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# Monetary policy, Credit and Economic growth - a comparison between Japan, UK, US and Euro Area

André Filipe Dias dos Reis

*Master* in Economics

Supervisor:
PhD, Sofia Vale, Assistant Professor,
ISCTE-IUL, Economics department

October, 2020

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BUSINESS SCHOOL

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# Resumo

Esta dissertação pretende estudar todas a possíveis relações entre a política monetária, o crédito e o crescimento económico no Japão, no Reino Unido, nos Estados Unidos da América, entre 1995T1 e 2019T2, e na Zona Euro, entre 1999T1 e 2019T2. Para isso foi estimado um modelo VAR para cada país que inclui três variáveis: a Taxa Sombra de Curto Prazo, o crédito concedido ao setor privado não-financeiro e o Produto Interno Bruto. Os resultados mostram que os efeitos de alterações na política monetária no crédito e no PIB não estão de acordo com a teoria económica, dadas as reações positivas destas variáveis após um aperto na política monetária. Para além disso, analisando e comparando as respostas da política monetária a choques no crédito e no PIB, conclui-se que o rácio crédito-PIB e a inflação parecem ser fatores importantes para explicar as diferenças nas respostas. Finalmente, no Reino Unido, nos Estados Unidos e na Zona Euro existe uma relação bidirecional positiva entre PIB e crédito – um choque no crédito estimula o PIB e o crédito cresce quando a economia está em expansão. Enquanto no Japão apenas existe uma resposta positiva do crédito aquando de um choque no PIB. O baixo peso do crédito nesta economia e o baixo volume de crédito parecem explicar a reação negativa do PIB a um choque no crédito.



*Códigos JEL:* C32; E51; E52

*Palavras-chave:* modelo VAR; Crédito; Política monetária; Efeitos das políticas

# Abstract

This dissertation pretends to study the relationship between monetary policy, credit and economic growth in Japan, the United Kingdom, the United States, between 1995Q1 and 2019Q2, and the Euro Area, between 1999Q1 and 2019Q2. For that it was estimated a VAR model for each country including three variables: the Short-run Shadow Rate, the credit to the private non-financial sector and the Gross Domestic Product. The results show that the effects of monetary policy changes on credit and on GDP are not in accordance with economic theory, given positive responses of these variables following a monetary policy tightening. Moreover, analyzing and comparing monetary policy responses to credit and GDP shocks, it is possible to conclude that credit-to-GDP ratio and inflation seem to be important factors to explain the differences found in the responses. Finally, in the UK, the US and the Euro Area there is a bidirectional positive relation between credit and GDP – a credit shock stimulates GDP and credit increases when the economy expands. However, Japan just presents a positive reaction of credit after a GDP shock. The low credit weight in this economy and the low credit volume seem to explain the negative GDP reaction to a credit shock.

*JEL Codes:* C32; E51; E52

*Keywords:* VAR model; Credit; Monetary policy; Policy effects

# Index

CHAPTER 1

# Introduction

Monetary policy is mostly determined by Central Banks which are, on their turn, responsible for the maintenance of price stability and the stability of the financial system.

Besides being a monetary policy transmission mechanism (Bernanke and Gertler (1995), it is widely known that credit is a very important engine in modern economies – e.g. from housing credit to credit that allows a firm to make an investment. Also, credit may have an inflationary impact in the economy, which would imply with Central Banks' main objectives (Saiki and Frost, 2014).

Given this, in this study it is inspected the relationship between monetary policy, credit and economic growth in the four most important Central Banks' areas under their regulation – Japan, United Kingdom, United States and Euro Area.

Economic theory assume that with an interest rate reduction – a monetary policy easing – the economy expands. However, the literature that investigated this claim, e.g. Lee and Werner (2018), found a positive relation and that the interest rates are Granger-caused by the GDP, which contradict the theoretical assumption.

Regarding the relation between monetary policy and credit, Bernanke and Gertler (1995) and Berkelmans (2005) present theoretical reasoning for a negative correlation between these variables. There is also some empirical studies, e.g., Aiyar et al (2016), Bowman et al (2015), Giannone et al (2012) and Kuttner (2018), that focus on this relation and found results consistent with the theory, i.e., a monetary policy easing leads to an increase in credit supply or a monetary policy tightening lowers credit.

These articles do not analyze the other way of these relations, i.e., how monetary policy reacts to changes in credit and in the economic growth. Also, the authors treat only a period of conventional monetary policy, in which they use interest rates, or they only deal with a period where the Zero Lower Bound is binding. There are few authors and studies (e.g. Wu and Xia (2016) and Damjanovic and Masten (2016)) that use a monetary policy representative variable that allows to look at both periods.

This study will analyze all possible relations between the monetary policy, the total credit to the private non-financial sector and the GDP, in Japan, the UK, the US and the Euro Area. The time period of analysis starts in the first quarter of 1995 for Japan, the UK and the US, in the first quarter of 1999 for the Euro Area and ends in the second quarter of 2019 for all countries. It is used as a monetary policy representative an estimated variable that overcomes the ZLB problem – the Short-run Shadow Rate. A VAR model including the three variables will be estimated for each country.

This dissertation contributes to the literature in three ways. First, it contributes to the scarce literature that uses the Short-run Shadow Rate as a monetary policy representative, overcoming the ZLB problem. Secondly, it contributes to the empirical analysis of the relation between monetary policy, economic growth and credit. Lastly, it also allows for the comparison of these variables responses between Japan, the UK, the US and the Euro Area – the countries with the four most important Central Banks.

Briefly, these are the main obtained results: (i) the effects of monetary policy changes in economic growth and in credit are not in accordance with the theory since it was found that credit and GDP rose following a policy tightening; (ii) the ratio of total credit to the private non-financial sector to the GDP and the inflation seem to be important factors to explain the countries' differences in the monetary policy reaction to credit and GDP positive shocks; (iii) the relation between GDP and credit in the UK, the US and the Euro Area is in accordance with the theoretical positive correlation between these variables. In the Japan case, the credit-to-GDP ratio and the credit volume seem to explain the obtained result – credit does not stimulate economic growth but a GDP expansion makes credit to increase.

In Section 2, it is done a review on the literature that delves into the relations between monetary policy and credit and between monetary policy and economic growth. In section 2 it is also presented a way to overcome the problem that the ZLB period raises to the study of the monetary policy stance. Section 3 shows the adopted methodology for the development of this study. In Section 4 there is the application of what was previously announced. In Section 5, it is done a comparison of the results of the outputs analysis between the countries under study. Section 6 concludes.

CHAPTER 2

# Literature Review

In the end of the 1960s, Milton Friedman presented a conflicting theory with the, at that time, dominant Keynesian paradigm. Monetarist economists advocated that public spending and investment would not have effects on the economic activity. Instead, monetary policy – changes in the stock of money – would have a strong influence in the output level, in the short run, despite causing inflation. Besides this, Friedman stood up for the existence of a monetary authority – central banks – independent from political powers that supervises credit and money stock in order to control inflation.

Traditionally, Central Banks have at their disposal two main policy instruments which are mutually exclusive: interest rates and money stock (Poole, 1970). Before the 1980s, monetary policy changes were implemented suddenly (as a surprise element so that agents could not anticipate them) and they were not committed to any specific rule. Instead it was believed that that policy should be conducted with discretion. Also, there was a permanent trade-off between inflation and unemployment, which is represented by the Phillips curve and means that a necessary reduction of inflation would cost employment and output. After the oil shocks in the 1970s and the stagflation phenomenon, Central Banks became committed to certain defined targets for inflation to prevent the output and employment loss (or most of it) during a disinflation process. From the 80s of the last century until now, interest rates are considered the main monetary policy tool. The most successful interest rate rule adopted by Central Banks as a guidance for desirable policy was presented by John Taylor in 1993. The Taylor rule defines interest rate as a feedback result to changes in the actual inflation rate, the inflation target and in the output gap and desired output gap.

Most economic thought streams argue that lowering interest rates boosts economic growth. Following this claim, Lee and Werner (2018), tested and analyzed the relation between interest rates (short- and long-term) and economic growth (GDP growth) using data covering approximately 50 years until 2008 for the United States, the United Kingdom, Japan and Germany. They concluded that there was a positive relation between output growth and both interest rates. Lee and Werner (2018) have also found that these interest rates were Granger-caused by GDP. These findings clearly contradict what is advocated by the economic schools and may indicate that interest rate targeting may not have the theorized effects.

A known pass-through channel of monetary policy to the economic environment is the credit channel. One of the most noteworthy and cited studies on the credit channel was written by Bernanke and Gertler (1995). In this article, these authors clarify how monetary policy influences the economy. Bernanke and Gertler argue that the effects of monetary policy on interest rates are amplified by changes in the “external finance premium” – which is the difference between raising funds externally and generate them internally. Interest rates and the “external finance premium” tend to move in the same direction.

Bernanke and Gertler (1995) present two possible channels for the monetary policy to influence the “external finance premium”. First, the balance sheet channel predicts that a borrower’s stronger financial position should reduce its “external finance premium”. Second, the bank lending channel says that monetary policy may affect commercial banks’ credit supply. If bank credit supply decreases, the “external finance premium” may rise and real activity could fall. According to the authors, the latter is a more controversial channel.

According to Berkelmans (2005), there is a bidirectional relation between credit and output. On the one hand, the spending backed by conceded credit will allow output to grow. While on the other hand, “strong output growth can stimulate the demand for credit to finance further expenditure” (Berkelmans, 2005: 4). In this article, Berkelmans minds the relation between credit and monetary policy. The latter may respond to credit growth since it could trigger an inflationary hike and, consequently, a central bank response. However, this relation is mainly viewed through the credit channel: “monetary policy changes cause financial institutions to alter the volume of loans that they issue” (Berkelmans, 2005: 4). For Australia, Berkelmans (2005) concludes that a positive shock in the interest rate leads the credit level to fall in the short-term.

Jiménez et al (2012) study how Spanish monetary and economic conditions affect the supply of loans in this country. They found that an increase in interest rate made loan supply to decrease and, also, that higher GDP growth leads to higher levels of loan supply. Jimenez et al (2012) also test the bank balance sheet channel. They found that banks with weaker financial position are more affected by increases in interest rates and lower GDP growth, i.e., these banks reduce loan supply more than other banks with stronger financial positions.

In the 1980s, a real estate bubble popped in Japan and during the decade after, deflationary pressures emerged. To deal with these issues, the Bank of Japan (BoJ) reduced interest rates in order to stimulate the economy.

Despite the interest rates were reduced and reached their zero-lower bound, the economy did not responded as intended by the Japanese central bank. Therefore, on March 2001, the

Bank of Japan (BoJ) announced “New Procedures for Money Market Operations and Monetary Easing” (Wieland, 2009: 3). It informed that the policy rate would stay close to zero for an extended period (forward guidance) and that it would purchase government securities held by banks hoping to lead up the prices of assets and, therefore, erasing the deflationary pressures (Joyce et al, 2012). The first round of Quantitative Easing – QE1 – ended in 2005.

Japan was the first country to adopt Quantitative Easing (QE) – the most highlighted unconventional monetary policy tool – in order to push the economy up from a depression.

In his 2011 speech, John C. Williams (president of the Federal Reserve Bank of San Francisco), pointed that forward policy guidance and large-scale asset purchases are the two most used and most relevant tools. Large-scale asset purchases implied changing the composition and/or expanding the size of Central Banks’ balance sheet (Smaghi, 2009).

Dell’Ariccia et al. (2018) provide conceptual definitions on each of the unconventional monetary policy tools – forward guidance, large-scale asset purchases and negative interest rates. Forward guidance consists in informing market participants on policymakers’ intentions regarding the future path of the policy rate. The large-scale asset purchases imply the Central Banks to buy long-term government bonds and, afterwards, to increase the reserve accounts held by commercial banks at the CB as a counterpart, in this case the Central Banks buy these bonds from commercial banks and not from any other economic agents. Negative interest rates was implemented, for example, by the ECB and the Bank of Japan, and instead of paying, the Central Bank charges “interest rates on the reserves that commercial banks hold at the Central Bank”, inducing them to reduce excess reserves and channeling those to lending and/or other investments.

