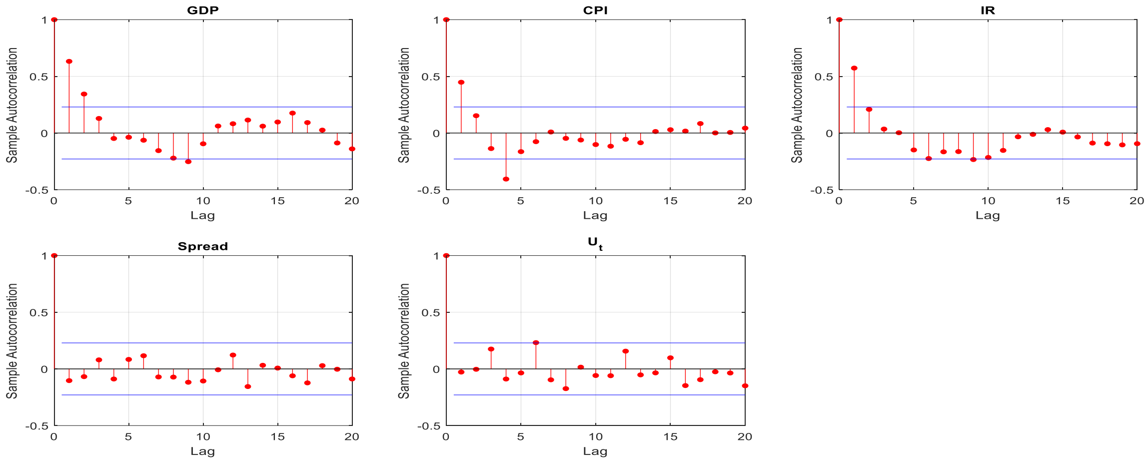



Figure 2

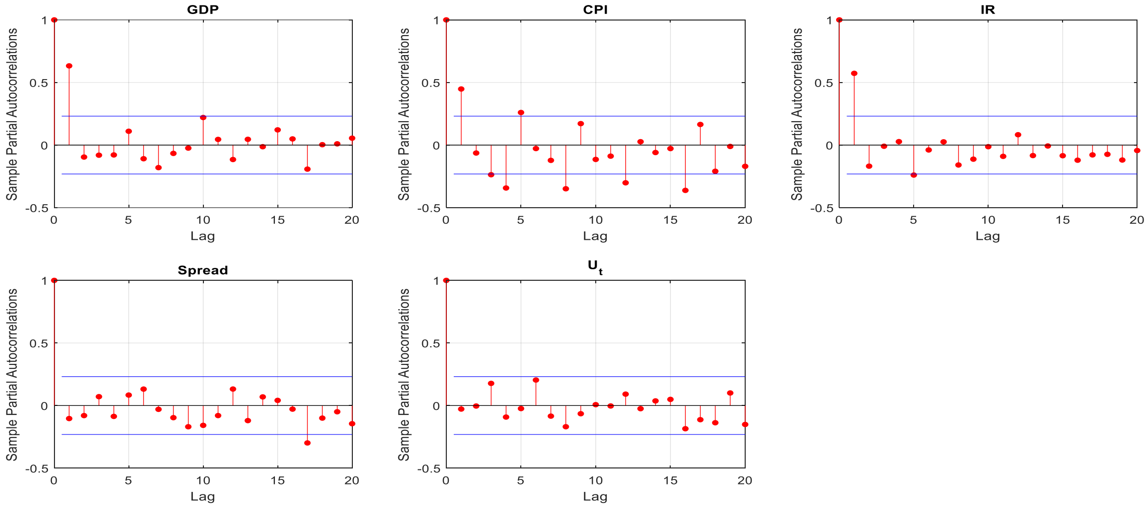



Figure 3 (Spread's residuals without extreme realizations)

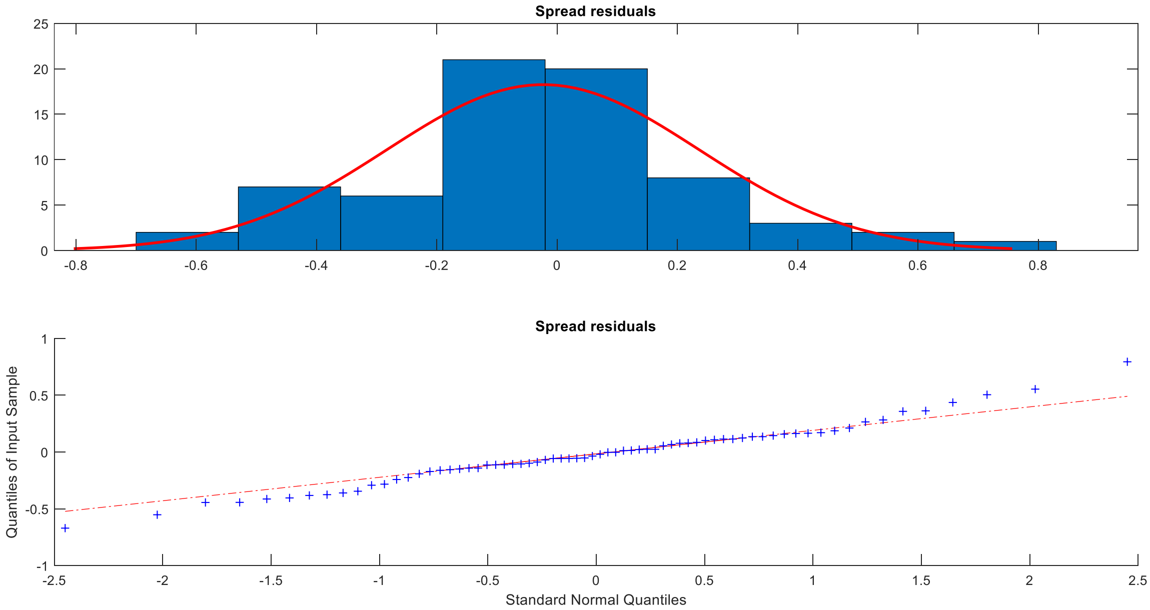


Figure 4

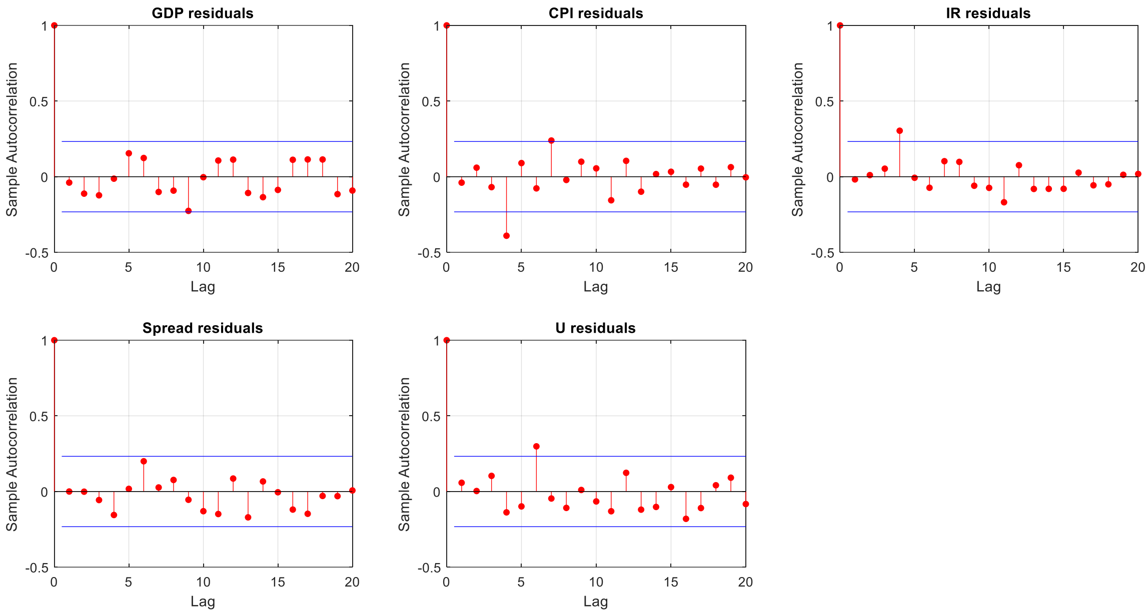



Figure 5

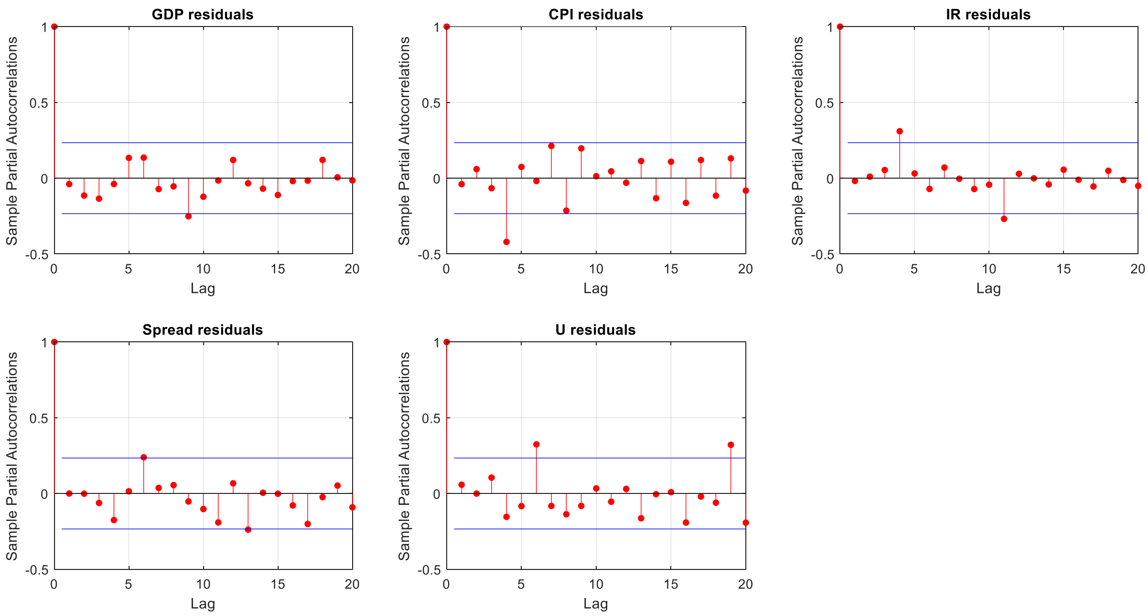


Figure 6 (Impulse response functions with the indicator U)

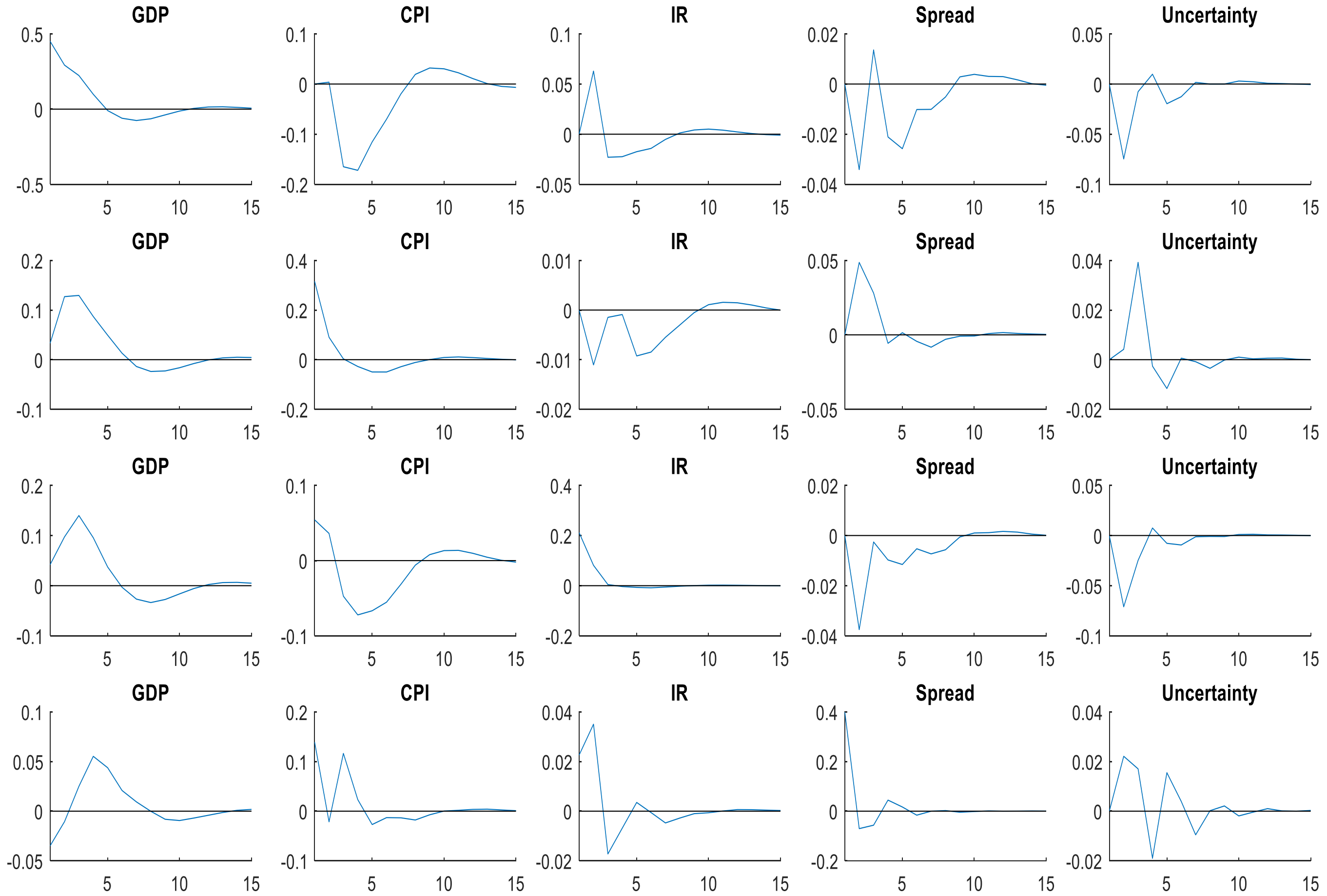



Figure 7 (Impulse response functions with the EPU index)

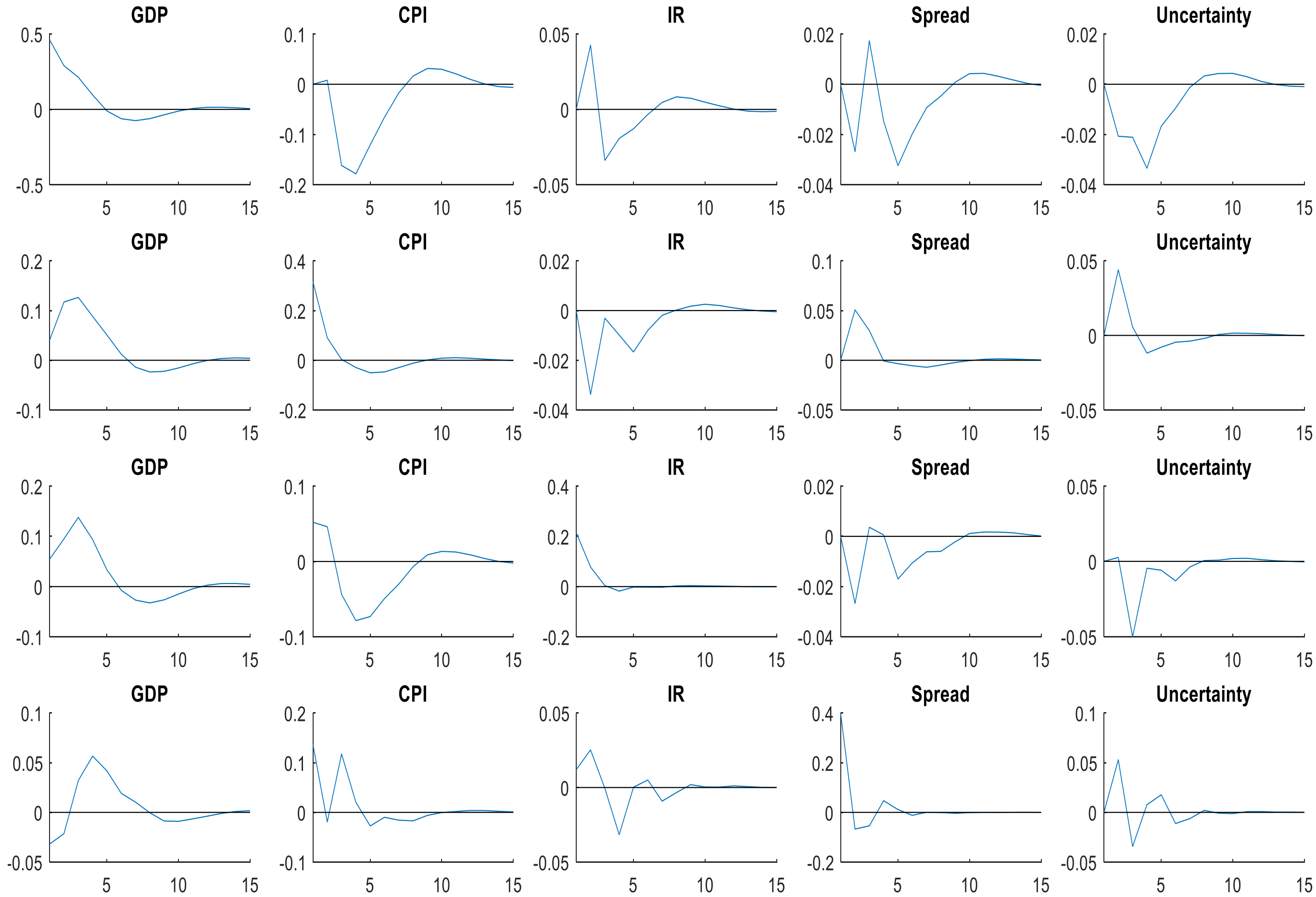
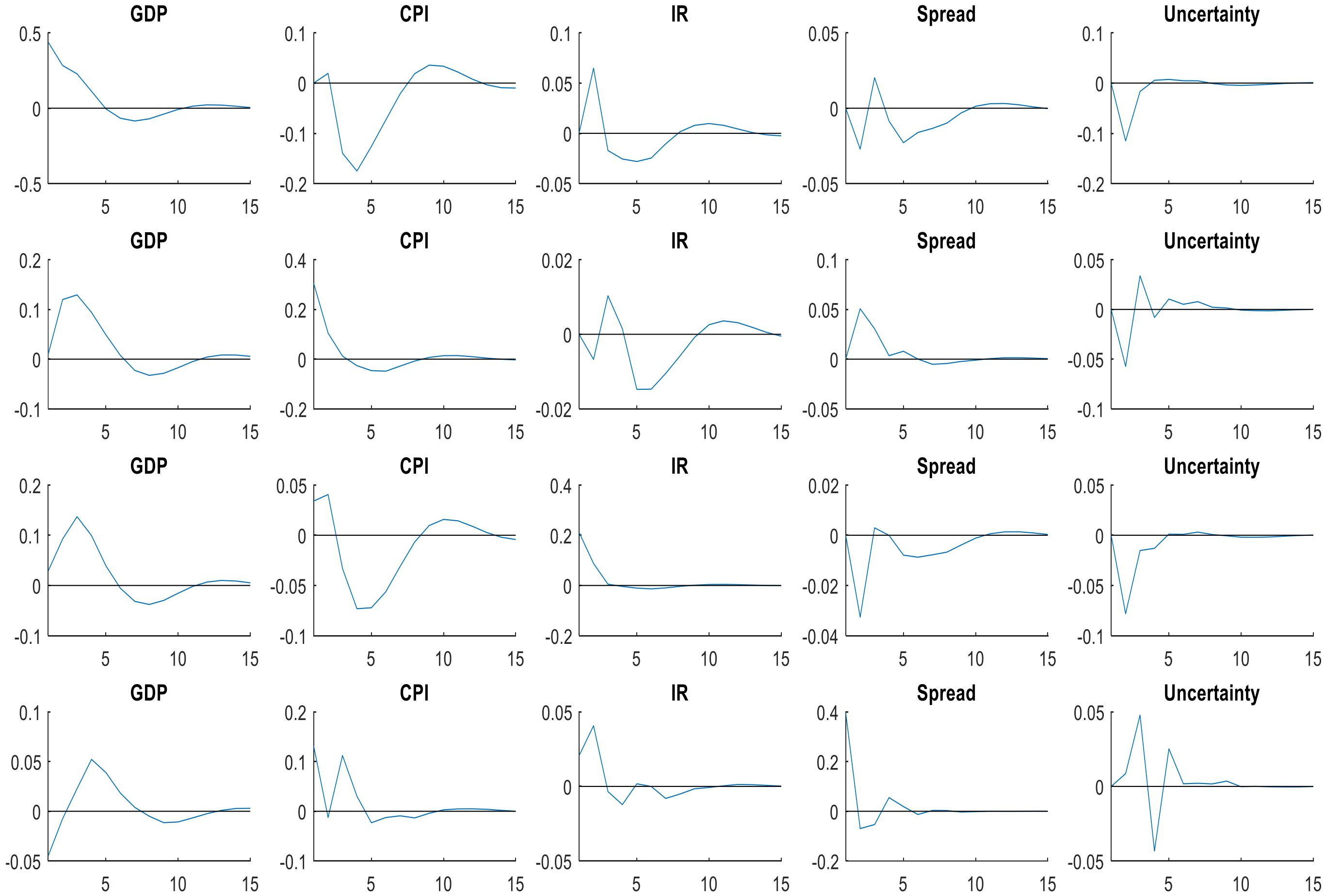
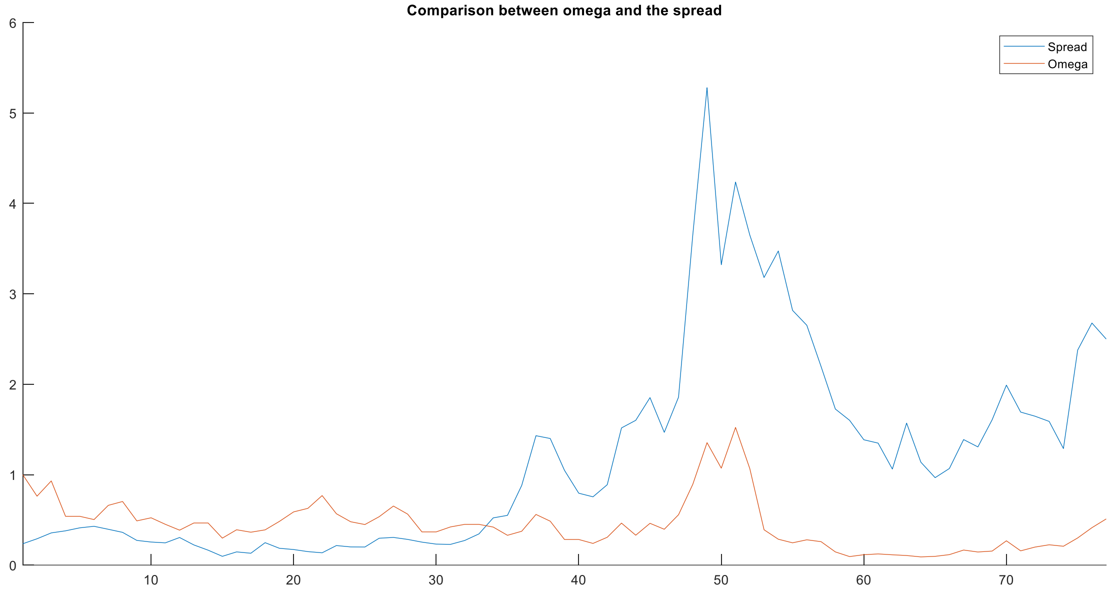


Figure 8 (Impulse response functions with Historic volatility)



### *4.1.3) The relationship between ω and spread*

The indicator is constructed entirely manipulating differences in 10Y BTP and 10Y BUND interest rates. Since another variable of the system is strongly related to this difference, it is the case to analyse the relationship between these variables. To answer this question, it is the case to analyse the variable's movements and to calculate their correlation:

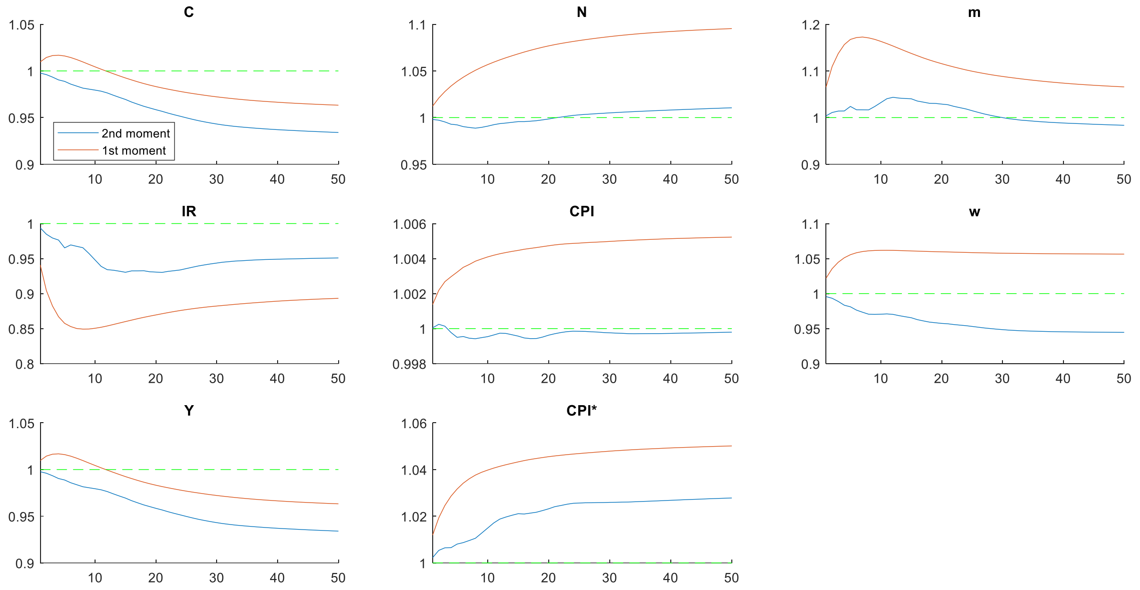



The correlation between variables is 0.2622. This indicates that variables are slightly correlated. The presence of correlation is expected since they are based on the same fundamentals and are expected to covary under some economic scenarios. However, 26% is not considerable. This suggests that $\omega$ and spread capture different information. After all, spread is just a difference of interest rate while $\omega$ is constructed from interest rates' divergences. It is influenced by the amount of divergent variation, that spread does not capture, and by the direction of these variations.