When Japan was still stabilizing, the 2008 financial crisis hit and, so, the BoJ introduced forward guidance announcements and launched a small-size asset purchase program (compared to the program that would be implemented later) in October 2010. After the election of Shinzo Abe as Prime Minister, the Bank of Japan announced expansions of quantitative and qualitative easing programs two times: in April 2013 (QQE1) and October 2014 (QQE2) and, also, adopted an explicit inflation target. This period became known as the “Abenomics” period. In January 2016, the Bank of Japan started charging negative interest rates on commercial banks reserves deposited at the central bank (Dell’Ariccia et al, 2018; Matousek et al, 2019).

Bowman et al. (2015) point out a positive but weak response from GDP to Quantitative Easing. They also suggest that the QE policy adopted by the BoJ helped to increase the credit flow. However, the authors found that this credit boost only had a small overall size and, even before Japan exited QE1 – when "bank health and confidence in the banking system had been restored" – this relation had already disappeared.

Dell'Ariccia et al. (2018) highlight that the studies analyzed by these authors found a positive, but not very significant, effect of both QQE1 and QQE2 on GDP and on inflation.

Matousek et al. (2019) used a panel VAR model to find if there is an active bank lending channel in Japan, which included the following variables: GDP, inflation, a volatility index and central bank's current account balance growth. They found the existence of a lagged significant positive correlation between the Japanese QE and its GDP and, also, between QE and inflation.

The Fed, European Central Bank and the Bank of England followed the steps of the Bank of Japan, although with differences among them (Joyce et al, 2012).

After the announcement and first expansion of QE in the UK, US and Euro Area, it was feared that it could cause an inflationary hike. However, according to Bukowski and Gowers (2018) it seems to be replicating Japan's path, having a reduced consequence on consumer price inflation.

The Bank of England bought UK government bonds from non-bank private sector, with the intention to "affect the yields of the assets issued to finance the lending of companies and households" (Joyce et al, 2012).

Following Dell'Ariccia et al. (2018), the first phase of unconventional monetary policy implemented by the Bank of England started in 2009. After the financial crisis hit the UK economy, the Bank of England decided to reduce interest rates to values slightly above zero. Despite this, the Bank of England feared that the inflation target would not be fulfilled. Then, the first round of quantitative easing (QE1) was launched. The threat caused by the Euro Area sovereign debt crisis, led the Bank of England to announce QE2 in October 2011 and the QE3 in July 2012. The second phase consisted in forward guidance announcements in August 2013 and February 2014. Given the belief that interest rates could increase, in 2013, the Bank of England informed that policy rates would not rise nor would the stock of assets purchased be reduced. In 2014, announced that policy rates are expected to be kept low and could only be increased gradually. The third phase included a fourth round of large-scale asset purchases (QE4) in August 2016, after the "Brexit" voting.

Aiyar et al. (2016) find that a monetary policy tightening causes a reduction in bank lending supply. However, they point out that monetary policy "was not a very powerful tool for managing bank lending" in the analysis' time period – from 1998 until 2007 – in the United Kingdom.

Bukowski and Gowers (2018) developed a VAR model incorporating data on United Kingdom's GDP, GDP deflator, monetary aggregate M3, 3-months LIBOR and the currency rate of exchange GBP/USD, from 2007 until 2016. They found that the expansion of the monetary aggregate did not met the expected effects on GDP, but it explains a larger part of GDP growth than interest rates do. However, interest rates provided a stronger impulse to GDP than M3. Also, the authors identify the exchange rate as an important explanatory variable for UK's GDP growth, yet it was not possible to unveil its individual effects once that UK and US adopted QE at the same time.

Studies analyzed by Dell'Ariccia et al. (2018) allow these authors to conclude that QE had little effect on bank lending since "UK banks were poorly capitalized and trying to deleverage". QE had significant positive effects on GDP growth and inflation. On the other hand, the evidence of forward guidance announcements effects on the UK economy is very limited.

The Federal Reserve bought US government bonds, agency debt and mortgage-backed securities with the same purpose as the policies implemented by the Bank of England (Joyce et al, 2012).

Kuttner (2018) details the unconventional monetary policy operations implemented by the Fed. It all started in November 2008, after the crisis hatched. The Fed launched the first round of the large-scale asset purchases – QE1 – in which were bought agency debt and mortgage-backed securities. This first round was, then, expanded in March 2009. QE2 was implemented in November 2010 and it involved the purchase of longer-term government bonds. The third round of quantitative easing (QE3) started in September 2012 with the purchase of mortgage-backed securities and was expanded three months later in order to include government bonds. QE3 differs from QE1 and QE2 in following aspect: it did not had a defined ending date neither an expenditure limitation.

Joyce et al. (2012) and Kuttner (2018) mention a Maturity Extension Program, known as "Operation Twist". It was implemented in September 2011 and consisted in the purchase of longer-term treasury bonds (6-years to 30-years maturity) and the sale of shorter-term securities (1-year to 3-years maturity). This program did not changed the size of the Fed's balance sheet and it allowed to reduce longer-term interest rates and improve financial conditions.

Throughout these programs, the Federal Reserve also made forward guidance announcements. Starting in December 2008 with only qualitative information, as time advanced the Fed started to include quantitative guidance (Kuttner, 2018).

Wu and Xia (2016) found using shadow rate that the unconventional monetary policies adopted by the Federal Reserve helped reducing the unemployment and boosted real economic activity without increasing inflation – it has actually decreased.

The articles included in the analysis made by Kuttner (2018) conclude that the first and third round of large-scale asset purchases (QE1 and QE3) had the most significant (positive) effects on bank lending.

Other articles analyzed by Kuttner (2018), find that the multiple rounds of quantitative easing implemented by the Fed helped to sustain GDP fall and, further in time, to increase it.

On its turn, European Central Bank implemented repo operations – provided loans in exchange for bank loans and non-government bonds as collateral – to tackle the crisis and the imbalances created by the "flight-to-safety" event within the Euro Area (Joyce et al, 2012).

According to Dell'Ariccia et al. (2018), ECB's unconventional monetary policy can be divided in three periods: the first, between September 2008 and the end of 2009, to deal with the financial crisis; the second, from the beginning of 2010 until the last months of 2012, to deal with the sovereign debt crisis; and the third, which started in 2013.

The first round of unconventional monetary policy was implemented to compensate the fall in interbank market activity. Therefore, ECB increased its intermediation role and eased the access for banks to refinancing operations.

In the second phase, the ECB launched the Security Markets Program, where it bought government debt from Greece, Ireland and Portugal. Later during this phase, the ECB also announced the purchase of bonds issued by the governments of Italy and Spain. Despite ECB's efforts some of these countries requested bailouts, their borrowing spreads kept increasing and Euro Area's real GDP kept decreasing. Therefore, ECB's president at that time, Mario Draghi, stated that "the ECB is ready to do whatever it takes to preserve the euro" and the ECB announced the Outright Monetary Transactions program – implied the purchase of "government bonds in secondary markets for member countries that requested its activation and accepted monitoring" (Dell'Ariccia et al, 2018).

During the third phase, the ECB adopted forward guidance and announced a negative rate for the deposit facility and new credit easing measures. However, the highlight of this phase is the creation of the large-scale asset purchase program on September 4, 2014: European Central Bank purchased asset-backed securities, covered bonds, corporate sector bonds and government bonds.

Giannone et al. (2012) argued that the increase of Central Bank intermediation created an incentive for and, in fact, increased interbank lending. Furthermore, it also led up bank loans to non-bank agents to rise over time. Besides this, ECB's larger intermediary role sustained short and long-term loans to the domestic private sector.

Darracq-Paries and De Santis (2015) investigated the effects caused by the 3-year Long-Term Refinancing Operations implemented by the European Central Bank. The authors found that this unconventional monetary policy program had positive effects on the Euro Area macroeconomic scenario – increases in GDP, prices, loan volume and a reduction of lending spreads.

Damjanovic and Masten (2016) show that the responses from the Euro Area's GDP and price index to a shock in monetary policy are in accordance to the economic theory: a positive shock in the monetary policy instrument (shadow short rate) leads the output and the price level to fall.

Dell'Ariccia et al. (2018) summarize the effects found by the existent literature from the unconventional monetary policy actions. In general, it is found significant effects from these actions implemented by the ECB: it allowed the peripheral countries – and most affected by the sovereign debt crisis – to increase their government bond yields, reduce the investment risk and increase GDP and the price level. Countries from central Europe (e.g. France and Germany), also benefited from peripheral countries growth through trade.

Dell'Ariccia et al. (2018), citing Altavilla, Giannone and Lenz (2014), point out that the Outright Monetary Transactions program helped the peripheral countries to increase the level of credit (the case of Spain and Italy).

A problem for researchers emerged once the short rates got stuck near zero (Damjanovic and Masten, 2016) and change it to affect the economy is not possible anymore. This structural break in the overnight rates does not allow researchers to study the monetary policy stance adopted by central banks around the world during the ZLB period (Wu and Xia, 2016).

To go around this problem, Damjanovic and Masten (2016) present three possible alternative measures: long-maturities interest rates, the quantity of money and the shadow short rate (SSR).

The first two approaches carry some issues. Rates of longer-maturities may lead to erroneous interpretations, since it may include information other than related to monetary policy, like credit and liquidity risk. The quantity of money may register an ambiguous relation to other macroeconomic variables.

Shadow short rates, on its turn, are "obtained by modelling the term structure of the yield curve" (Damjanovic and Masten, 2016) and sum up markets perception and expectations on the monetary policy, inflation and economic activity. SSR do not comply with the ZLB constraint and allows to study the different stances of monetary policy adopted by central banks. The previously cited authors emphasize that, since the shadow short rates are built upon data from financial markets, these rates are not directly controlled by the central bank.

Claus et al. (2014), cited by Damjanovic and Masten (2016), found that the shadow short rate play a good role at representing the instrument of monetary policy.

The most remarkable studies on the ZLB yield curve term structure modelling were made by Krippner and Wu and Xia (2016).

Francis et al. (2014) found that a VAR model that uses Wu and Xia's SSR show a "structural break and parameter instability at the onset of the crisis" (Damjanovic and Masten, 2016). These authors also found that the estimations made by Krippner are a better proxy for the policy instrument when compared to Wu and Xia (2013) and a model using US overnight interest rate (Fed funds rate).

CHAPTER 3

# Methodology

Following the critique made by Sims (1980), many empirical studies are based on VAR processes (Brüggemann and Lütkepohl, 2001). VAR models often succeed in capturing the "dynamic relationships among variables, since they can be used to simulate the response over time of any variable in the set to either an 'own' disturbance or a disturbance to any other variable in the system" (Bernanke and Gertler, 1995: 4). The coefficients of a VAR model are estimated by OLS and the regressors are the lagged values of all the variables included in the system. Generally, a VAR model of order $p$ has the following form:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \varepsilon_t \qquad (1)$$

where $y_t$ is a vector of dimension $k$ that includes the stationary variables, $x_t$ is a vector of dimension $d$ that includes the exogenous variables, $A_1, \ldots, A_p$ and $B$ are the coefficients matrices to be estimated and $\varepsilon_t$ is a vector of error terms that may be contemporaneously correlated but are uncorrelated with their own lagged variables and uncorrelated with the exogenous variables and the lagged stationary variables.

In this study it will be included three variables: a variable to represent the monetary policy stance, an output measure and a credit variable. To capture the impact of the monetary policy, the data has a quarterly frequency and refers to the Euro Area, to the United Kingdom, to the United States and to Japan. Euro Area data covers the period from the first quarter of 1999 until the second quarter of 2019. While the data related to the UK, the US and Japan covers from the first quarter of 1995 until the second quarter of 2019.

The monetary policy stance will be represented by the shadow short rate (SSR), made available by Leo Krippner at the Reserve Bank of New Zealand website. The nominal estimations of the shadow rate are obtained from yield curve data with maturities from 0.25 to 30 years and can evolve into negative values during periods where a lower-bound (assumed to be 12.5 basis points) is binding. During non-binding lower-bound periods or in conventional monetary policy environments, it is defined as being equal to the policy interest rate (Krippner, 2016). Since it is obtained from financial data, the SSR is not directly controlled by monetary policy authorities. Also, it is not a rate at which economic agents can trade or invest (Krippner, 2016). The SSR was downloaded from the Reserve Bank of New Zealand website with a monthly frequency. Some authors (e.g. Lee and Werner, 2018) compute quarterly frequency rates based on monthly observations using the geometric average. However, given that the SSR registers values below zero, it is not possible to compute the geometric average. Therefore, the SSR was converted into quarterly frequency using its arithmetic average.