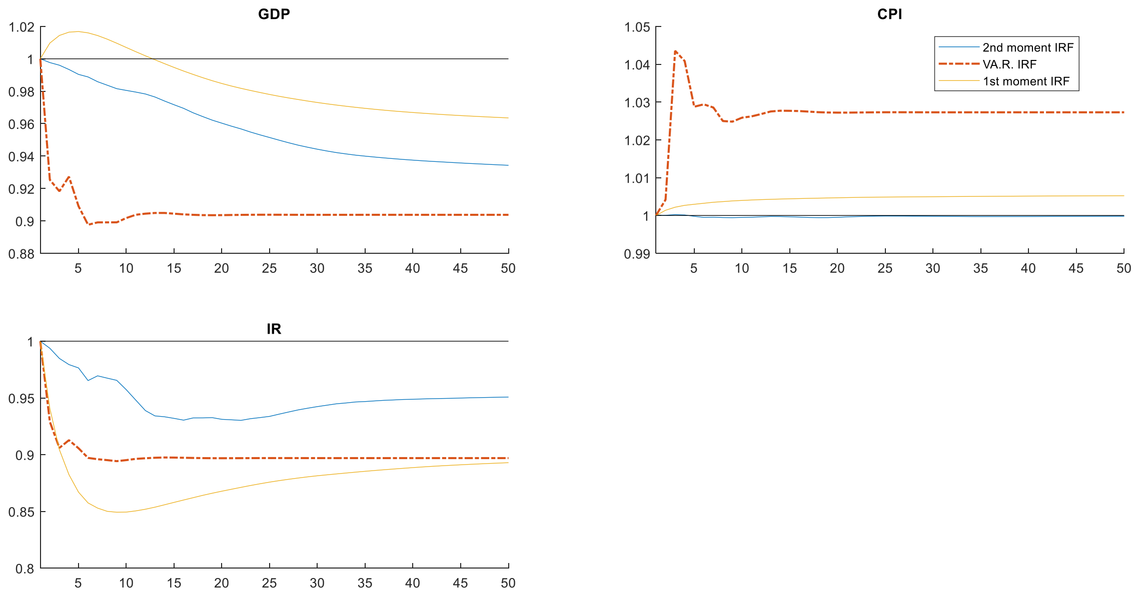
## 4.2) Chapter 2

### 4.2.1) Interest rate shock

The following figure contains the comparison between the impulse response functions with first and second moment. shocks




The following figure contains the comparison between the level change in the different cases.



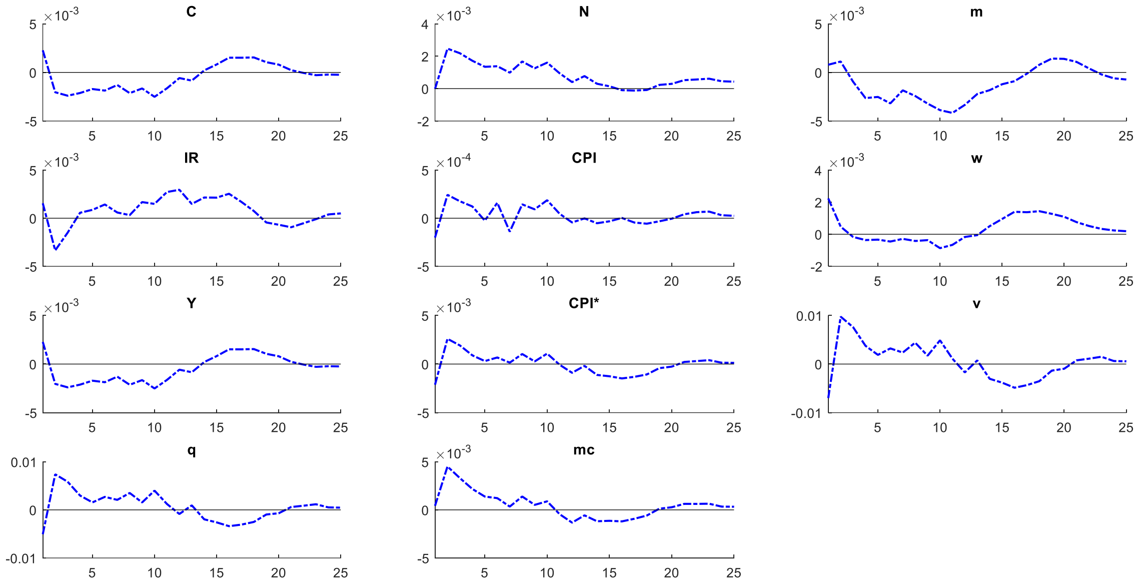

The main differences between first and second moment shock are in the magnitude of shock's effects and in curves' smoothness. First moment shock has better performances in forecasting CPI and IR, while it fails to match the short run movement of GDP.

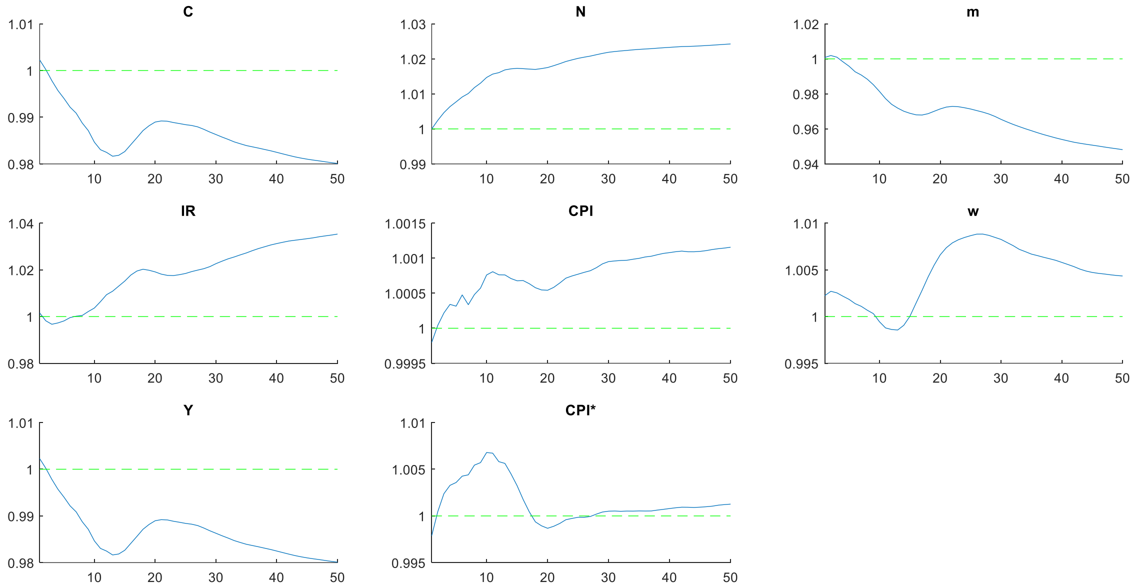
### *4.2.1) Productivity shock*

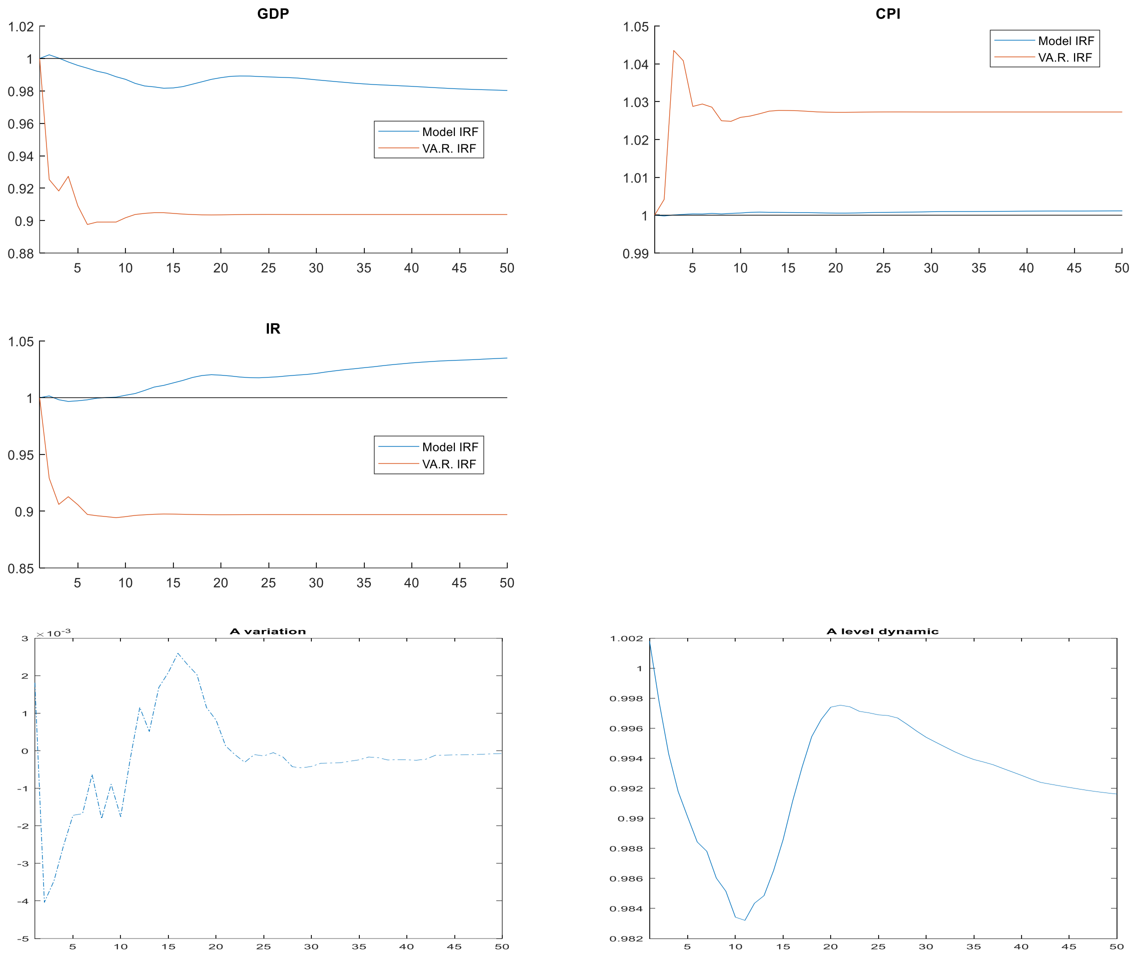
In this section all the additional figures on the second moment productivity shock are illustrated.

#### *4.2.1.1) Forced technological recession*

The following figures report impulse response functions to a second moment shock when $A$ is constrained to follow a negative path.

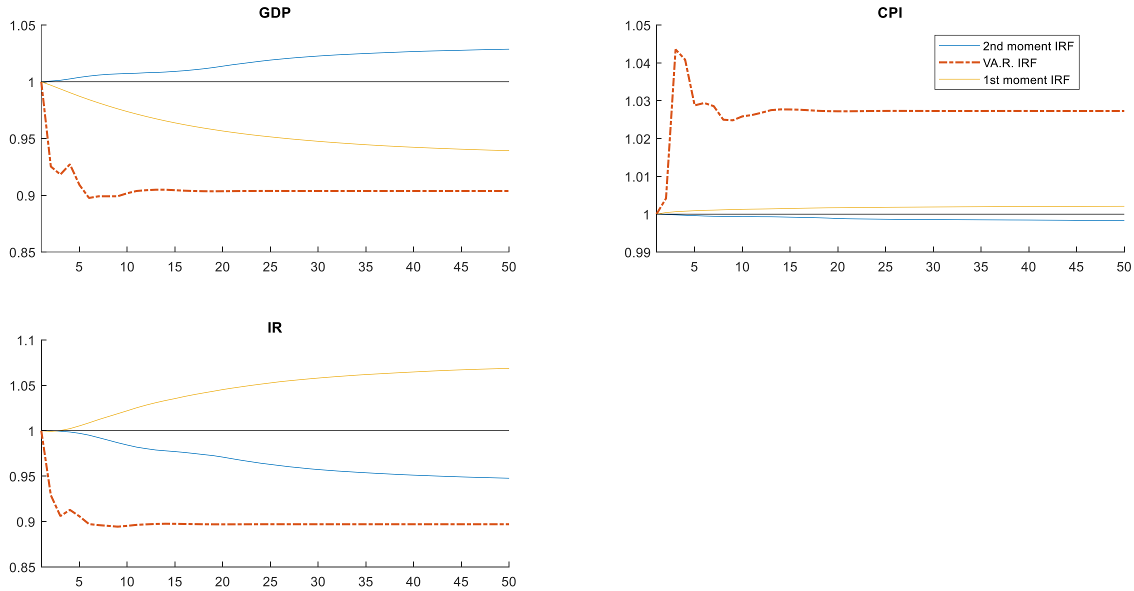





The shock produces negative effects. The variables have interesting dynamic behaviour. The predictions of increasing GDP and CPI are verified, but both the short run behaviour and the magnitude are not consistent with empirical evidence. Second moment shock on productivity fails to replicate empirical evidences about uncertainty shock.

#### *4.2.1.1) First and second moment productivity shock*




The impulse response functions in the case of productivity shock are different. This difference comes from positive technological progress after the second moment shock. Considering ‘’forced’’ case, responses are similar for both shock’s order. The only difference is in smoothness.

## Appendix B, MATLAB code

This section contains the MATLAB® code used for empirical analysis and simulations. The script has been coded in the MATLAB® version R2017b. The recent MATLAB® versions may not read the code because the function ‘’xlsread’’ has been modified.