Total output is captured by the Gross Domestic Product (GDP) measured by the expenditure approach. The data was obtained at OECD Statistics and is published quarterly at the OECD's Quarterly National Accounts. According to the OECD, the GDP is the "measure of the value added created through the production of goods and services in a country during a certain period". This indicator is measured in US dollars (fixed PPPs), is seasonally adjusted and the reference year is 2015, as it is assumed by OECD.

The last variable is the total credit to the private non-financial sector. The data is obtained from the Bank for International Settlements (BIS) credit statistics database. Total credit to the private non-financial sector comprises, according to the BIS, conceded financing – currency and deposits, loans and debt securities – by domestic financial corporations (banks and others), non-financial corporations and non-residents to domestic non-financial corporations and households. These credit instruments are valued at market prices and measured in US dollars.

In order to use VAR models, the theory suggests that we must ensure that the time series variables are stationary, although there is some literature (e.g. Berkelmans (2005)) which estimate VARs in levels despite the non-stationarity of the variables. There are informal and formal methods in econometrics to find if the model variables are stationarity. Informal methods consist in plotting the time series and its autocorrelation function. On its turn, formal methods include unit root tests, e.g. the Augmented Dickey-Fuller (ADF) test and the KPSS test.

According to Ozcicek and Douglas McMillin (1999) a VAR model crucial feature is the specification of the lag length. Ivanov and Kilian (2005) argue that the chosen lag-order determines the outputs obtained from a VAR model and, therefore, the interpretation of the obtained impulse response functions. The lag-order is usually chosen based on a criterion. In this article, these authors compare the six most used criteria: SIC (Schwarz Information Criterion), HQC (Hannan-Quinn Criterion), AIC (Akaike Information Criterion), LR (Likelihood Ratio test), SLR (Small-sample Likelihood Ratio test) and LM (Lagrange Multiplier test). Ivanov and Kilian (2005) analyze several quarterly and monthly VAR models and some quarterly VEC (Vector Error Correction) models. The authors conclude that for VAR models with monthly data, the AIC is the best criterion. While for quarterly data, SIC is the best criterion for samples up to 120 quarters and HQC for larger samples. Finally, for VEC processes, the SIC is the best criterion. Given the quarterly frequency and the data's temporal dimension, the Schwarz Information Criterion seems to be the most proper criterion to take into account for the selection of the optimal lag-order of each country's VAR model in the present estimations.

Since the Cholesky decomposition of the variance-covariance matrix of residuals will be used, in order to identify monetary policy shocks, the variables are ordered based on an exogeneity criterion: starting with the most exogenous to the least exogenous. Given this, different order combinations will be tested, also, as a robustness test.

The procedure following the estimation of the model is to implement diagnostic tests. These tests allow to conclude on the model's stability, on the residuals variance and statistical distribution and if there is serial correlation between errors.

The stability of the model is indicated by the observation of characteristic polynomial's roots. If the modulus of these eigenvalues are less than one, therefore it is possible to conclude that the VAR system is stable.

Multivariate ARCH test indicates the behavior of residuals' variance. If the p-value of the test stands above the standard significance levels, the ARCH test null hypothesis of constant variance is not rejected, i.e., the residuals are homoscedastic. Otherwise, the null hypothesis is rejected and it is concluded that there is heteroscedasticity in the residuals.

Jarque-Bera, Skewness and Kurtosis tests compare the model's data distribution with the normal distribution. If it is the case of any of these three tests to have a higher p-value than the standard significance levels, the null hypothesis of that test of following the normal distribution is not rejected, i.e., the data distribution is similar to the normal distribution. If this is not the case, then the data distribution does not approach the normal distribution. According to Lütkepohl (2013), non-normality of data does not represent a problem to the validation of VAR models' statistical procedures. Given that the Jarque-Bera, skewness and kurtosis tests use the Choleski decomposed residuals, the Choleski variance-covariance matrix will also be presented.

The existence or not of serial correlation between errors is indicated by the asymptotic and adjusted Portmanteau tests and the Breusch-Godfrey LM test. Lütkepohl (2013) suggests that Portmanteau tests is more suitable to check for residual autocorrelation of high order, while the LM test proposed by Breusch and Godfrey fits better for low order autocorrelation The same rejection rule applies to these tests: if the p-value is higher than the standard significance levels, therefore the null hypothesis of no serial correlation between the errors is not rejected, i.e., the desirable condition of no serial correlation between errors is fulfilled. Otherwise, there is residual autocorrelation in the estimated VAR model.

If, according to the diagnostic tests, the model presents the desirable features, therefore "the VAR model represents the DGP [data generating process] of the variables" (Lütkepohl, 2013: 11). In order to better acknowledge the relations between the variables under study it is usually done a structural analysis. This analysis includes, namely, the study of impulse response functions and the study of the forecast error variance decomposition.

Impulse response functions show and allow to follow the evolution of a variable reaction/response to a shock/impulse in one or more variables included in the VAR model. This characteristic makes impulse response functions very helpful in the evaluation process of, in this case, monetary policies. The predetermined impulse, innovation or shock size to which the other variables react is equal to one standard-deviation of the variable that suffers the shock.

On its turn, the forecast error variance decomposition (FEVD) allows to find how much, shocks in a variable, contribute to the forecast uncertainty of each variable in the model.

CHAPTER 4

# Variables and Models

## 4.1. Japan’s Variables and Model

As it can be seen in figure 4.1, the Japanese short-run shadow rate exhibits a downward trend during the period of analysis. The trend is clearly more pronounced after the 2008 financial crisis, which reflects the forward guidance announcements, the asset purchase program and its later expansion. Regarding the Japanese GDP, plotted in figure 4.2, it is possible to see an overall increasing trend in the period under analysis. With few diversions from this tendency, the bigger highlight appears in the couple of years after the financial crisis. The last variable for Japan, the total credit to the private non-financial sector, plotted in figure 4.3 does not present a clear trend over the period of analysis. Summary statistics for these variables are presented in table 4.1.

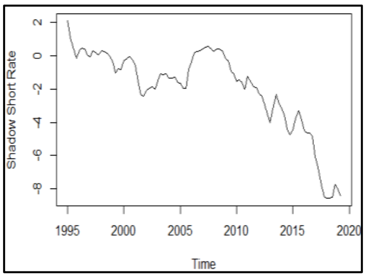


*Figure 4.1 – Short-run shadow rate for Japan (1995Q1 until 2019Q2)*

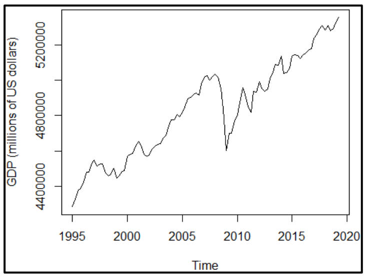


*Figure 4.2 – Japanese Gross Domestic Product (1995Q1 to 2019Q2)*

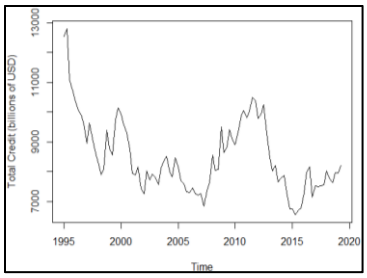


*Figure 4.3 – Total credit to the private non-financial sector in Japan (1995Q1 - 2019Q2)*

*Table 4.1 – Japanese variables summary statistics*

| | Minimum | First Quartile | Median | Mean | Third Quartile | Maximum | Standard Deviation |
|---|---|---|---|---|---|---|---|
| SSR | -8.56557 | -3.10524 | -1.1208 | -1.98171 | -0.04657 | 2.07816 | 2.516206 |
| GDP | 4,282,105 | 4,583,054 | 4,850,367 | 4,834,845 | 5,039,095 | 5,355,833 | 278,529.4 |
| Credit | 6,546 | 7,631 | 8,121 | 8,502 | 9,375 | 12,810 | 1,224.934 |

The existence of trends in the shadow rate and GDP may suggest that they are non-stationary. Plus, the slowly decaying autocorrelation functions of these variables, plotted in figures A1 and A2, present another sign of non-stationarity. Regarding total credit, the not so clear trend and the fact that the autocorrelation function, represented in figure A3, does not fall quickly may leave an unclear view if the variable is stationary or not.

Therefore an ADF test was applied to these variables to check if they are stationary or non-stationary. Table 4.2 displays the ADF's Tau3 and Phi3 test statistics and their critical values for standard significance values. The Tau3 statistic allows to conclude if a variable is stationary or non-stationary, while the Phi3 detects if the variable presents a stochastic trend. The lower Tau3 and Phi3 test statistics than the respective critical values confirm the non-stationarity and stochastic trend, respectively, of the Japanese variables.

*Table 4.2 – Test statistics and critical values of ADF's Tau3 and Phi3 for Japanese variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR | -1.374 | | | | 1.5329 | | | |
| GDP | -2.6733 | -4.04 | -3.45 | -3.15 | 3.6109 | 8.73 | 6.49 | 5.47 |
| Credit | -2.5756 | | | | 3.8009 | | | |

Given the stationarity condition for a variable to fit in a VAR model, a transformation has to be applied to make it stationary. Since the SSR evolves into negative values, a logarithm is not possible to be applied. Therefore, the first-difference, i.e., the quarter-on-quarter variation of the shadow rate was computed and is plotted in figure 4.4. To the GDP and the credit it is applied the log-difference, so that the growth rate of GDP and the growth rate of credit are obtained and are presented in figures 4.5 and 4.6, respectively.

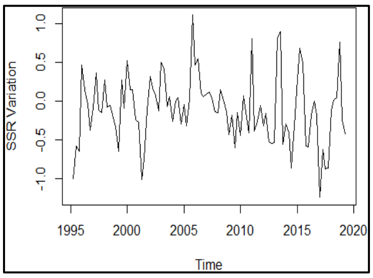


*Figure 4.4 – Japanese Short-run Shadow Rate variation (1995Q1 to 2019Q2) [s.d. = 0.4358537]*

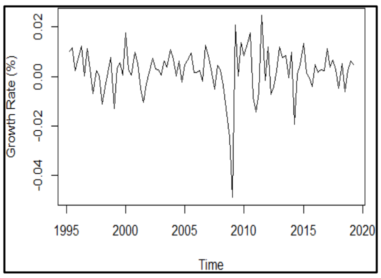


*Figure 4.5 – Japanese GDP growth rate (1995Q1 until 2019Q2) [s.d.=0.009567677]*

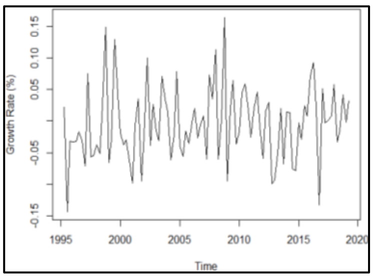


*Figure 4.6 – Total credit to the private non-financial sector growth rate in Japan (1995Q1 - 2019Q2) [s.d.=0.05771411]*

More constant variances than the untransformed variables and means closer to zero may suggest that the variables are now stationary. To check if this conclusion is valid, an ADF test was applied to each of the transformed variables. The ADF's Tau3 and Phi3, showed in table 4.3, confirms the stationarity of the transformed variables.

*Table 4.3 – Test statistics and critical values of ADF's Tau3 and Phi3 for Japanese transformed variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR variation | -5.5466 | | | | 15.3825 | | | |
| GDP growth rate | -5.7874 | -4.04 | -3.45 | -3.15 | 16.7841 | 8.73 | 6.49 | 5.47 |
| Credit growth rate | -7.3802 | | | | 27.2337 | | | |

The next step in the estimation of a VAR model with the stationary variables – short-run shadow rate first-difference, GDP growth rate and credit growth rate – is to choose the optimal lag-order.

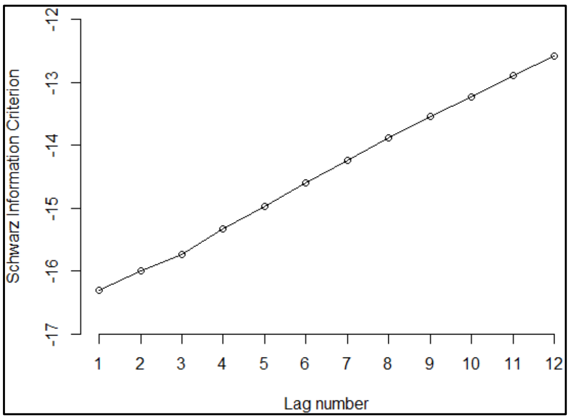


*Figure 4.7 – Schwarz information criterion values for Japan*

Observing the Schwarz Information criterion statistics, plotted in figure 4.7, the optimal lag-order, i.e., the number of lags that minimizes the value of the SIC, is 1. Therefore, the VAR model with these three variables will embody one lag.

Since the Cholesky decomposition of the variance-covariance matrix of residuals will be used, in order to identify monetary policy shocks, the variables are ordered based on an exogeneity criterion: starting with the most exogenous to the least exogenous. Given this, different order combinations will be tested, also, as a robustness test.

For the base version of the model, it is assumed that a shock to the shadow rate variation that would trigger reactions to the other variables, i.e. the shadow rate variation is the most exogenous variable. It is also assumed that the growth rate of credit will have a faster reaction than the GDP growth rate. Then, the SSR variation will be order first, the credit growth rate second and the GDP growth rate in last place.

An estimated VAR model, in matrix form, with these variables ($k = 3$) and one lag ($p = 1$) would have the following equation:

$$\begin{bmatrix} ssr_t \\ credit_t \\ gdp_t \end{bmatrix} = \begin{bmatrix} 0.34318 & -0.23202 & 3.22487 \\ 0.010384 & -0.036554 & 0.014053 \\ -0.001269 & -0.042022 & 0.139376 \end{bmatrix} \begin{bmatrix} ssr_{t-1} \\ credit_{t-1} \\ gdp_{t-1} \end{bmatrix} + \begin{bmatrix} -0.07127 \\ -0.003753 \\ 0.001573 \end{bmatrix} \quad (2)$$

Where $ssr$ represents the first-difference of the shadow short rate, $gdp$ represents the growth rate of GDP, $credit$ represents the growth rate of total credit to the private non-financial sector and $c_1$, $c_2$ and $c_3$ are constants.

After estimating the equation, the next step is to apply diagnostic tests on the estimated model.

By observing the roots of characteristic polynomial, presented in table A6 in the annexes, it is possible to conclude that this VAR(1) process is stable, since these eigenvalues are less than 1.

The ARCH test presented in table A7, in the annexes, allow to conclude that the model's residuals are homoscedastic, i.e., they have constant variance.

The analysis of the normality tests (Jarque-Bera, Skewness and Kurtosis) suggest that the residuals do not follow the theoretical normal distribution. Although the residuals do not fulfill the normality condition, it does not compromise the validity of VAR model output analysis. Given that these normality test use the standardized residuals by the Choleski decomposition, the decomposed variance-covariance matrix of residuals is presented in table 4.4.

*Table 4.4 – Choleski decomposed variance-covariance matrix of residuals of Japan's estimated model*

| | $ssr$ | $credit$ | $gdp$ |
|---|---|---|---|
| $ssr$ | 0.4059359490 | 0 | 0 |
| $credit$ | 0.0002332332 | 0.05867238 | 0 |
| $gdp$ | 0.0005973056 | -0.00001427061 | 0.009283727 |

The last diagnostic tests presented in table A7 are on the serial correlation in errors. The analysis of the results of the Portmanteau and Breusch-Godfrey LM test suggest that there is no serial correlation between the errors of Japan's VAR model.

Given that the diagnostic tests returned the desirable properties of the model, the next step will be to analyze the impulse response functions obtained from this VAR(1) process. The 12-steps ahead orthogonal impulse response functions presented are obtained with a 95% confidence interval for the bootstrapped errors bands and through 1000 bootstrap runs.

Following the used variables order in the estimated model, the first IRFs will reflect the triggered responses in the credit growth rate and GDP growth rate by a shock in SSR variation.

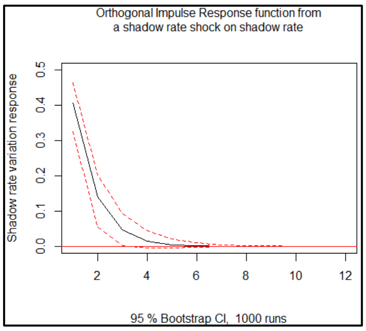


*Figure 4.8 – IRF of a SSR variation shock in SSR variation*

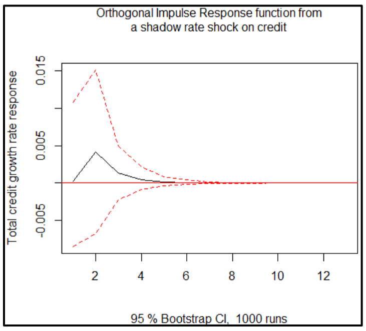


*Figure 4.9 – IRF of a SSR variation shock in credit growth rate*

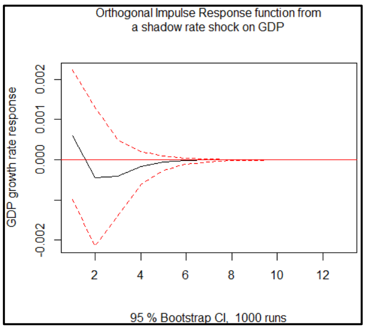


*Figure 4.10 – IRF of a SSR variation shock in GDP growth rate*

The observed effect of a positive shock in SSR, which represents a monetary policy tightening, in credit was not the expected. According to the economic theory, a monetary policy tightening reduces credit. However, for Japan, an increase in the SSR causes a positive response in credit growth rate, as can be seen in figure 4.9.

Regarding the short-run shadow rate variation shock in GDP growth rate, represented in figure 4.10, it is possible to see that a monetary policy tightening causes a GDP contraction. The literature points out a positive response of Japanese GDP to the adopted Quantitative Easing policy by the Bank of Japan. Knowing that the QE can be represented by a reduction in the SSR, therefore a negative variation of the SSR caused a positive response of GDP growth rate. Jointly with the result obtained in the IRF it may be confirmed that there is a negative correlation between SSR variation and GDP growth rate.

In the next three figures are plotted the responses of the variables to a shock in the credit growth rate.

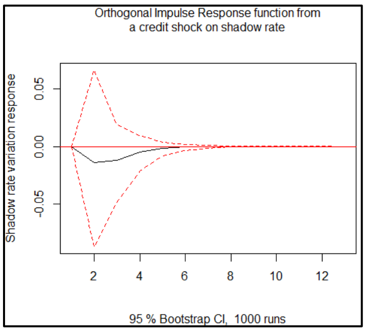


*Figure 4.11 – IRF of a credit growth rate shock in SSR variation*

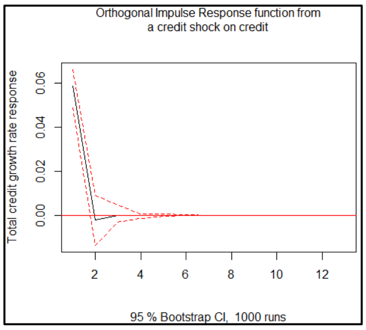


*Figure 4.12 – IRF of a credit growth rate shock in credit growth rate*

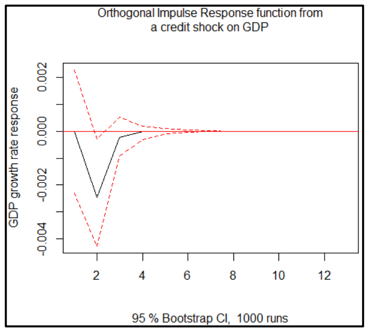


*Figure 4.13 – IRF of a credit growth rate shock in GDP growth rate*

Most central banks, including the Bank of Japan, have the objective to maintain the stability of prices and the financial system. Shocks or pressures in the credit market could threaten the aimed stability. According to Saiki and Frost (2014), these pressures should be contained with a monetary policy tightening. The impulse response function, in figure 4.11, presents a negative effect on shadow rate from a credit shock, which means that the monetary policy would ease after a positive credit shock. This evidence does not meet the expected result of a positive response of the SSR variation to an increase in credit growth rate.

According to the economic theory stated in Berkelmans (2005), a positive shock in credit should cause GDP to grow since it would allow agents to spend more. However, the IRF of a credit growth rate shock effect on GDP (figure 4.13) shows a short but negative reaction of the GDP growth rate to a positive variation in credit.

The last bundle of IRFs regarding the Japanese variables show the reactions to a shock in GDP.

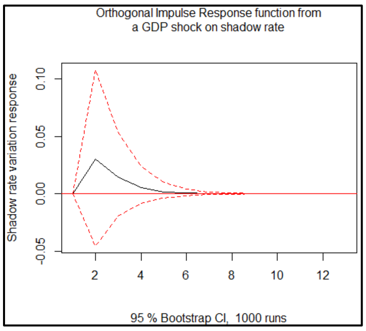


*Figure 4.14 – IRF of a GDP growth rate shock in SSR variation*

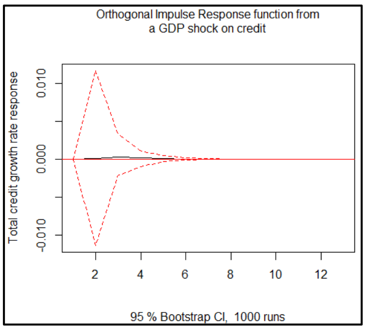


*Figure 4.15 – IRF of a GDP growth rate shock in credit growth rate*

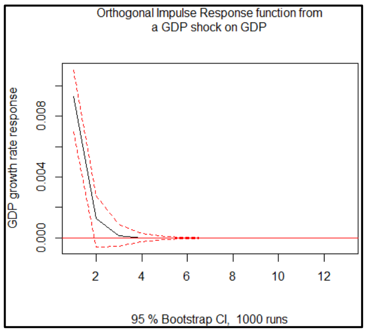


*Figure 4.16 – IRF of a GDP growth rate shock in GDP growth rate*

Figure 4.14 shows that SSR increases when a positive shock in GDP happens. Essentially, it means that monetary policy tightens when the economy suffers an expansionary shock.

It is possible to observe a positive response of credit to a GDP shock, in the impulse response function presented in figure 4.15. However, the GDP growth rate shock has a very small, almost null, effect on credit. This result, jointly with the response of GDP to a credit shock (figure 4.13), allows to conclude that the expected positive bidirectional relation between credit and GDP is not confirmed.

Analyzing the decomposition of the forecasted error variance of the three variables included in the model, presented in tables A8, A9 and A10, it is possible to conclude that almost all of the uncertainty of the variables comes from the own variables. This means that SSR variation contributes the most to SSR variation uncertainty, credit growth rate contributes the most to credit growth rate uncertainty and GDP growth rate contributes the most to GDP growth rate uncertainty.

## 4.2. United Kingdom's Variables and Model

The United Kingdom will be the second country to be analyzed. Starting with the short-run shadow rate, it is possible to see, in figure 4.17, its evolution over time. Until 2009, the UK's shadow rate behaved closely to the Bank of England base rate. From 2009 onwards, while the Bank Rate stood relatively constant, the shadow rate reflected the quantitative easing rounds with large-scale asset purchases and forward guidance announcements. As can be seen in figure 4.18, the GDP of the United Kingdom is continuously growing in the period of analysis with the exception for the period of the 2008-2009 financial crisis. Regarding UK's total credit to the private non-financial sector, in figure 4.19, it is possible to see that it had a clear upward trend from 1995Q1 until 2008Q2, but during the year after the latter quarter it fell sharply and maintained a more constant but noisy trend until the end of the period of analysis. Summary statistics for these variables are presented in table 4.5.