Dataset

```
clc

clear



[Data1,txt,raw]=xlsread('macrodataita','V.A.R.');
[Data2,txt1,raw1]=xlsread('Segnale spread per var');
[Data3,txt3,raw3]=xlsread('macrodataita','V.A.R.3');
[Data4,txt4,raw4]=xlsread('macrodataita','V.A.R.4');
Spread_index=Data2(1:78,2);
txt={'GDP', 'CPI', 'IR', 'Spread', 'U'};
txt1={'GDP', 'CPI', 'IR', 'Spread', 'Uncertainty'};
txtres={'GDP residuals', 'CPI residuals', 'IR residuals', 'Spread
residuals', 'U residuals'};
Time=(raw(3:end,1));
```

Constructing the indicator omega

```
for i=1:77
    unc_index(i)=std(Data2(Spread_index(i)-1:Spread_index(i+1)-
1))*(sum(Data2(Spread_index(i)-1:Spread_index(i+1)-1)))*0.1;
end
for i=1:77
    Unc_level(1)=1;
    Unc_level(i+1)=(1+unc_index(i))*Unc_level(i);
end
```

constructing the uncertainty indicator with linear combination

```
fiducia_cons_mens=xlsread('macrodataita','clima fiducia trimestrale');
index_fid=[1:3:231];
for i=1:77
    fiducia_cons_tri(i)=mean(fiducia_cons_mens(index_fid(i):index_fid(i)+2));
end

VIX_us=xlsread('macrodataita', 'Quarter VIX');
Data_vix=xlsread('Europe VIXs');
corr([VIX_us Data_vix],'rows','complete'); %very high correlation among the
differenc volatility measure

uncU=0.425*[fiducia_cons_tri/mean(fiducia_cons_tri)].^-
1+0.075*Unc_level(2:end)/mean(Unc_level(2:end))+0.35*[Data4(:,end)/mean(Data4(:
,end))]'+0.15*[0.4*Data_vix(:,1)/mean(Data_vix(:,1))]';
y_agg_lev=cumprod(1+Data1(:,1)/100);
intercept_aux=1-mean(uncU);

figure
plot(y_agg_lev)
```

```
set(gca,'xtick',[1:7:77],'xticklabel',Time(1:7:77))
title('GDP')
xlim([1,76])

figure
subplot(2,1,1)
plot(uncU)
title('Mixed uncertainty level')
set(gca,'xtick',[1:7:77],'xticklabel',Time(1:7:77))
xlim([1,77])
subplot(2,1,2)
title('Mixed uncertainty Variation')
hold on
plot(uncU(2:end)-uncU(1:end-1),'*-')
plot([1:76]*0,'k')
hold off
set(gca,'xtick',[1:7:77],'xticklabel',Time(1:7:77))
xlim([0,76])

figure
hold on
plot(intercept_aux+uncU,'*-')
plot(y_agg_lev/mean(y_agg_lev))
hold off
set(gca,'xtick',[1:7:77],'xticklabel',Time(1:7:77))
title('Uncertainty and GDP levels')
legend('Mixed Unc. Ind.', 'GDP_I_T')
xlim([0,77])

Variables_correlation=corr(uncU', y_agg_lev/mean(y_agg_lev));
Ind_corr=corr([Data3(:,end) Data4(:,end) Unc_level(2:end)'
[fiducia_cons_tri]'.^-1 Data_vix(:,1) uncU']);
Data=[Data1 uncU'];
Data3=[Data3];
```

Data analysis and manipulation

```
for i=1:5
    [adf(i),apval(i)]=adftest(Data(:,i))
    [kpss(i),kpval(i)]=kpsstest(Data(:,i))
end

%adf test indicates that gdp is stationary while th other series have unit
%root. Kpss test suggest non stationarity for all the series. It would be
%the case to detrend each time series.

dData=[Data(2:end,1) Data(2:end,2:end)-Data(1:end-1,2:end)];
dData3=[Data(2:end,1) Data3(2:end,2:end)-Data3(1:end-1,2:end)];
dData4=[Data(2:end,1) Data4(2:end,2:end)-Data4(1:end-1,2:end)];

for i=1:5
    [dadf(i),dapval(i)]=adftest(dData(:,i))
    [dkpss(i),dkpval(i)]=kpsstest(dData(:,i))
end

figure
for i=1:5
    subplot(2,3,i)
```

```
    plot(dData(:,i))
    hold on
    plot([0:1:76]*0,'k')
    xlim([0,76])
    set(gca,'xtick',[2:16:77],'xticklabel',Time(1:16:76))
    ytickformat('percentage')
    title(txt(i))
    hold off
end

dCorrelations=corr(dData);

figure
for i=1:5
    subplot(2,3,i)
    autocorr(dData(:,i))
    title(txt(i))
end
figure
for i=1:5
    subplot(2,3,i)
    parcorr(dData(:,i))
    title(txt(i))
end
```

Order selection

```
for j=1:6
    model(j)=varm(5,j);
end
for i=1:6
    var(i)=estimate(model(i),dData);
    selection(i)=summarize(var(i));
end

% considering values of AIC and BIc V.AR(2) is a second best choice.
```

V.A.R.(2)

```
model2=varm(5,2)

[var2,var2ParamCov,var2logL,var2info]=estimate(model2,dData);

[resultsv2]=summarize(var2)

coeff2_t1=var2.AR{1,1};

coeff2_t2=var2.AR{1,2};

intercept_2=var2.Constant;

%The following line contains an example to estimate the model with the OLS
%estimator. The function used is coded by J.P. Lesage, and available online.
%results_ols_p2=ols(dData(3:end,1),[ones(74,1) dData(2:end-1,:) dData(1:end-
2,:) ]);

figure
```

```
for j=1:5
    for i=2:76
        Y_fitted_p2(j,i-1)=coeff2_t1(j,:)*dData(i,:)'+coeff2_t2(j,:)*dData(i-
1,:)';
    end
    subplot(3,2,j)
    plot(Y_fitted_p2(j,:),'k')
    hold on
    stem(dData(3:end,j),'.r')
    plot([1:1:76]*0,'k')
    legend('Fitted','Realized','location','best')
    set(gca,'xtick',[2:16:77],'xticklabel',Time(1:16:76))
    ytickformat('percentage')
    xlim([1,76])
    title(txt(j))
    hold off
end
```

Error analysis VAR(2)

```
figure

for j=1:5
    resid_p2(j,:)=Y_fitted_p2(j,1:end-1)-dData(3:end,j)';
    subplot(2,3,j)
    histfit(resid_p2(j,:))
    title(txtres(j))
end
figure
for j=1:5
    [jb(j), jbpvalue(j)]=jbtest(resid_p2(j,:));
    [lilt(j), liltpvalue(j)]=lillietest(resid_p2(j,:));
    subplot(2,3,j)
    qqplot(resid_p2(j,:))
    title(txtres(j))
end

figure
for j=1:5
    subplot(2,3,j)
    plot(resid_p2(j,:))
    hold on
    plot([1:75]*0,'k')
    hold off
    xlim([1,75])
    set(gca,'xtick',[2:16:77],'xticklabel',Time(1:16:76))
    ytickformat('percentage')
    title(txtres(j))
end
figure
for j=1:5
    subplot(2,3,j)
    autocorr(resid_p2(j,:))
    title(txtres(j))
end
figure
for j=1:5
    subplot(2,3,j)
```

```
    parcorr(resid_p2(j,:))
    title(txtres(j))

end

for j=1:5
    [lbqt(j), pval_lbqt(j)]= lbqtest(resid_p2(j,:));
    [lilcor1(j), lilcorpvalue1(j)]=lillietest(resid_p2(j,:));
end
```

Residuals without extreme events

```
for j=1:5
    for i=1:74
        if abs(resid_p2(j,i))<0.95
            normres(j,i)=resid_p2(j,i);
    else
        normres(j,i)=nan;
        end
    end
    [lilcor(j), lilcorpvalue(j)]=lillietest(normres(j,:));
end

figure
subplot(2,1,1)
histfit(normres(4,:))
title(txtres(4))
subplot(2,1,2)
qqplot(normres(4,:))
title(txtres(4))
```

V.AR.(2) impulse response function (non-orthogonalized, not presented in the thesis)

```
T_k=22;

for h=1:5
    iDataes=zeros(T_k,5);
    iDataes(2,h)=0.1; %positive shock
    for i=3:T_k
        for j=1:5
            iDataes(i,j)=coeff2_t1(j,:)*iDataes(i-
1,:)'+coeff2_t2(j,:)*iDataes(i-2,:)';
        end
        impulse_resp_s(i-2,:)=iDataes(i-2,:);
    end
    figure
    for j=1:5
        subplot(2,3,j)
        hold on
        plot(impulse_resp_s(:,j),'-*')
        plot([1:T_k]*0,'k')
        y1=get(gca,'ylim');
        plot([2 2],y1,'--k')
        hold off
       xlim([2,T_k-2])
       title(txt(1,j))
    end
end
```

```
figure
for j=1:5
    for i=2:20
        aggr_imp_resp(i-1,j)=sum(impulse_resp_s(1:i,j));
    end
    subplot(2,3,j)
    hold on
    plot(aggr_imp_resp(:,j), '--o')
    plot([0:1:19]*0,'-k')
    title(txt(j))
    xlim([1,19])
    ylim([-max(abs(aggr_imp_resp(:,j)))-0.025,
max(abs(aggr_imp_resp(:,j)))+0.025])
end
```

Orthogonalized impulse response

```
model3=varm(5,2);

model4=varm(5,2);

[var3,var3ParamCov,var3logL,var3info]=estimate(model3,dData3);

[var4,var4ParamCov,var4logL,var4info]=estimate(model4,dData4);

coeff3_t1=var3.AR{1,1};

coeff3_t2=var3.AR{1,2};

coeff4_t1=var4.AR{1,1};

coeff4_t2=var4.AR{1,2};

[resultsv3]=summarize(var3)

[resultsv4]=summarize(var4)



[imp_resp_ort] = armairf({coeff2_t1
coeff2_t2},[],'InnovCov',resultsv2.Covariance,'Method','orthogonalized','NumObs
',50);
[imp_resp_ort3] = armairf({coeff3_t1
coeff3_t2},[],'InnovCov',resultsv3.Covariance,'Method','orthogonalized','NumObs
',50);
[imp_resp_ort4] = armairf({coeff4_t1
coeff4_t2},[],'InnovCov',resultsv4.Covariance,'Method','orthogonalized','NumObs
',50);

figure
for i=1:5
    subplot(2,3,i)
    hold on
    plot(imp_resp_ort(:,i,5),'--o')
    plot([1:25]*0,'k')
```

```
    xlim([1,25])
    title(txt(1,i))
    hold off
end

T_k=22;
for h=1:5
    h=5;
    iDataes=zeros(T_k,5);
    iDataes(2,h)=1; %positive shock
    for i=3:T_k
        for j=1:5
            iDataes(i,j)=coeff2_t1(j,:)*iDataes(i-
1,:)'+coeff2_t2(j,:)*iDataes(i-2,:)';
        end
        impulse_resp_s(i-2,:)=iDataes(i-2,:);
    end
end

imp_responses=[imp_resp_ort(:,:,end) imp_resp_ort3(:,:,end)
imp_resp_ort4(:,:,end)];
cum_level_responses=cumprod([1+imp_responses],1);

figure
for j=1:5
    subplot(2,3,j)
    hold on
    plot(cum_level_responses(:,j))
    plot(ones(1,50),'g--')
    title(txt(1,j))
    legend('Level evolution', 'Initial value', 'location', 'best')
    xlim([1,50])
end

figure
for j=1:4
    subplot(2,2,j)
    hold on
    plot([cum_level_responses(:,j)], '-*')
    plot([cum_level_responses(:,j+5)], '-o')
    plot([cum_level_responses(:,j+10)], '-+')
    plot(ones(1,50),'-k')
    hold off
    legend('U', 'EPU', 'HV', 'location', 'best')
    title(txt(1,j))
end

figure
subplot(2,1,1)
hold on
plot([cum_level_responses(:,5)], '-*b')
plot([cum_level_responses(:,10)], '-or')
plot(ones(1,50),'--g')
hold off
ylim([0.95,1.15])
xlim([1,20])
legend('U', 'EPU', 'Initial level','location', 'best')
title('U & EPU levels changes')
subplot(2,1,2)
```

```
hold on
plot([cum_level_responses(:,15)], '-+y')
plot(ones(1,50),'--g')
hold off
ylim([0.85,3.5])
xlim([1,20])
legend('HV', 'Initial shock level', 'location', 'best')
title('Historic volatility level change')
```

Other impulse response functions

```
figure

for j=1:5
    for i=1:4
        subplot(4,5,j+5*(i-1))
        hold on
        plot(imp_resp_ort(:,i,j))
        plot(ones(1,15)*0, 'k')
        title(txt1(1,j))
        xlim([1,15])
    end
end

figure
for j=1:5
    for i=1:4
        subplot(4,5,j+5*(i-1))
        hold on
        plot(imp_resp_ort3(:,i,j))
        plot(ones(1,15)*0, 'k')
        title(txt1(1,j))
        xlim([1,15])
    end
end

figure
for j=1:5
    for i=1:4
        subplot(4,5,j+5*(i-1))
        hold on
        plot(imp_resp_ort4(:,i,j))
        plot(ones(1,15)*0, 'k')
        title(txt1(1,j))
        xlim([1,15])
    end
end
```