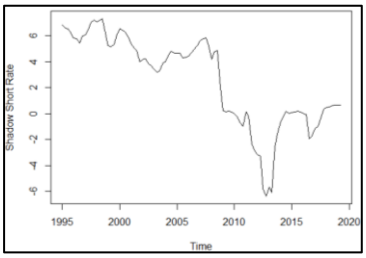


*Figure 4.17 – Short-run shadow rate for UK (1995Q1 until 2019Q2)*

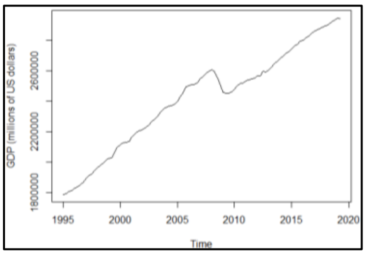


*Figure 4.18 – United Kingdom's gross domestic product (1995Q1 - 2019Q2)*

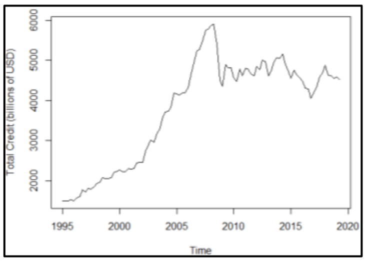


*Figure 4.19 – Total credit to the private non-financial sector in the UK (1995Q1 - 2019Q2)*

*Table 4.5 – UK's variables summary statistics*

| | Minimum | First Quartile | Median | Mean | Third Quartile | Maximum | Standard Deviation |
|---|---|---|---|---|---|---|---|
| SSR | -6.37257 | 0.03438 | 3.94477 | 2.54476 | 5.38468 | 7.3261 | 3.476102 |
| GDP | 1,787,391 | 2,169,349 | 2,497,533 | 2,417,071 | 2,620359 | 2,948,726 | 326,404.7 |
| Credit | 1,503 | 2,307 | 4,338 | 3,783 | 4,773 | 5,907 | 1,312.195 |

The existent trends found in UK's variables alongside with the slow decaying pace of the autocorrelation functions, plotted in figures A7, A8 and A9, suggests non-stationarity in these variables. Then, an ADF test was applied to the considered variables.

ADF's Tau3 and Phi3 test statistics and their critical values for standard significance values, displayed in table 4.6, confirm the non-stationarity and the stochastic trend of the United Kingdom's variables.

*Table 4.6 – Test statistics and critical values of ADF's Tau3 and Phi3 for United Kingdom's variables*

<table>
<tr><th rowspan="3"></th><th colspan="4">Tau3</th><th colspan="4">Phi3</th></tr>
<tr><th rowspan="2">Test statistic</th><th colspan="3">Critical values</th><th rowspan="2">Test statistic</th><th colspan="3">Critical values</th></tr>
<tr><th>1%</th><th>5%</th><th>10%</th><th>1%</th><th>5%</th><th>10%</th></tr>
<tr><td>SSR</td><td>-1.8563</td><td rowspan="3">-4.04</td><td rowspan="3">-3.45</td><td rowspan="3">-3.15</td><td>2.0565</td><td rowspan="3">8.73</td><td rowspan="3">6.49</td><td rowspan="3">5.47</td></tr>
<tr><td>GDP</td><td>-2.0077</td><td>2.1715</td></tr>
<tr><td>Credit</td><td>-1.6417</td><td>2.3364</td></tr>
</table>

Since the variables are non-stationary, the next step to fit them in a VAR model is to apply transformations to make them stationary. It will be applied to the UK's variables the same transformations that were applied to the Japanese variables, i.e., the first-difference to the short-run shadow rate and the log-difference to the GDP and to total credit. The newly computed variables are presented in the following three figures.

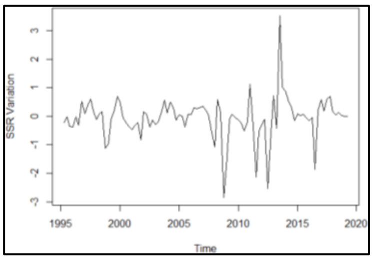


*Figure 4.20 – United Kingdom's Short-run Shadow Rate variation (1995Q1 to 2019Q2) [s.d.=0.7457352]*

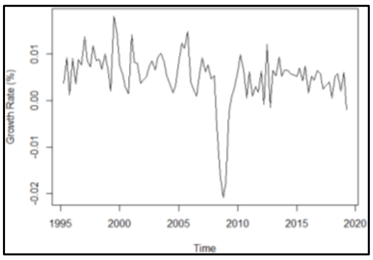


*Figure 4.21 – United Kingdom's GDP growth rate (1995Q1 until 2019Q2) [s.d.=0.005745575]*

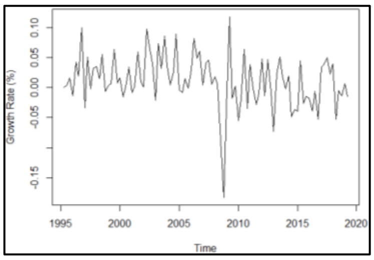


*Figure 4.22 – Total credit to the private non-financial sector growth rate in the UK (1995Q1 - 2019Q2) [s.d.=0.04352011]*

In order to check if the transformed variables are now stationary, another ADF test is applied. The analysis of the ADF's Tau3 and Phi3, in table 4.7, suggest that the transformed variables – short-run shadow rate variation, GDP growth rate and credit growth rate – are now stationary and, therefore, can be included in a VAR model.

*Table 4.7 – Test statistics and critical values of ADF's Tau3 and Phi3 for UK's transformed variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR variation | -5.4777 | | | | 15.0053 | | | |
| GDP growth rate | -4.5205 | -4.04 | -3.45 | -3.15 | 10.2477 | 8.73 | 6.49 | 5.47 |
| Credit growth rate | -6.3182 | | | | 19.9822 | | | |

A vital procedure to estimate a VAR model is to choose the model's optimal lag order. In this case, as for Japan, the minimum value of Schwarz Information Criterion will determine the number of optimal lags.

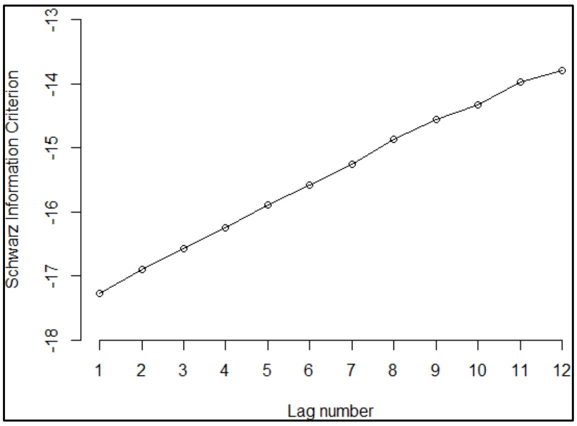


*Figure 4.23 – Schwarz information criterion values for the UK*

Following the SIC values, plotted in figure 4.23, one lag is the optimal lag number for the UK's model. Therefore, there will be one lag in the VAR model that includes these variables.

Using the same variable order as in Japan's model, the estimated VAR, for the UK, including the SSR variation, credit growth rate and GDP growth rate has the following equation:

$$\begin{bmatrix} ssr_t \\ credit_t \\ gdp_t \end{bmatrix} = \begin{bmatrix} 0.1599 & 3.0239 & 26.3044 \\ -0.001799 & 0.093364 & 1.652673 \\ 0.0001647 & 0.0148887 & 0.5486588 \end{bmatrix} \begin{bmatrix} ssr_{t-1} \\ credit_{t-1} \\ gdp_{t-1} \end{bmatrix} + \begin{bmatrix} -0.2239 \\ 0.001645 \\ 0.0021335 \end{bmatrix} \quad (3)$$

With model's estimation completed, diagnostic tests have to be computed to check if the model represents the data in an adequate manner.

Roots of the characteristic polynomial lower than one, presented in table A11, indicate that the estimated VAR(1) process is stable.

The ARCH test presented in table A12 suggests that the null hypothesis of constant variance (homoscedasticity) is rejected. Despite the heteroscedasticity of the residuals, much of the analysis can still be performed (Lütkepohl, 2013).

Jarque-Bera and Kurtosis tests suggest that residuals do not follow the normal distribution and, as was said for the Japan case, the non-normality condition do not invalidate VAR model outputs. However, the Kurtosis test, at a significance level of 5%, point for he residuals to follow normal distribution's kurtosis. Trailing the normality tests analysis, the Choleski decomposition of the variance-covariance matrix of residuals is presented in table 4.8.

*Table 4.8 – Choleski decomposed variance-covariance matrix of residuals of UK's estimated model*

| | *ssr* | *credit* | *gdp* |
|---|---|---|---|
| *ssr* | 0.004679445 | 0 | 0 |
| *credit* | 0.012561368 | 0.04107357 | 0 |
| *gdp* | 0.079236899 | 0.15244932 | 0.6766126 |

The tests' output regarding the serial correlation in errors, presented in table A12, indicate that, at a significance level of 5%, and 1% for the adjusted Portmanteau test, the null hypothesis of no residual serial correlation is not rejected.

Given the features returned by the diagnostic tests, the following step is to analyze the impulse response functions generated by this VAR(1) process. As for the Japan's analysis, the IRFs of the responses of a SSR variation shock will be the first to be analyzed.

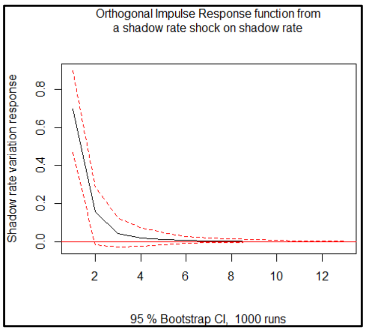

*Figure 4.24 – IRF of a SSR variation shock in SSR variation*

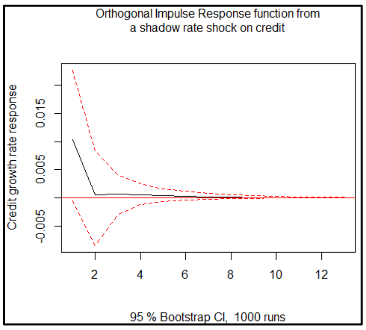

*Figure 4.25 – IRF of a SSR variation shock in credit growth rate*

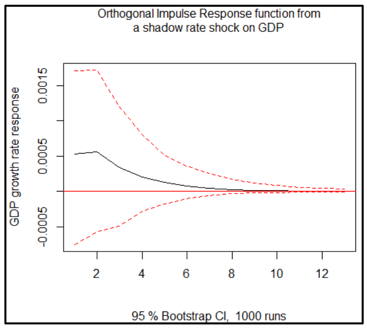

*Figure 4.26 – IRF of a SSR variation shock in GDP growth rate*

Through the analysis of the IRF in figure 4.25, it is possible to see that a monetary policy tightening would have an immediate positive impact in credit growth rate and that this effect becomes almost null very quickly. But, most importantly, the impact on credit of a SSR shock does not show the expected negative sign. However, it still overlaps the reduced impact pointed out by the literature.

The impulse response function of the reaction of GDP from a shock in monetary policy, in figure 4.26, shows a small but positive effect from the response variable. As stated before, Quantitative Easing can be represented by a SSR reduction since it represents a monetary policy easing. The result indicated by the IRF, in figure 4.26, do not confirm the expected negative correlation between SSR variation and GDP growth rate.

Impulse response functions of the effect of a credit growth rate shock in the other variables will be next to be analyzed.

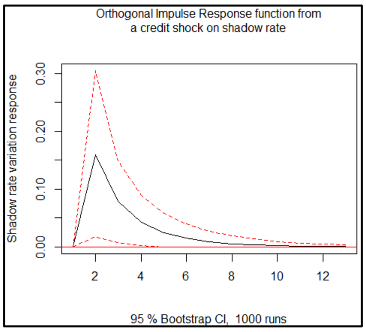


*Figure 4.27 – IRF of a credit growth rate shock in SSR variation*

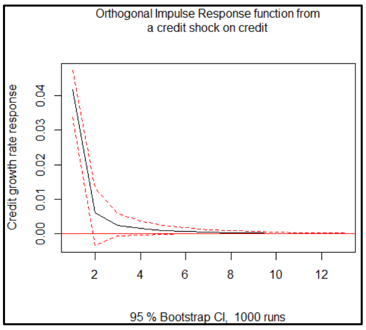


*Figure 4.28 – IRF of a credit growth rate shock in credit growth rate*

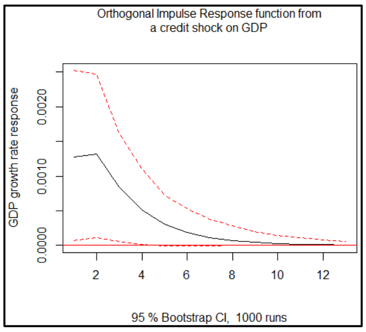


*Figure 4.29 – IRF of a credit growth rate shock in GDP growth rate*

According to the IRF plotted in figure 4.27, a positive credit growth rate shock would lead the SSR to increase and such response is extended over the medium run, i.e., over a year but under two years. After 8 quarters the effect becomes almost null. This shadow rate response matches with the theoretical and expected effect to a credit hike. Since it could lead to inflation, the Bank of England tightens monetary policy to guarantee price stability.

A positive credit shock causes a positive response on GDP growth rate, as shown in figure 4.29. This rise in GDP after the credit shock corroborates one of the sides of the expected positive correlation between GDP and credit.

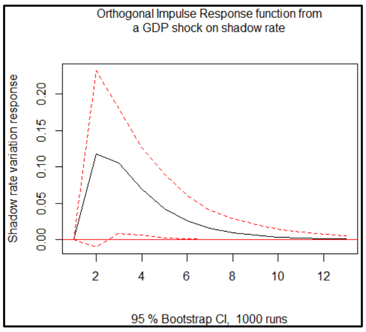


*Figure 4.30 – IRF of a GDP growth rate shock in SSR variation*

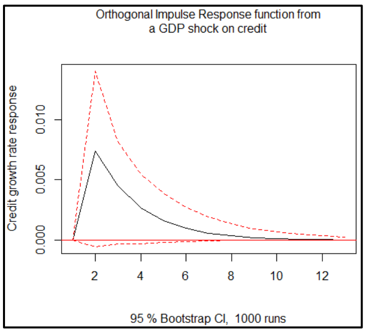


*Figure 4.31 – IRF of a GDP growth rate shock in credit growth rate*

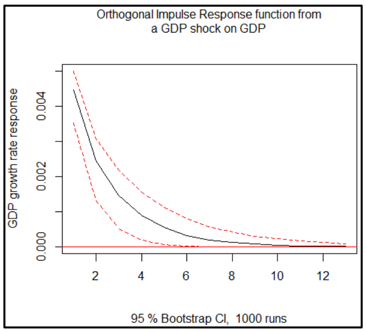


*Figure 4.32 – IRF of a GDP growth rate shock in GDP growth rate*

Observing figure 4.30, where the IRF of a positive GDP shock effect in SSR is plotted, it is possible to conclude that monetary policy becomes tighter when GDP grows.

Figure 4.31 shows the impulse response function of a GDP shock effect on credit. It is possible to see that a positive GDP shock causes credit to increase. Alongside the previously analyzed effect of a credit shock on GDP (figure 4.29), the expected theoretical positive bidirectional relation between GDP and credit is confirmed.

The forecast error variance decomposition, in tables A13, A14 and A15, suggest that the major part of the variables' uncertainty comes from the own variables. If the own variables are excluded, arises that credit contributes more to the uncertainty of the other two variables and it is the shadow rate that contributes the most to the forecast uncertainty of credit.

## 4.3. United States' Variables and Model

Figure 4.33 presents the SSR estimations for the United States. It is not possible to see a clear upward or downward trend over the whole period of analysis. Instead some trends are distinguished in subsamples of the timeline. As an example, the sharp fall that started in 2007Q2 until 2012Q4 matches with the launch and implementation of quantitative easing programs following the 2007-2008 financial crisis. Generally, GDP and credit had an upward trend over the analysis period, as can be seen in figures 4.34 and 4.35. At the fourth and third quarter of 2008, respectively, GDP and credit suffered a setback in this evolution, but after approximately one, two years the ascending path was resumed. Table 4.9 presents US' variables summary statistics.

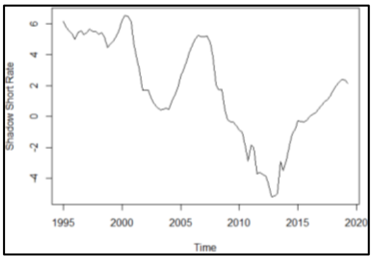


*Figure 4.33 – Short-run shadow rate for the United States (1995Q1 until 2019Q2)*

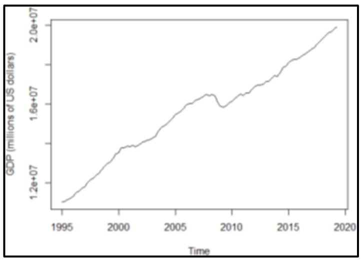


*Figure 4.34 – United States' gross domestic product (1995Q1 - 2019Q2)*

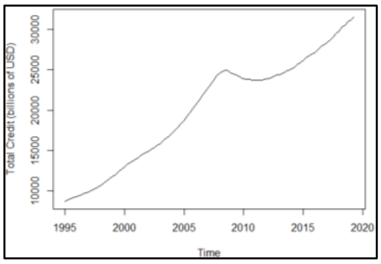


*Figure 4.35 – Total credit to the private non-financial sector in the US (1995Q1 - 2019Q2)*

*Table 4.9 – Summary statistics of United States' variables*

| | Minimum | First Quartile | Median | Mean | Third Quartile | Maximum | Standard Deviation |
|---|---|---|---|---|---|---|---|
| SSR | -5.2030 | -0.3252 | 1.7049 | 1.7558 | 5.0401 | 6.5383 | 3.187386 |
| GDP | 11,040,986 | 13,873,655 | 16,036,921 | 15,603,448 | 17,171,623 | 19,919,119 | 2,378,321 |
| Credit | 8,723 | 14,006 | 22,999 | 20,174 | 24,800 | 31,572 | 6,723.57 |

The existence of the referred trends alongside with the slow falling pace of the autocorrelation functions, presented in figures A13, A14 and A15, may indicate that the variables are non-stationary.

So, as done before, an ADF test was applied to the US' variables. ADF's Tau3 and Phi3, presented in table 10, point for the non-stationarity and the existence of stochastic trend, respectively.

*Table 4.10 – Test statistics and critical values of ADF's Tau3 and Phi3 for United States' variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR | -2.4517 | -4.04 | -3.45 | -3.15 | 3.8408 | 8.73 | 6.49 | 5.47 |
| GDP | -1.3468 | | | | 1.1321 | | | |
| Credit | -2.8094 | | | | 3.9561 | | | |

Following the previous methodology, the next step to model these variables through a VAR is to make them stationary. Therefore, the first-difference of the short-run shadow rate (figure 4.36), the log-difference of GDP (figure 4.37) and the log-difference of total credit (figure 4.38) were computed.

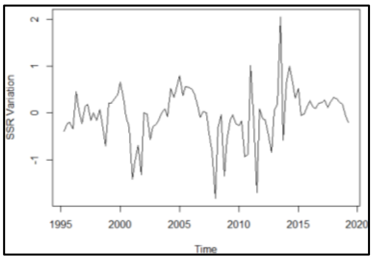


*Figure 4.36 – US' Short-run Shadow Rate variation (1995Q1 to 2019Q2) [s.d.=0.5710451]*

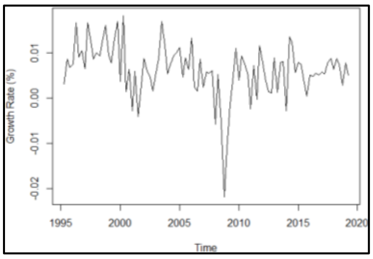


*Figure 37 – US GDP growth rate (1995Q1 until 2019Q2) [s.d.=0.009476335]*


*Figure 38 – Total credit to the private non-financial sector growth rate in the US (1995Q1 - 2019Q2) [s.d.=0.005879627]*

As for Japan and the UK, it is expected that the applied transformations should make the variables stationary. However, the ADF's Tau3 and Phi3 test statistics, presented in table 4.11, suggest that this only happens for the GDP growth rate, i.e., the SSR variation and credit growth rate are still non-stationary.

*Table 4.11 – Test statistics and critical values of ADF's Tau3 and Phi3 for United States' transformed variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR variation | -3.2481 | | | | 5.3229 | | | |
| GDP growth rate | -4.3787 | -4.04 | -3.45 | -3.15 | 9.718 | 8.73 | 6.49 | 5.47 |
| Credit growth rate | -1.893 | | | | 2.0115 | | | |

Therefore, a KPSS test, a more powerful test than the ADF, was applied to the latter two variables. The nil, short and long intercept and trend statistics of the KPSS applied to the SSR variation, presented in table A5, point for the non-rejection of the null hypothesis of stationarity at the most commonly used significance level of 5%. In the case of the credit growth rate, the long intercept and trend suggest stationarity condition at the same significance level of 5%.

Given that the stationarity condition was achieved, the next step is to find the optimal number of lags of the VAR model. The Schwarz information criterion, whose statistics are plotted in figure 4.39, indicate that one is the optimal number of lags.

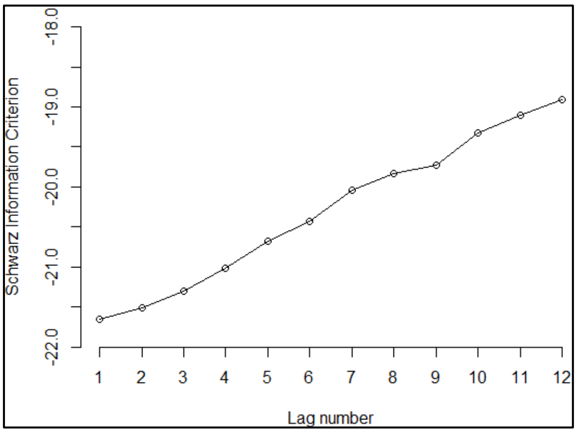


*Figure 4.39 – Schwarz information criterion values for the US*

The estimated VAR model, for the US, using the same variable order – SSR variation, credit growth rate and GDP growth rate – has the following equation:

$$\begin{bmatrix} ssr_t \\ credit_t \\ gdp_t \end{bmatrix} = \begin{bmatrix} 0.34267 & 0.22968 & 6.66616 \\ 0.0004896 & 0.7798842 & 0.1266646 \\ 0.001513 & 0.089574 & 0.259318 \end{bmatrix} \begin{bmatrix} ssr_{t-1} \\ credit_{t-1} \\ gdp_{t-1} \end{bmatrix} + \begin{bmatrix} -0.06774 \\ 0.0020875 \\ 0.003405 \end{bmatrix} \quad (4)$$

The last step to evaluate the model before moving to the analysis of the outputs is the implementation of diagnostic tests.

Presented in table A16, the roots of the characteristic polynomial show that the estimated VAR(1) model is stable, since they are less than 1.

According to the ARCH test, in table A17, the residuals of the model are not homoscedastic, i.e., there is not constant variance. As stated for the UK's model, based on Lütkepohl (2013), much of the analysis underlying a VAR model can still be performed.

In the case of the normality tests, the Jarque-Bera and the Kurtosis tests statistics indicate that the null hypothesis of a normal distribution is rejected. However, the skewness of the VAR process' distribution is similar to the skewness of a normal distribution. The normality tests use the standardized residuals estimated in the Choleski decomposed variance-covariance matrix of residuals, which is presented next.

*Table 4.12 - Choleski decomposed variance-covariance matrix of residuals of US' estimated model*

| | $ssr$ | $credit$ | $gdp$ |
|---|---|---|---|
| $ssr$ | 0.539149499 | 0.000000000 | 0.000000000 |
| $credit$ | 0.001303698 | 0.005271647 | 0.000000000 |
| $gdp$ | 0.001796429 | 0.001470871 | 0.004895964 |

The last diagnostic tests applied to be analyzed, presented in table A17, are on residual serial correlation. The asymptotic and the adjusted Portmanteau test, at standard significance levels of 0.05 and 0.01, respectively, point for the existence of no residual autocorrelation. On its turn, the Breusch-Godfrey test suggests low order autocorrelation of the residuals.