Dynare® section, first moment interest rate shock

```
dynare newkeynesian

var_dyn_ei=[ci_ei ni_ei mi_ei iri_ei piti_ei wi_ei yi_ei pisi_ei vi_ei qi_ei
mci_ei];
[row,col]=size(var_dyn_ei);
agg_dyn_ei=cumprod([1+var_dyn_ei],1);
txt_dyn={'C' 'N' 'm' 'IR' 'CPI' 'w' 'Y' 'CPI*' 'v' 'q' 'mc'};
aux_Dyn_i=[var_dyn_ei(:,7) var_dyn_ei(:,5) var_dyn_ei(:,4)];
```

```
aux_cum_Dyn_tit={'GDP' 'CPI' 'IR'};
cum_imp_resp=cumprod(1+imp_resp_ort(:,:,5));
aux_cum_Dyn_i=[agg_dyn_ei(:,7) agg_dyn_ei(:,5) agg_dyn_ei(:,4)];

figure
for i=1:6
    subplot(3,2,i)
    hold on
    plot(var_dyn_ei(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
    xlim([1,25])
    hold off
    title(txt_dyn(i))
end

figure
for i=7:11
    subplot(3,2,i-6)
    hold on
    plot(var_dyn_ei(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
    xlim([1,25])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:8
    subplot(3,3,i)
    hold on
    plot(agg_dyn_ei(:,i))
    plot(ones(50,1),'g--')
    xlim([1,50])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([aux_Dyn_i(:,i)],'-*')
    plot(imp_resp_ort(2:end,i,5),'-o')
    plot(zeros(25,1),'k')
    hold off
    title(aux_cum_Dyn_tit(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,30])
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([1; aux_cum_Dyn_i(:,i)])
    plot(cum_imp_resp(:,i))
    plot(ones(50,1),'k')
    hold off
    title(aux_cum_Dyn_tit(i))
```

```
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,50])
end
```

First moment Productivity shock

```
var_dyn_eia=[ci_ea ni_ea mi_ea iri_ea piti_ea wi_ea yi_ea pisi_ea vi_ea qi_ea
mci_ea];

agg_dyn_eia=cumprod([1+var_dyn_eia],1);

aux_Dyn_ia=[var_dyn_eia(:,7) var_dyn_eia(:,5) var_dyn_eia(:,4)];

aux_cum_Dyn_ia=[agg_dyn_eia(:,7) agg_dyn_eia(:,5) agg_dyn_eia(:,4)];



figure

for i=1:6
    subplot(3,2,i)
    hold on
    plot(var_dyn_eia(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
    xlim([1,25])
    hold off
    title(txt_dyn(i))
end

figure
for i=7:11
    subplot(3,2,i-6)
    hold on
    plot(var_dyn_eia(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
    xlim([1,25])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:8
    subplot(3,3,i)
    hold on
    plot(agg_dyn_eia(:,i))
    plot(ones(50,1),'g--')
    xlim([1,50])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([aux_Dyn_ia(:,i)],'-*')
    plot(imp_resp_ort(:,i,5),'-o')
```

```
    plot(zeros(25,1),'k')
    hold off
    title(aux_cum_Dyn_tit(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,25])
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([1; aux_cum_Dyn_ia(:,i)])
    plot(cum_imp_resp(:,i))
    plot(ones(50,1),'k')
    hold off
    title(aux_cum_Dyn_tit(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,50])
end

figure
subplot(1,2,1)
plot(ai_ea,'-.')
xlim([1,50])
title('A variation')
subplot(1,2,2)
plot(cumprod(1+ai_ea))
title('A level dynamic')
xlim([1,50])
```

IRFs with first and second moment shock (IR shock)

```
var_dyn_eii=[ci_eii ni_eii mi_eii iri_eii piti_eii wi_eii yi_eii pisi_eii
vi_eii qi_eii mci_eii];

[row,col]=size(var_dyn_eii);

agg_dyn_eii=cumprod([1+var_dyn_eii],1);

txt_dyn={'C' 'N' 'm' 'IR' 'CPI' 'w' 'Y' 'CPI*' 'v' 'q' 'mc'};

figure
for i=1:6
    subplot(3,2,i)
    hold on
    plot(var_dyn_eii(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
    xlim([1,25])
    hold off
    title(txt_dyn(i))
end

figure
for i=7:11
    subplot(3,2,i-6)
    hold on
    plot(var_dyn_eii(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
```

```
    xlim([1,25])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:8
    subplot(3,3,i)
    hold on
    plot(agg_dyn_eii(:,i))
    plot(ones(50,1),'g--')
    xlim([1,50])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:8
    subplot(3,3,i)
    hold on
    plot(agg_dyn_eii(:,i))
    plot(agg_dyn_ei(:,i))
    plot(ones(50,1),'g--')
    xlim([1,50])
    hold off
    legend('2nd moment','1st moment', 'location', 'best')
    title(txt_dyn(i))
end

aux_Dyn_ii=[var_dyn_eii(:,7) var_dyn_eii(:,5) var_dyn_eii(:,4)];
aux_cum_Dyn_titi={'GDP' 'CPI' 'IR'};

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([aux_Dyn_ii(:,i)],'-*')
    plot(imp_resp_ort(2:end,i,5),'-o')
    plot(zeros(25,1),'k')
    hold off
    title(aux_cum_Dyn_titi(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,30])
end

cum_imp_respi=cumprod(1+imp_resp_ort(:,:,5));
aux_cum_Dyn_ii=[agg_dyn_eii(:,7) agg_dyn_eii(:,5) agg_dyn_eii(:,4)];

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([1; aux_cum_Dyn_ii(:,i)])
    plot(cum_imp_respi(:,i))
    plot(ones(50,1),'k')
    hold off
    title(aux_cum_Dyn_titi(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,50])
```

```
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([1; aux_cum_Dyn_ii(:,i)])
    plot(cum_imp_respi(:,i), '-.','LineWidth',1.5)
    plot([1; aux_cum_Dyn_i(:,i)])
    plot(ones(50,1),'k')
    hold off
    title(aux_cum_Dyn_titi(i))
    legend('2nd moment IRF', 'V.AR. IRF', '1st moment IRF', 'location', 'best')
    xlim([1,50])
end
```

IRFs with first and second moment shocks (productivity shock)

```
%dynare Newkeyprodshock2mom.mod %run this line to oblige the productivity
%to follows a negative path.

var_dyn_eia=[ci_eia ni_eia mi_eia iri_eia piti_eia wi_eia yi_eia pisi_eia
vi_eia qi_eia mci_eia];
agg_dyn_eiaa=cumprod([1+var_dyn_eia],1);
aux_Dyn_iaa=[var_dyn_eia(:,7) var_dyn_eia(:,5) var_dyn_eia(:,4)];
aux_cum_Dyn_iaa=[agg_dyn_eiaa(:,7) agg_dyn_eiaa(:,5) agg_dyn_eiaa(:,4)];

% figure
% for i=1:11
%     subplot(4,3,i)
%     hold on
%     plot(var_dyn_eia(:,i),'-.b','LineWidth',1.5)
%     plot(zeros(25,1),'k-')
%     xlim([1,25])
%     hold off
%     title(txt_dyn(i))
% end

% figure
% for i=1:11
%     subplot(4,3,i)
%     hold on
%     plot(var_dyn_eia(:,i),'-.b','LineWidth',1.5)
%     plot(zeros(25,1),'k-')
%     xlim([1,25])
%     hold off
%     title(txt_dyn(i))
% end

figure
for i=1:6
    subplot(3,2,i)
    hold on
    plot(var_dyn_eia(:,i),'-.b','LineWidth',1.5)
    plot(zeros(25,1),'k-')
    xlim([1,25])
    hold off
    title(txt_dyn(i))
```

```
end

figure
for i=1:8
    subplot(3,3,i)
    hold on
    plot(agg_dyn_eiaa(:,i))
    plot(ones(50,1),'g--')
    xlim([1,50])
    hold off
    title(txt_dyn(i))
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([aux_Dyn_iaa(:,i)],'-*')
    plot(imp_resp_ort(:,i,5),'-o')
    plot(zeros(25,1),'k')
    hold off
    title(aux_cum_Dyn_tit(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,25])
end

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([1; aux_cum_Dyn_iaa(:,i)])
    plot(cum_imp_resp(:,i))
    plot(ones(50,1),'k')
    hold off
    title(aux_cum_Dyn_tit(i))
    legend('Model IRF', 'V.AR. IRF', 'location', 'best')
    xlim([1,50])
end

figure
subplot(1,2,1)
plot(ai_eia,'-.')
xlim([1,50])
title('A variation')
subplot(1,2,2)
plot(cumprod(1+ai_eia))
title('A level dynamic')
xlim([1,50])

figure
for i=1:3
    subplot(2,2,i)
    hold on
    plot([1; aux_cum_Dyn_iaa(:,i)])
    plot(cum_imp_respi(:,i), '-.','LineWidth',1.5)
    plot([1; aux_cum_Dyn_ia(:,i)])
    plot(ones(50,1),'k')
    hold off
    title(aux_cum_Dyn_titi(i))
```

```
    legend('2nd moment IRF', 'V.AR. IRF', '1st moment IRF', 'location', 'best')
    xlim([1,50])
end
```

The support file for the Dynare® software is:

```
%New Keynesian model simulation
%Variables and parameters
var ci ni mi iri piti wi gami yi pisi vi qi ai mci sigmai sigmaa;

varexo ea ei eii eia;

parameters sig  etaa thet eps pa pii pih psii fi b fii i piy roei roea;
sig=0.99;
etaa=1.01;
thet=1;
eps=10;
pa=0.9;
pii=0.7;
pih=0.0199;
psii=1;
fi=0.7;
b=0.965;
fii=2;
i=0.05;
piy=3;
roei=0.9;
roea=0.9;

%model part
model;
exp(ci)^(-sig)=b*exp(ci(+1))^(-sig)*(1+exp(iri))/exp(piti(+1));
psii*exp(ni)^etaa=exp(ci)^(-sig)*exp(wi);
exp(mi)=thet*(1+exp(iri))/exp(iri)*exp(ci)^sig;
exp(mci)=exp(wi)/exp(ai);
exp(ci)=exp(yi);
exp(yi)=exp(ai)*exp(ni)/exp(gami);
exp(gami)=(1-fi)*((exp(pisi))^-
eps)*((exp(piti))^eps)+((exp(piti))^eps)*fi*exp(gami(-1));
(exp(piti))^(1-eps)=(1-fi)*(exp(pisi))^(1-eps)+fi;
exp(pisi)=(eps/(eps-1))*(exp(piti))*exp(vi)/exp(qi);
exp(vi)=(exp(ci)^(-sig))*exp(mci)*exp(yi)+fi*b*(exp(piti(+1))^eps)*exp(vi(+1));
exp(qi)=(exp(ci)^(-sig))*exp(yi)+fi*b*(exp(piti(+1))^(eps-1))*exp(qi(+1));
ai=pa*ai(-1)-sigmaa*ea;
exp(iri)=(1-pii)*i+pii*exp(iri(-1))+(1-pii)*fii*(exp(piti)-exp(pih))+(1-
pii)/piy*(exp(yi)-exp(yi(-1)))/exp(yi(-1))-sigmai*ei;
sigmai=(1-roei)+roei*(sigmai(-1))+eii;
sigmaa=(1-roea)+roea*(sigmaa(-1))+eia; %it is possible to change sign to force A to
follow a negative path
end;

initval;
ai=0;
piti=log(1+pih);
iri=log((1/b)*exp(piti)-1);
pisi=log(((exp(piti)^(1-eps)-fi)/(1-fi))^(1/(1-eps)));
gami=log((1-fi)*(exp(piti))^eps/(exp(pisi)^eps)/(1-fi*(exp(piti))^eps));
```

```
mci=log(exp(pisi)/exp(piti)*(eps-1)/eps*(1-fi*b*exp(piti)^eps)/(1-
fi*b*exp(piti)^(eps-1)));
wi=mci;
ni=log((1/psii*exp(gami)^sig*exp(mci))^(1/(etaa+sig)));
yi=log(exp(ni)/exp(gami));
ci=yi;
vi=log((exp(ci)^-sig)*exp(mci)*exp(yi)/(1-fi*b*exp(piti)^eps));
qi=log((exp(ci)^-sig)*exp(yi)/(1-fi*b*exp(piti)^(eps-1)));
mi=log(thet*(1+exp(iri))/exp(iri)*exp(yi)^sig);
end;

steady;
check;

shocks;
var ei=0.00005;
var eii=0.7;
end;

shocks;
var ea=0.00005;
var eia=0.7;
end;

stoch_simul(order=3,irf=50);
```