The first set of impulse response functions to be analyzed exhibit the response of the three variables to a short-run shadow rate variation shock of one standard deviation.

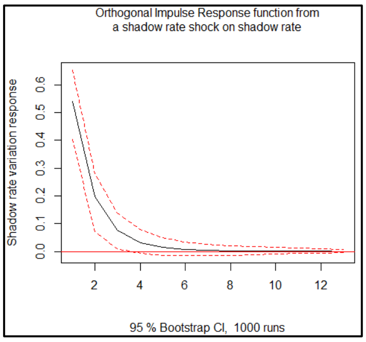


*Figure 4.40 – IRF of a SSR variation shock in SSR variation*

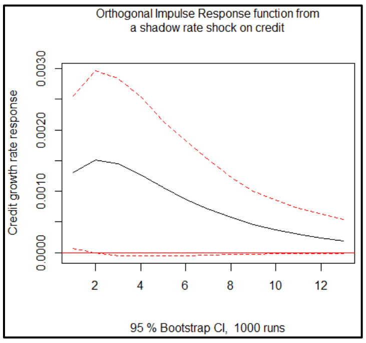


*Figure 4.41 – IRF of a SSR variation shock in credit growth rate*

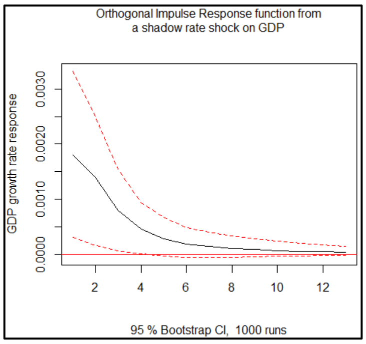


*Figure 4.42 – IRF of a SSR variation shock in GDP growth rate*

The IRF in figure 4.41 shows that credit growth rate does not have the expected reaction advocated by economic theories to a monetary policy tightening. Instead of the expected contraction of credit, there is a positive variation in the conceded credit to the private non-financial sector.

The other IRF, in figure 4.42, shows the response of the GDP growth rate to an impulse in SSR. Also in this case the expected result was not obtained. In fact, it shows the opposite, where the GDP growth rate increases with a monetary policy tightening.

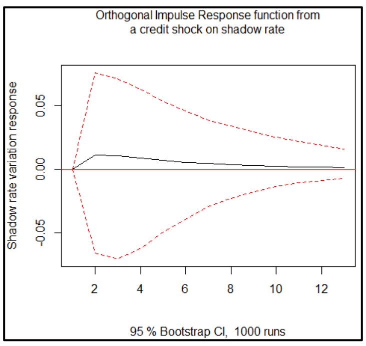


*Figure 4.43 – IRF of a credit growth rate shock in SSR variation*

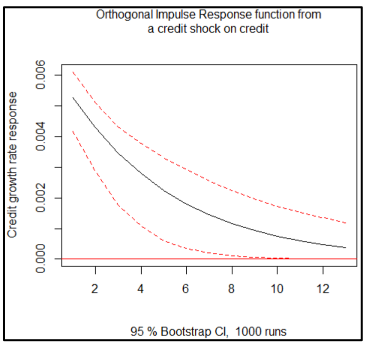


*Figure 4.44 – IRF of a credit growth rate shock in credit growth rate*

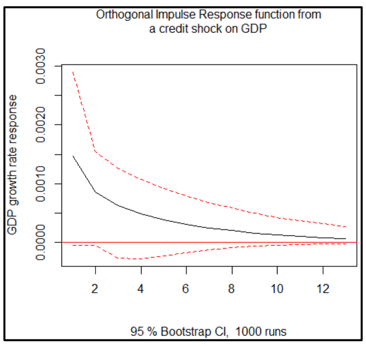


*Figure 4.45 – IRF of a credit growth rate shock in GDP growth rate*

These IRFs show how variables respond to a credit growth rate shock.

First, the threat of price instability that could be caused by a credit hike would lead the Fed to tighten the monetary policy stance, in order to smooth the cycle of credit. Figure 4.43 shows that the SSR would increase following a positive credit shock, which is in accordance with the expected result.

In second place, the shock in credit causes a positive response from GDP. The IRF presented in figure 4.45 checks one way of the theoretical relation between credit and GDP.

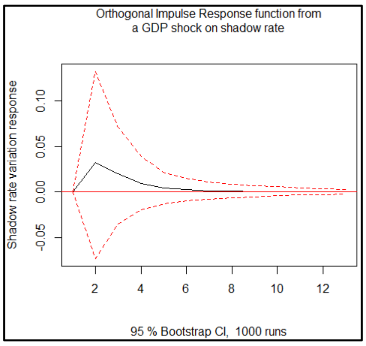


*Figure 4.46 – IRF of a GDP growth rate shock in SSR variation*

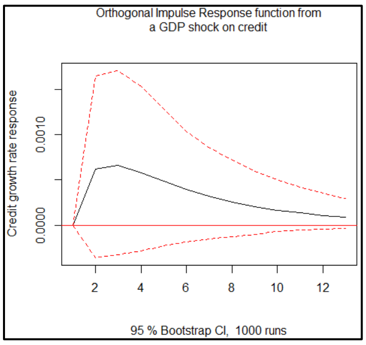


*Figure 4.47 – IRF of a GDP growth rate shock in credit growth rate*

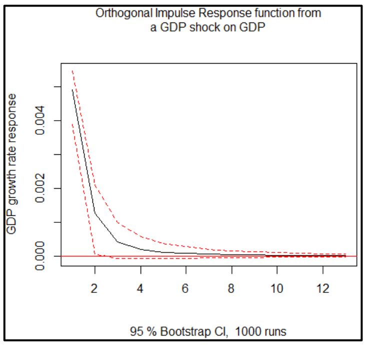


*Figure 4.48 – IRF of a GDP growth rate shock in GDP growth rate*

Following a GDP shock, the impulse-response function in figure 4.46 suggests that the Short-run Shadow Rate rise. This means that monetary policy is tightened when the economy expands.

A positive credit response to a GDP shock, as shown in figure 4.47, allows to conclude, alongside the result suggested by the IRF in figure 46, that there is a positive bidirectional relation between credit and GDP.

The forecast error variance decomposition of US' variables, presented in tables A18, A19 and A20, show that the majority of the uncertainty comes from the own variables. If the own variables are excluded, GDP growth rate is the second variable that causes more uncertainty in SSR variation and it is the SSR variation that causes more forecast uncertainty, in second place, to the credit growth rate and to the GDP growth rate.

## 4.4. Euro Area's Variables and Model

As seen in figure 4.49, Euro Area's SSR appear to have a downward trend namely after the financial crisis reached Europe (2008) and even more pronounced after the sovereign debt crisis (2011-2012). Regarding the GDP, plotted in figure 4.50, it shows an upward tendency with the exception for the period of one and two years, respectively, after the events referred before. The total credit to the private non-financial sector grew almost constantly until the second quarter of 2008 and then it stood relatively constant but with a noisier behavior, as shown in figure 4.51. The summary statistics of Euro Area's variables are presented in table 4.13.

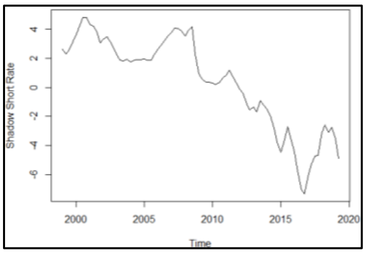


*Figure 4.49 – Short-run shadow rate for the Euro Area (1999Q1 until 2019Q2)*

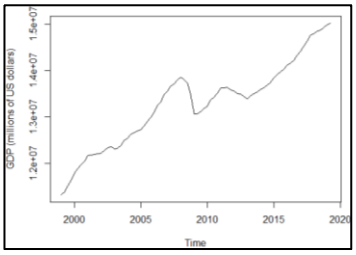


*Figure 4.50 – Euro Area's gross domestic product (1999Q1 - 2019Q2)*

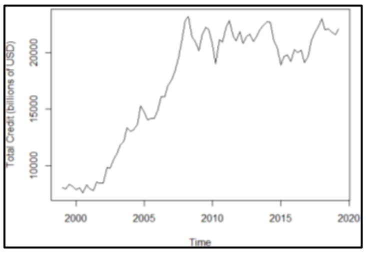


*Figure 4.51 – Total credit to the private non-financial sector in the Euro Area (1999Q1 - 2019Q2)*

*Table 4.13 - Euro Area's variables summary statistics*

| | Minimum | First Quartile | Median | Mean | Third Quartile | Maximum | Standard Deviation |
|---|---|---|---|---|---|---|---|
| SSR | -7.3361 | -1.8620 | 1.0511 | 0.3642 | 3.0070 | 4.8306 | 3.191567 |
| GDP | 11,320,190 | 12,567,027 | 13,465,724 | 13,277,745 | 13,777,924 | 15,012,897 | 901,414.1 |
| Credit | 7,562 | 13,247 | 19,752 | 17,267 | 21,527 | 23,236 | 5,295.757 |

The referred trends in the period under analysis alongside the slowly falling autocorrelation functions point for the non-stationarity of the variables. So, following the same steps as for the other countries, an ADF test was applied to the Euro Area's variables.

Tau3 and Phi3 statistics, presented in table 4.14, suggest that GDP, credit and the SSR (at a 5% significance level) are non-stationary and that they have a stochastic trend.

*Table 4.14 – Test statistics and critical values of ADF's Tau3 and Phi3 for Euro Area's variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR | -3.3126 | | | | 5.736 | | | |
| GDP | -2.1769 | -4.04 | -3.45 | -3.15 | 2.4136 | 8.73 | 6.49 | 5.47 |
| Credit | -2.2617 | | | | 3.1246 | | | |

The same transformations will be applied to the variables. The computed SSR variation, GDP log-difference and credit log-difference are presented in the following figures alongside their standard deviation.

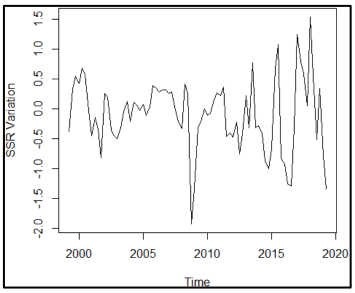


*Figure 4.52 – Euro Area's Short-run Shadow Rate variation (1999Q1 to 2019Q2) [s.d.=0.6024484]*

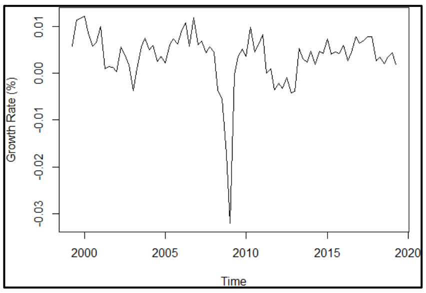


*Figure 4.53 – Euro Area GDP growth rate (1999Q1 until 2019Q2) [s.d.=0.006058623]*

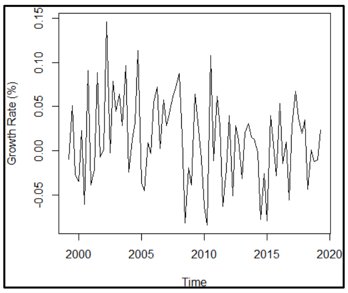


*Figure 4.54 – Total credit to the private non-financial sector growth rate in the Euro Area (1999Q1 - 2019Q2) [s.d.=0.0492651]*

The expected stationarity condition of the referred transformed variables was obtained for the SSR variation and the credit growth rate, as pointed by the ADF test statistics in table 4.15. Regarding the GDP growth rate, the ADF only suggests stationarity at 10% significance level. Then, a KPSS test was applied to the Euro Area's GDP growth rate to verify its condition. Five out of the six KPSS statistics, showed in table A5, confirm that the GDP growth rate is a stationary variable.