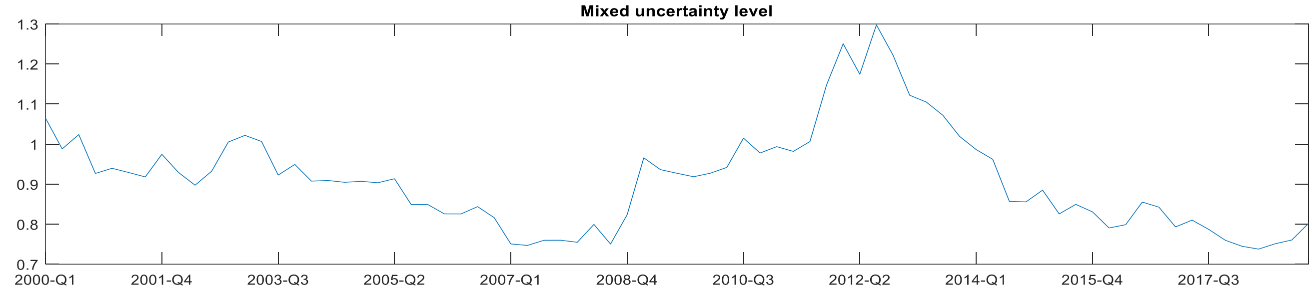
## References

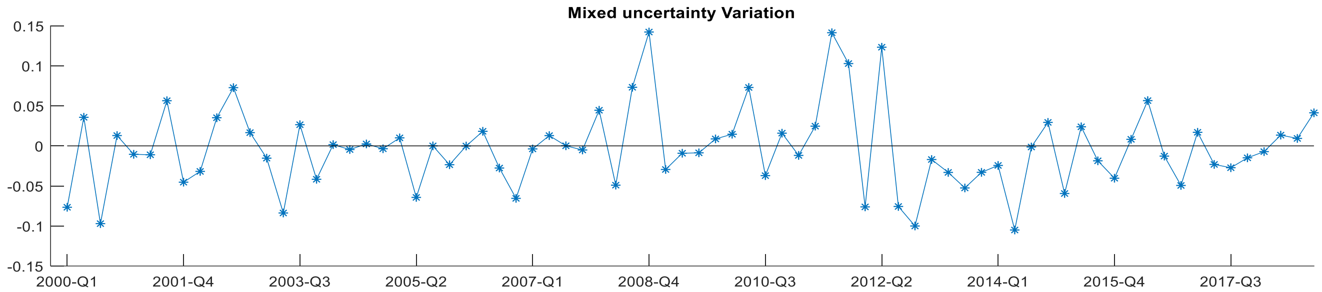

- N. Bloom, ‘’The impact of uncertainty shocks’’, Econometrica, 2009
- J. Fernández-Villaverde, P. Guerrón-Quintana, J. F. Rubio-Ramírez, M. Uribe, ‘’Risk Matters: The Real Effects of Volatility Shocks’’, American economic review, 2011.
- S. Basu, B. Bundick, ‘’Uncertainty shock in a world of effective demand’’, Econometrica, 2017.
- De Groot, O., A. W. Richter, And N. A. Throckmorton, “Uncertainty Shocks in a Model of Effective Demand: Comment,” Econometrica, 2018.
- S. Basu, B. Bundick, ‘’Uncertainty shock in a world of effective demand: Reply’’, Econometrica, 2018.
- S. Yıldırım-Karaman, ‘’Uncertainty in financial markets and business cycles’’, Economic modelling, 2018.
- C. Bayer, R. Lütticke, L. Pham-Dao, V. Tjaden, ‘’Precautionary savings, illiquid assets, and the aggregate consequences of shocks to household income risk’’, Econometrica, 2019.
- A. Carriero, T. E. Clark, M. Marcellino, ‘’Measuring uncertainty and its impact on the economy’’, The review of economics and statistics, 2018.
- B. Born and J. Pfeifer, ‘’Policy risk and the business cycle’’, Journal of monetary economy, 2014.
- J. Fernández-Villaverde, P. Guerrón-Quintana, K. Kuester, J. Rubio-Ramírez, ‘’Fiscal Volatility Shocks and Economic Activity’’, American economic review, 2015.
- A. Anzuini, L. Rossi, P. Tommasino, ‘’Fiscal policy uncertainty and the business cycle: time series evidence from Italy’’, Bank of Italy, Working paper, 2017
- J. Crespo Cuaresma, F. Huber, L. Onorante, ‘’The macroeconomic effects of international uncertainty’’, E.C.B. working paper, 2019.
- Scott R. Baker, Nicholas Bloom, Steven J. Davis, Measuring Economic Policy Uncertainty, The Quarterly Journal of Economics, Volume 131, Issue 4, November 2016;
- M. Woodfort, ‘Interest and prices- Fundations of a Theory of Monetary policy’’, Priceton University press, 2003.
- J. Galì ‘’Monetary Policy, Inflation, and the Business Cycle-An Introduction to the New Keynesian Framework and Its Applications’’, Princeton university press, 2008.
- G. Calvo, ’’Staggered prices in a utility-maximizing framework,’’ Journal of Monetary Economics, 1983.
- J. B. Taylor, "Discretion versus policy rules in practice’’, Elsevier, 1993.
- B. E. Hansen, ‘’Econometrics’’, 2017.
- H. Lütkepohl, ‘’New introduction to multiple time series analysis’’, Springer Verlag, 2005.
- J. Garìn, R. Lester, E. Sims, ‘’Intermediate macroeconomics’’, 2018.

# Summary

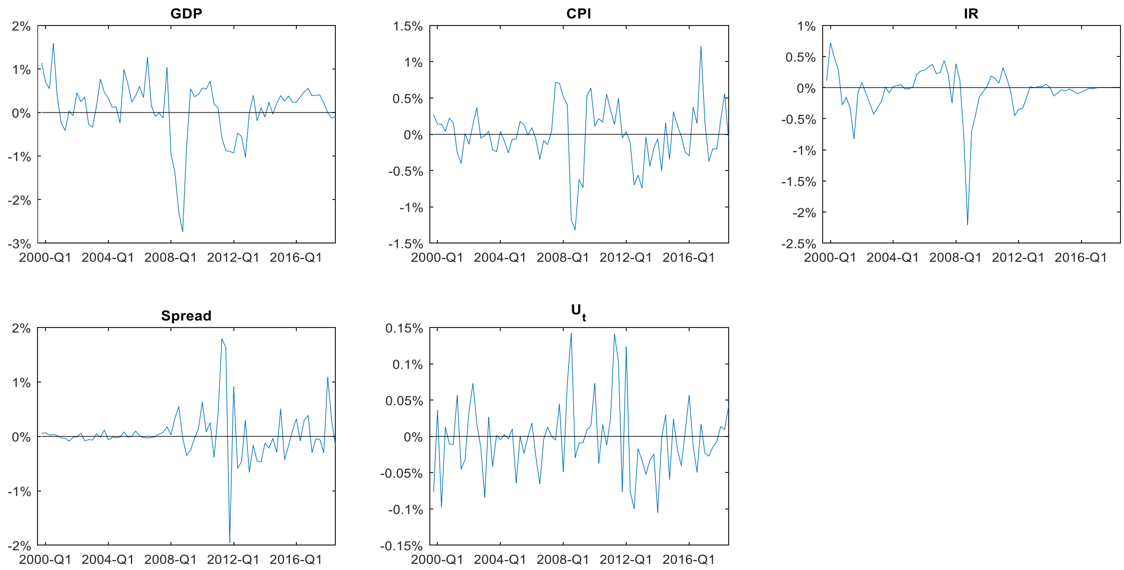
The main purpose of this thesis is to analyse the impact of uncertainty on the Italian economic system. In the first part, the analysis is conducted estimating impulse response functions of a fitted vector autoregression model (V.AR.). These results are analysed and compared to a theoretical model.

The dataset used in the empirical analysis contains gross domestic product (GDP), consumer price index (CPI), short-term interest rate (IR), spread between 10Y BTP and 10Y BUND and a measure of uncertainty. To measure uncertainty a mixed indicator has been constructed. This indicator is a linear combination of the inverse of consumers' confidence, FTSE MIB historic volatility (HV), Euro Stoxx 50 implied volatility and the indicator $\omega$. The latter is a new measure based on divergence of long-term bonds' returns.




Before estimating the V.AR. model it is the case to analyse the time series. The following figures contain the series:

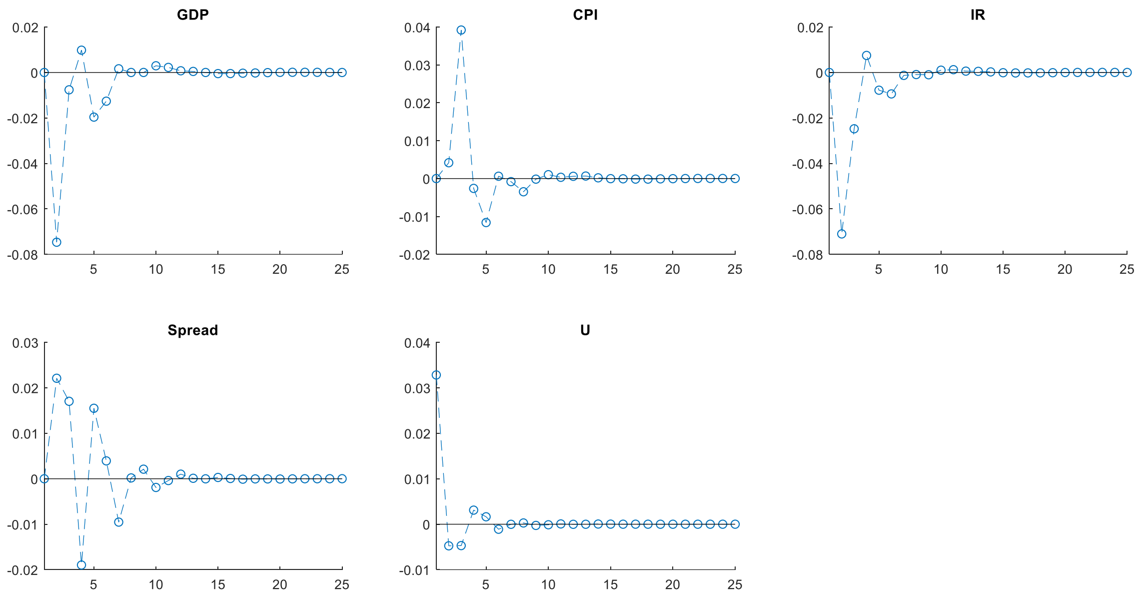


Series do not present major econometric issues. A V.AR. model of order two has been estimated. The estimated model's parameters are:

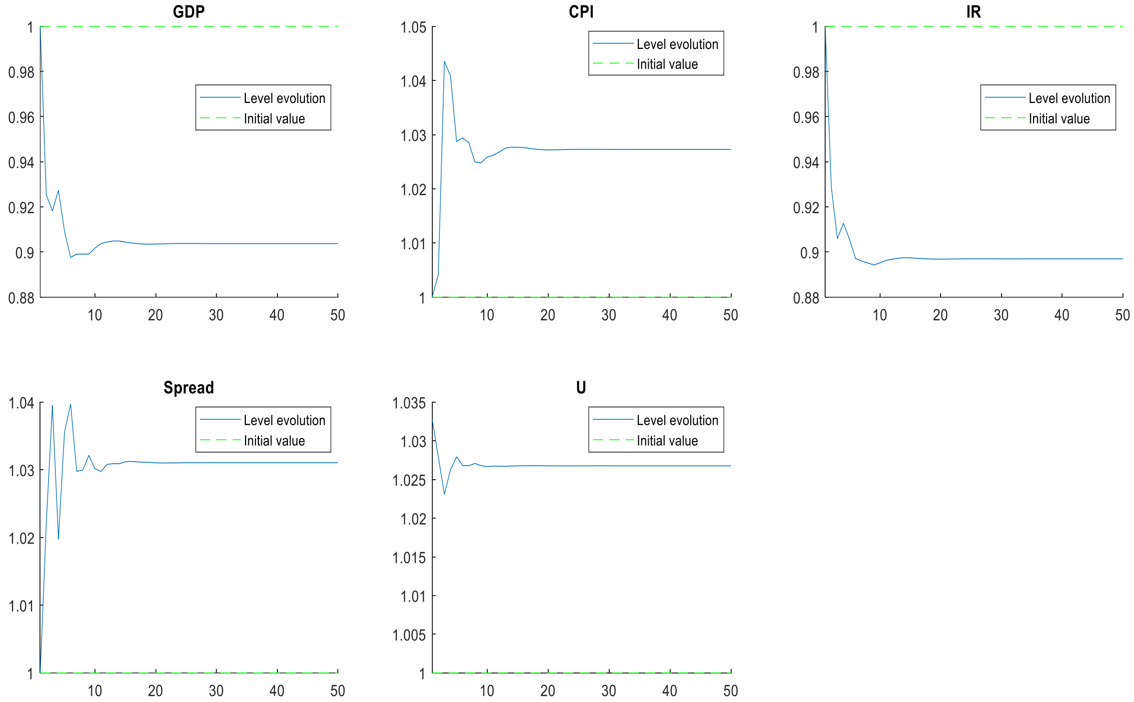
| | GDP(t-1) | CPI(t-1) | IR(t-1) | Spread(t-1) | U(t-1) | GDP(t-2) | CPI(t-2) | IR(t-2) | Spread(t-2) | U(t-2) |
|---|---|---|---|---|---|---|---|---|---|---|
| GDP(t) | 0,59 | 0,03 | 0,24 | 0,08 | -2,27 | 0,10 | -0,51 | -0,32 | 0,00 | 1,25 |
| CPI(t) | 0,28 | 0,24 | -0,06 | 0,11 | 0,13 | 0,09 | -0,09 | -0,04 | -0,04 | 1,61 |
| IR(t) | 0,15 | 0,12 | 0,33 | 0,06 | -2,16 | 0,10 | -0,16 | -0,12 | 0,02 | -0,07 |
| Spread(t) | -0,05 | -0,03 | 0,20 | -0,22 | 0,67 | 0,03 | 0,40 | -0,07 | -0,24 | 1,11 |
| ω(t) | -0,02 | 0,02 | 0,01 | 0,00 | -0,14 | 0,00 | 0,03 | 0,00 | 0,01 | -0,19 |

The residuals have been analysed to integrate V.AR. analysis. They are not correlated over time. Their normality has been tested. A formal test indicates residuals all normally distributed except for the spread's residuals. To further investigate this anomaly an additional analysis has been performed. Eventually it is possible to conclude that the anomaly comes from dataset shortness and that the model can be considered valid.

The orthogonal impulse response functions have been constructed. The system's dynamic response to an uncertainty shock is presented in the following figures:

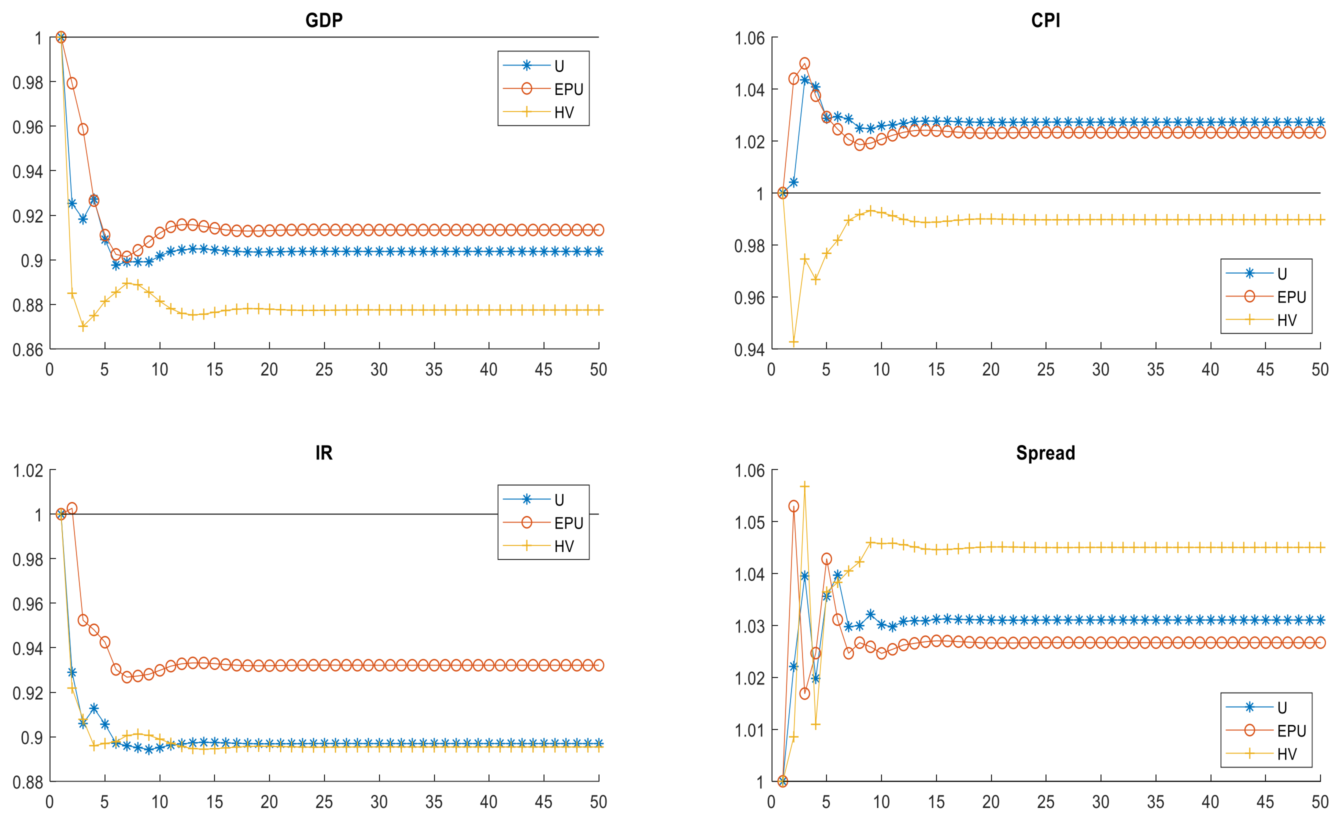


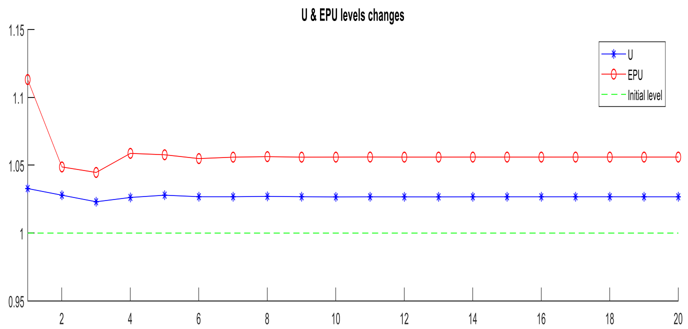
These functions are deviations from equilibrium level. The variables' level behaviours are presented in the following figures:

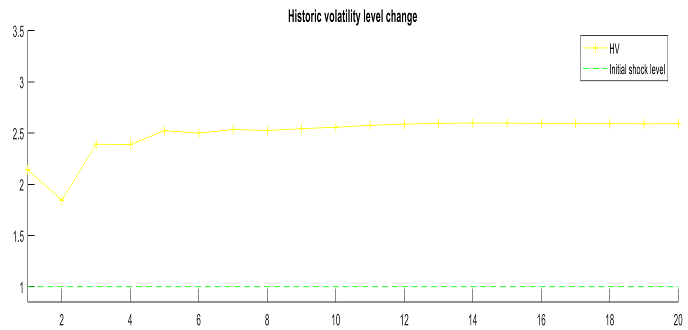



Empirical evidence suggests that the relationship between uncertainty and other variables is negative. In particular GDP decreases of 10% in less than eight quarters. Even the relationship between uncertainty and IR is negative. Short-term interest rate level falls 10% after the shock. This decline is justified by the historic events happened during dataset's time span. In particular, from U.S. financial crisis, E.C.B. has adopted expansive monetary policies. From the 5% level in the 2008 short-term rate decreased to the zero lower-bound, and below. These expansive policies were adopted to stimulate the economic recovery and to contrast the decline in economic activities due to uncertainty's effect. For this reason, model forecasts decreasing interest rate after uncertainty shocks. Spread's response is negative in economic terms because the government's cost of finance increases. The short-term dynamics is not clear because spread increases but oscillating. However, the long-term level is higher. Model suggests that inflation increases after the shock. Finally, uncertainty shock permanently increases the uncertainty level in the economy.

Results are similar to other results found estimating alternative V.AR. models with EPU index and HV only. EPU index is a new index proposed by Bayer et alt. freely available online for most of the developed countries. The impulse response functions to uncertainty shocks have been determined in alternative model specification. It is possible to observe the results in the following figure:




With the exception of CPI's impulse response function to an HV shock, the behaviours are similar. Even in other specifications, the spread response is oscillatory in the short run.

The theoretical model developed to simulate the impulse response functions belongs to the New Keynesian framework. It is a stochastic model with price rigidity and monetary policy expressed in terms of interest rate. The interest rate rule is specified in function of inflation level, interest rate level and GDP's variation. The agents in the economy are a representative household, a representative final produce, a continuum [0,1] of intermediate producers and the government. Intermediate producers' production technology follows an exogenous AR process. Intermediate producers are monopolistic competitors and have market power.

However, every period they can charge the price they prefer only with probability $\phi$, otherwise they must charge their previous period price. The model's solution is characterized by the following equilibrium conditions:

$$\left(\frac{C_t}{E_t[C_{t+1}]}\right)^{-\sigma} = \beta * \frac{(1+i_t)}{E_t[1+\pi_{t+1}]} \text{ (a)}$$

$$N_t^{\eta} = C_t^{-\sigma} * \frac{w_t}{\psi} \text{ (b)}$$

$$m_t^{-1} = \frac{1}{\theta} * C_t^{-\sigma} * \frac{i_t}{1+i_t} \text{ (c)}$$

$$(1+\pi_t)^{1-\varepsilon} = (1-\phi)(1+\pi_t^*)^{1-\varepsilon} + \phi \text{ (d)}$$

$$\gamma_t = (1-\phi)\left[\frac{(1-\pi_t)}{(1-\pi_t^*)}\right]^{\varepsilon} + \phi(1-\pi_t)^{\varepsilon}\gamma_{t-1} \text{ (e)}$$

$$v_t = C_t^{-\sigma}\mu_t Y_t + \beta\phi E_t[(1+\pi_{t+1})^{\varepsilon} v_{t+1}] \text{ (f)}$$

$$q_t = C_t^{-\sigma} Y_t + \beta\phi E_t[(1+\pi_{t+1})^{\varepsilon-1} q_{t+1}] \text{ (g)}$$

$$(1+\pi_t^*) = \frac{\varepsilon}{\varepsilon-1} * (1+\pi_t) * \frac{v_t}{q_t} \text{ (h)}$$

$$w_t = \mu_t A_t \text{ (i)}$$

$$C_t = Y_t \text{ (j)}$$

$$Y_t = \frac{A_t N_t}{\gamma_t} \text{ (k)}$$

$$\ln(A_t) = \rho_a \ln(A_{t-1}) + a_1 \varepsilon_{a,t} \text{ (l)}$$

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\varphi_\pi(\pi_t - \pi) + (1-\rho_i)\varphi_y\left(\frac{y_t - y_{t-1}}{y_t}\right) + a_2\varepsilon_{i,t} \text{ (m)}$$

To analyze the model's theoretical responses a starting steady state point must be found. The classical choice is the non-stochastic steady state. Non-stochastic steady state is characterized by the following equations:

$$A = 1\,.$$

$$(1+i) = \frac{1}{\beta}(1+\pi).$$

$$(1+\pi^*) = \left[\frac{(1+\pi)^{1-\varepsilon} - \phi}{1-\phi}\right]^{\frac{1}{1-\varepsilon}}.$$

$$\gamma = \frac{\varepsilon-1}{\varepsilon}\left(\frac{1-\pi}{1-\pi^*}\right)^{\varepsilon}\frac{1}{1-\phi(1-\pi)^{\varepsilon}}\ .$$

$$v = \frac{C^{-\sigma}\mu Y}{1-\phi\beta(1+\pi)^{\varepsilon}},$$

$$q = \frac{C^{-\sigma}Y}{1-\phi\beta(1+\pi)^{\varepsilon-1}}.$$

$$\frac{v}{q} = \mu\frac{1-\phi\beta(1+\pi)^{\varepsilon-1}}{1-\phi\beta(1+\pi)^{\varepsilon}}.$$

$$\frac{v}{q} = \frac{1+\pi^*}{1+\pi} * \frac{\varepsilon-1}{\varepsilon}\ .$$

$$\mu = \frac{1+\pi^*}{1+\pi} * \frac{\varepsilon-1}{\varepsilon} * \frac{1-\phi\beta(1+\pi)^{\varepsilon}}{1-\phi\beta(1+\pi)^{\varepsilon-1})}.$$

$$w = \mu.$$

$$C = Y.$$

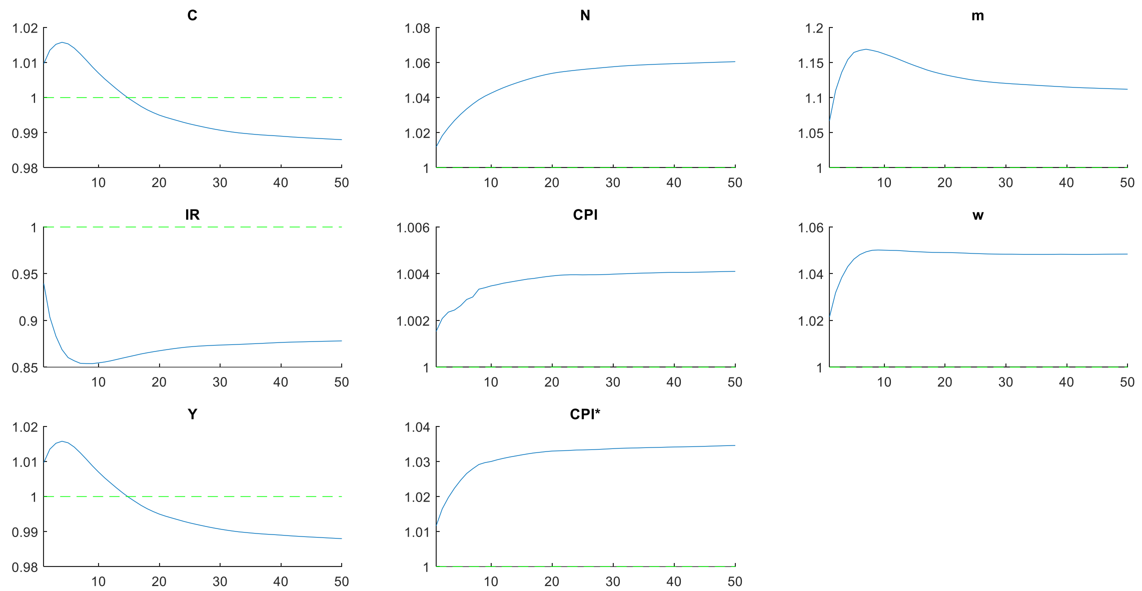
$$Y = \frac{N}{\gamma}.$$

$$N = \left(\frac{1}{\psi}\gamma^{\sigma}\mu\right)^{\frac{1}{\eta+\sigma}}.$$

$$m = \theta Y^{\sigma}\frac{1+i}{i}.$$

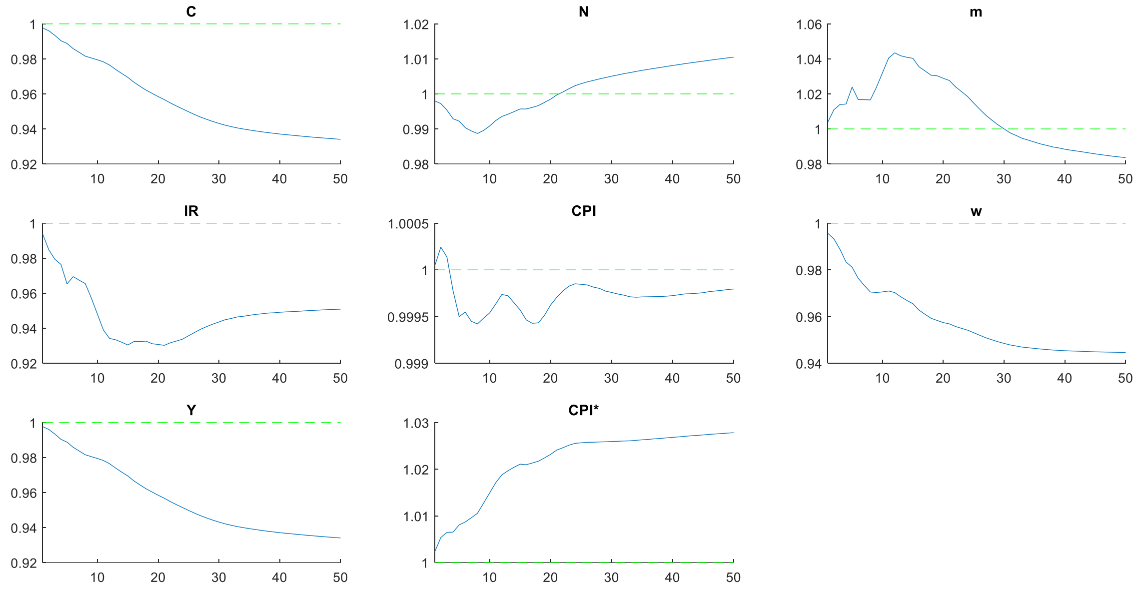
Starting from non-stochastic steady state it is possible to simulate model's impulse responses functions. Simulations have been performed with the software Dynare®. Performed simulations are 4. Two for first and second moment shocks hitting $\varepsilon_i$ and two for first and second moment shocks hitting $\varepsilon_a$. Results are reported in the following figures.

First moment shock on interest rate:



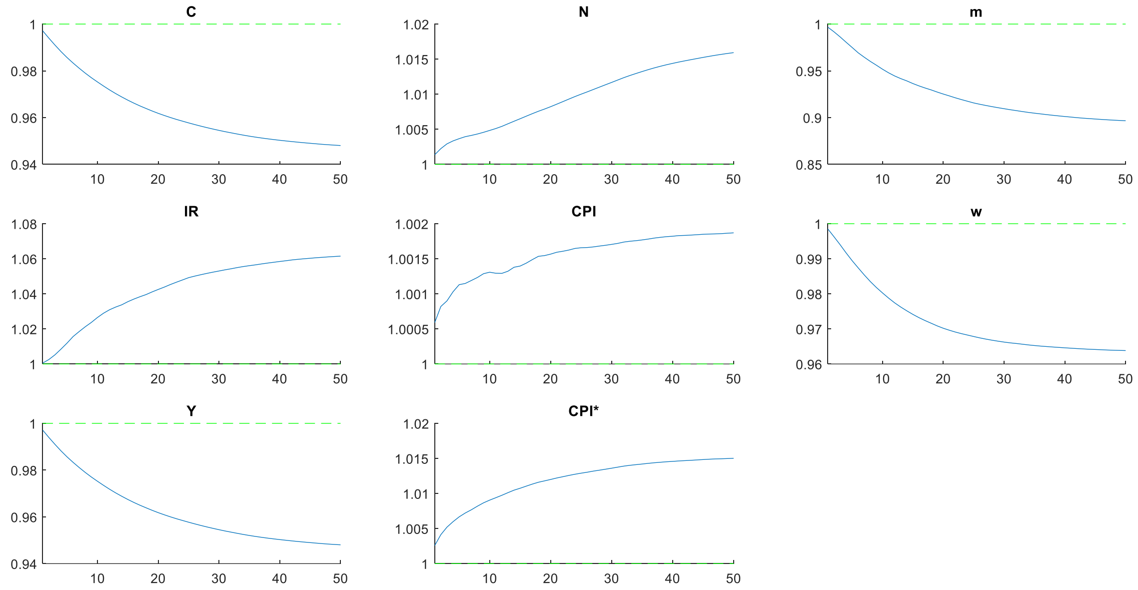

Expect for CPI, the empirical findings are in line with the theoretical forecasts.

Second moment shock on interest rate



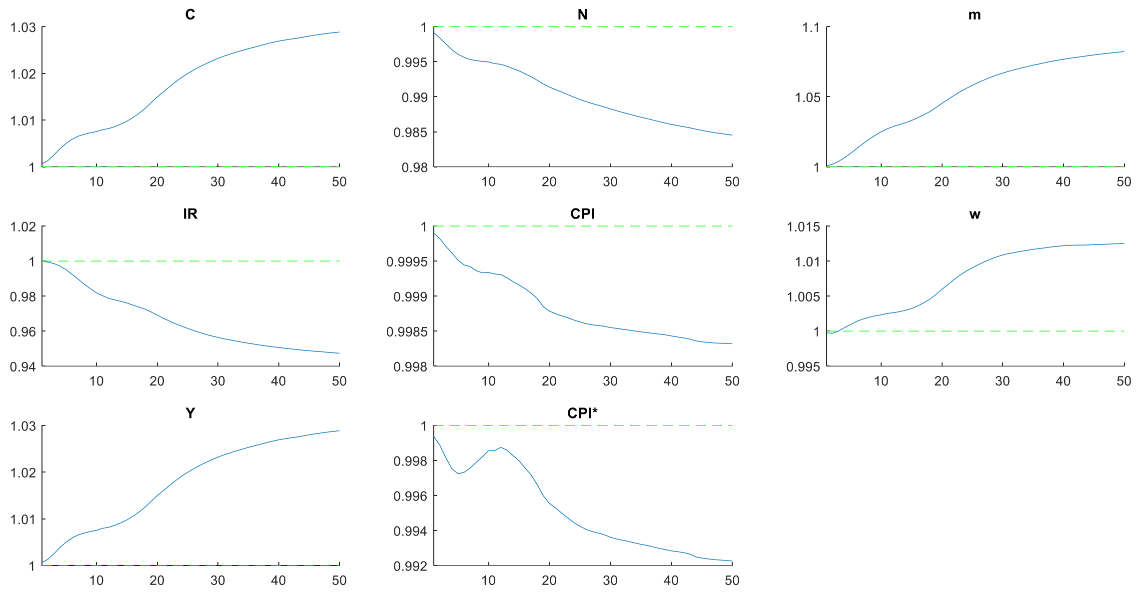

Model's forecasts are in line with empirical evidences. In the second moment setup short term performance improves, while long term slightly diverges. Effects on aggregate CPI are negligible.

First moment shock on productivity:



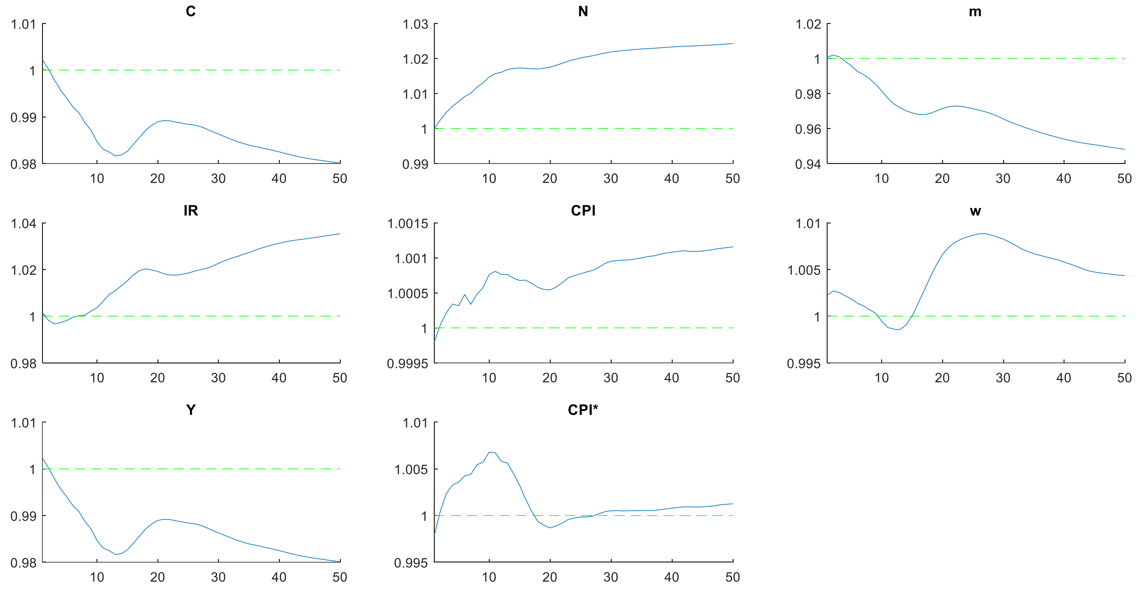

Results are not completely in line with empirical findings. GDP decreases, CPI slightly increase but interest rate follows a symmetrical path.

Second moment shock on interest rate




Second moment shock has positive effects on productivity. To compare results with empirical findings it is necessary a negative economic shock. It can be simulated forcing a negative path for the productivity factor.

''Forced'' second moment shock on interest rate




Results are similar to the first moment case. GDP and CPI dynamics are forecasted by the model, while it fails in forecasting interest rate level after the shock.

After the comparison, it is possible to highlight the major evidences of this analysis.

The financial market variables suggest that uncertainty shock causes even structural effects on the economy. Spread's response indicates that investors require higher premium to hold long term bond. Higher interest rates for long term government bonds are a symptom of increased riskiness, caused by the increasing possibility of public default.

Another interesting effect appears on real interest rate. Since short term interest rate falls and inflation increases, real interest rate has a strong decrease. Additionally, the nominal rate is currently at the zero bound, hence the shock may cause real interest rate to be negative. Negative real interest rate discourages investments.

GDP results are in line with the main findings in Bloom (2009) and in Basu, Bundick (2017). However, in Bloom[63] and in Basu, Bundick. The main difference with their findings is the negative growth's persistency, since in both papers the responses remain negative for several periods[64], while in the estimated model the response is negligible after 6 periods. Findings on interest rate are coherent with the evidences from Bloom, especially the short run response. Results on inflation are different from Bloom findings. In Bloom, inflation initially decreases, then recovers, while, in the model, the shock increases CPI in the short period, the it stagnates around the short term level in the long period. Basu and Bundick do not report empirical results on inflation and interest rate.

The relationship with the policy risk literature is not univocal. Considering the results by Fernandez-Villaverde et alt., their empirical findings differ partly. They forecast a short term GDP's decrease followed by an overshoot in the long run, while the empirical evidence on Italy suggests a permanent decrease. The IR dynamic is similar, but their level converges to the starting level in the long run. CPI differs because reacts negatively to the policy risk shock. Their results differ because they estimate a VAR model with additional variables, such as investment and consumption, and because their dataset starts in 1970.

In their analysis, Anzuini, Rossi and Tommasini. construct a fiscal policy uncertainty indicator and estimate the impulse response functions to a shock on that index. They find similar dynamic for the GDP but different for investment and inflation. Inflation first reacts negatively and then converges to a higher level. Instead, their interest rate impulse response function is increasing at decreasing rate. Even in this case the differences probably come from the dataset selection. Their dataset spans between 1981 and 2014, so it comprehends the transition period from high inflation[65] to the 2% level and misses the current period characterized by low GDP growth and by the Quantitative easing.

The comparison suggests the theoretical model fails to fully replicate the economic performances of the analyzed period, characterized by unconventional monetary policy and slow recover.

In conclusion, it is possible to state that uncertainty shocks have deleterious effects on the Italian economy. The GDP reacts particularly negative. There exist several interpretations to explain these effects. One of the main ideas is that rising uncertainty causes contraction in financial activity, in particular in the credit market. If borrowing conditions worsen, the economic activity wanes and GDP contracts. But this is only one aspect. For example, the analysis above suggests that the increasing spread plays an important role during the downturn. Spread has an indented increase during a crisis. The agents, or part of them, may become doubtful about future stability of the system and demand higher returns to finance public expenditure. This spread effect is particularly important in Italy. Public spending policy has been focal in the Italian system, but, when cost of financing increases, the budget constraint becomes tighten. Assuming that government's budget policy is believed to be stabilising, the uncertainty shock increases the cost of finance and decreases the stabilising role of the government[66]. This may cause another uncertainty shock and the cycle repeats. Moreover, the recent spread's movement suggest that the level changes are highly influenced by the government's spending intention[67]. This create a major friction between the government, that attempt to stimulate the economic system

[63] The analysis in bloom is based on monthly data.
[64] In Bloom the GDP keeps decreasing over time, while in Basu and Bundick the change is negligible after 12 periods.
[65] Their sample begin with 20% inflation level that keep decreasing for several periods until reaching the 2% target in 1996.
[66] Press usually refers to the spread as the differential in secondary market interest rate. This differential does not affect directly the titles because the interest regime is predetermined at issuance and does not vary according to the spread. However, the spread influences new issuance because the new bonds' prices must be marketable.
[67] In the last months the spread has struggled when the government tried to plan expansive policies and strongly soften when the fear of such policies vanished. Some press explain these movement: https://www.reuters.com/article/us-eurozone-bonds/italian-bonds-suffer-worst-day-in-more-than-25-years-idUSKCN1IU16G; https://www.reuters.com/article/eurozone-bonds/update-4-italian-german-bond-yield-spread-reaches-widest-since-2013-idUSL8N1VL235; https://www.ilsole24ore.com/art/conti-pubblici-vale-20-miliardi-l-eredita-lasciata-tria-gualtieri-ACrDRHi?fromSearch.

with expansive policies, and the agents, that are not willing to finance these policies. The uncertainty's rise depresses GDP and increase financing cost, stoking the spread effect.

Another result that the V.AR. analysis suggests is the interest rate level fall under rising uncertainty. As already pointed out, this mechanics has been important during the crises. The extraordinary expansive monetary policy adopted by the E.C.B. has limited the growth of the spread and has increased financial market capitalization. It has partially worked against the credit crunch. The V.AR. captures these policy movements, but the long run responses suggests that the main effect is to stabilize the system, not to reduce the uncertainty level or enhance the recover. Thus, these types of measures are not sufficient to reduce the level of uncertainty. Moreover, the E.C.B. cannot keep decreasing rates and, eventually, will have to stop this expansive policy.

The possibility that a new shock hits the economy must be feared, because the previous crises' effects have not completely vanished yet. The policy maker should not just pay attention to stabilizing the system, but also in mitigating the persistency of the uncertainty shocks and in enhancing the absorption ability. The monetary policy responses may stabilize the economy, but it does not appear to be effective against uncertainty.