*Table 4.15 - Test statistics and critical values of ADF's Tau3 and Phi3 for Euro Area's transformed variables*

| | Tau3 | | | | Phi3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Test statistic | Critical values | | | Test statistic | Critical values | | |
| | | 1% | 5% | 10% | | 1% | 5% | 10% |
| SSR variation | -4.6756 | -4.04 | -3.45 | -3.15 | 11.0226 | 8.73 | 6.49 | 5.47 |
| GDP growth rate | -3.3968 | | | | 5.775 | | | |
| Credit growth rate | -5.4186 | | | | 14.6809 | | | |

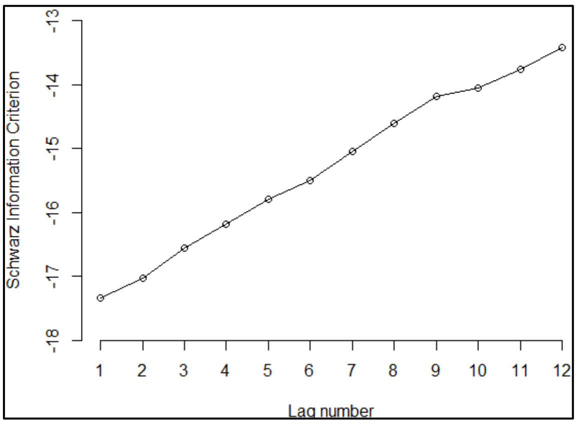


*Figure 4.55 - Schwarz information criterion values for the Euro Area*

According to the Schwarz information criterion, one is the optimal number of lags. Therefore, the VAR model with the previously used variable order – SSR variation, credit growth rate and GDP growth rate – will have the following estimated equation:

$$\begin{bmatrix} ssr_t \\ credit_t \\ gdp_t \end{bmatrix} = \begin{bmatrix} 0.33085 & 0.5476 & 24.70160 \\ 0.006708 & -0.28751 & 0.059114 \\ 0.001566 & -0.002677 & 0.551802 \end{bmatrix} \begin{bmatrix} ssr_{t-1} \\ credit_{t-1} \\ gdp_{t-1} \end{bmatrix} + \begin{bmatrix} -0.15713 \\ 0.013446 \\ 0.001676 \end{bmatrix} \quad (5)$$

Moving to the diagnostic tests, first, it is possible to see that the roots of the estimated VAR(1) process are lower than 1, as shown in table A21, therefore that the model is stable.

According to the ARCH test, presented in table A22, the residuals of the estimated VAR model do not have constant variance, which means that there is heteroscedasticity. Although it is not a desirable feature to find in the residuals of a VAR model, the majority of the analysis can still be done, as referred before.

Presented in the same table as the ARCH test, there are the normality tests. The Jarque-Bera, Skewness and Kurtosis tests indicate that the model’s residuals do not present a normal distribution. These normality tests use the residuals that are standardized through the Choleski decomposition, the decomposed variance-covariance matrix of residuals of the Euro Area's estimated model is presented next in table 4.16.

Last but not the least, the tests on the existence of residual serial correlation show that the null hypothesis of no serial correlation in errors is not rejected.

*Table 4.16 – Choleski decomposed variance-covariance matrix of residuals of Euro Area's estimated model*

| | $ssr$ | $credit$ | $gdp$ |
|---|---|---|---|
| $ssr$ | 0.535176798 | 0.000000000 | 0.000000000 |
| $credit$ | 0.009072621 | 0.0494819942 | 0.000000000 |
| $gdp$ | 0.001129118 | 0.0006596075 | 0.004641387 |

Following the order of the variables in the model, the first IRFs to be analyzed show the response to a shock in SSR variation.

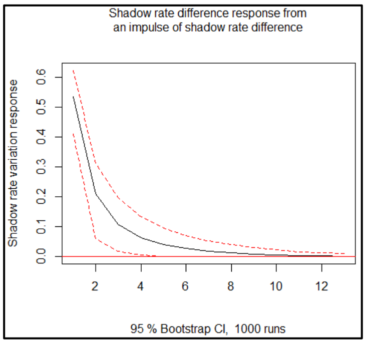


*Figure 4.56 – IRF of a SSR variation shock in SSR variation*

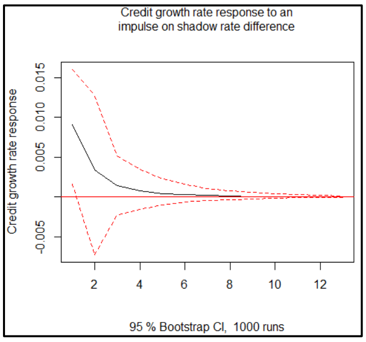


*Figure 4.57 – IRF of a SSR variation shock in credit growth rate*

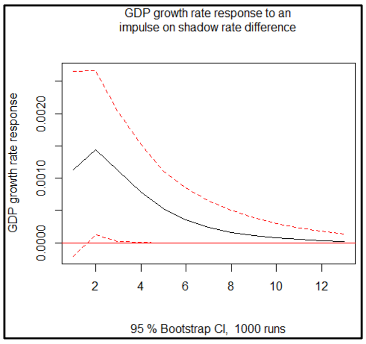


*Figure 4.58 – IRF of a SSR variation shock in GDP growth rate*

In the IRFs presented in figure 4.57 and 4.58, it is possible to see that a positive SSR shock generates a positive response in both credit and GDP. Which is an unexpected result according to the economic theory, as already concluded before.

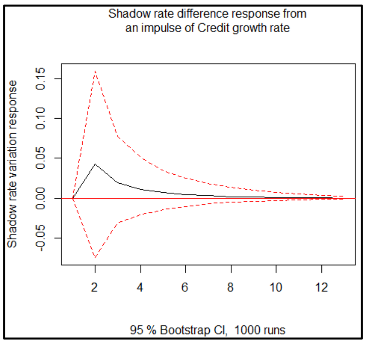


*Figure 4.59 – IRF of a credit growth rate shock in SSR variation*

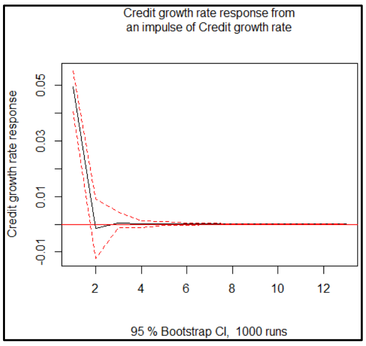


*Figure 4.60 – IRF of a credit growth rate shock in credit growth rate*

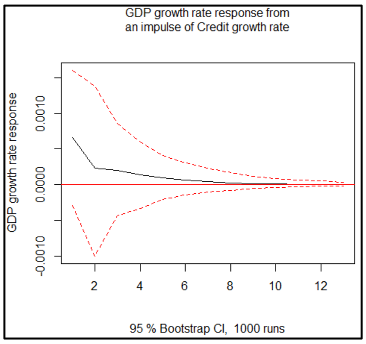


*Figure 4.61 – IRF of a credit growth rate shock in GDP growth rate*

By looking at the impulse response functions generated after the simulated shock in credit, first, observing figure 4.59, it is possible to conclude that an increase in credit growth rate leads the SSR to react positively. This means that the ECB would tighten the monetary policy stance, which meets the expected result.

Second, looking at figure 4.61, the GDP growth rate appears to increase after a credit positive shock. This result matches with one side of the bidirectional relationship between GDP and credit.

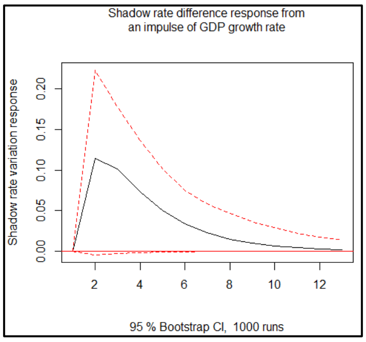


*Figure 4.62 – IRF of a GDP growth rate shock in SSR variation*

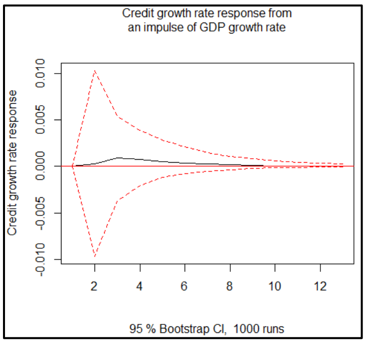


*Figure 4.63 – IRF of a GDP growth rate shock in credit growth rate*

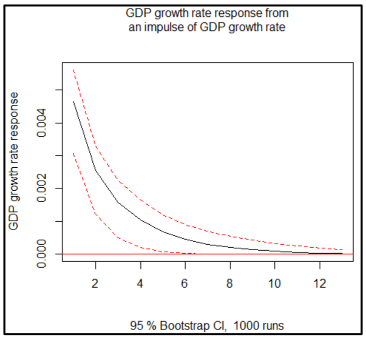


*Figure 4.64 – IRF of a GDP growth rate shock in GDP growth rate*

Observing figure 4.62, the IRF plotted indicates that there is an increase is the SSR after a positive GDP shock hits. As indicated before, this increase in the SSR represents a monetary policy tightening, which means that when GDP growth rate increases the ECB tightens the policy.

Regarding the reaction of credit to an impulse on GDP, plotted in figure 4.63, it is concluded that, alongside the result obtained from the analysis of the IRF in figure 4.61, the two-way relation between credit and GDP is confirmed for the Euro Area.

Looking at the forecast error variance decomposition of the Euro Area's variables included in the model, presented in tables A23, A24 and A25, it is concluded that it is the own variables that cause most of variables future uncertainty. Performing the same exclusion exercise done before, GDP contributes more for SSR uncertainty and it is the SSR that causes most of credit and GDP uncertainty.

CHAPTER 5

# Results Comparison

## 5.1. Reactions to a Short-run Shadow Rate shock

The IRFs show that, in the four countries under analysis, credit increases when there is a positive shock to the Short-run Shadow Rate. Japan presents the shorter response, that is, comparing to the other countries responses, the effect of the SSR shock in the Japanese credit fades away and becomes null more quickly. On the other hand, the response of longer duration, but of smaller magnitude, is found in the US. The UK and the Euro Area show similar response magnitude, however the first becomes null almost immediately.

These results show that the transmission of monetary policy changes to the "real" economy does not happen the same way economic theory advocates and, also, that these results are not in accordance with the literature. While some authors found that, after a monetary policy tightening, credit was reduced (e.g. Aiyar et al. (2016)), others found that credit increased as an effect of Quantitative Easing (e.g. Bowman et al. (2015) and Kuttner (2018)) – a monetary policy easing.

The positive GDP reaction to a monetary policy tightening in the UK, the US and Euro Area may indicate that the relation between monetary policy and the GDP does not occur in a similar way as the defended by most economic thought streams. This result matches with the conclusions obtained by Lee and Werner (2018) despite they just use interest rates – most usual conventional monetary policy instrument – until 2008. The responses presented by the US and the Euro Area have similar length and size, while in the UK it is found the smaller size effect.

The exception is the case of the GDP response to a monetary policy change in Japan. Here there is a monetary policy transmission to the economy accordingly to the theory, despite the shorter reaction than the other countries.

## 5.2. Short-run Shadow Rate reactions to a credit shock

According to the economic theory, a shock in credit may lead to an increase in inflation and to a financial system unbalance. This may compromise Central Banks main objectives: price stability and financial system stability. Therefore, according to theory, Central Banks tighten monetary policy in order to contain the potential side effects from the credit hike.

There is a positive reaction of the SSR in the UK, the US and the Euro Area to a credit shock. The consequent monetary policy tightening after a positive credit shock matches up with the monetary policy reaction defended by the economic theory. The UK and the Euro Area present the larger reactions, in terms of magnitude. Analyzing the ratio of total credit to the private non-financial sector to the GDP (plotted in figure A25) it is possible to see that these two countries have the highest values. Therefore, it is possible to conclude that the existence of a higher credit proportion in relation to the GDP, drives the Central Banks to change monetary policy more aggressively when there is a positive credit shock. On its turn, the US have the lower credit-to-GDP ratio and, also, the smaller effect in the SSR after a credit shock.

Last, but not the least, Japan presents a negative sign and the shorter SSR response to a credit shock. In other words, the Bank of Japan eases monetary policy when credit increases. Knowing that credit can influence inflation and that Japanese inflation (plotted in figure A26) has been below the 2% target adopted in 2013 (Jahan, 2012), the BoJ may be using this shock to leverage the inflation.

## 5.3. Relation between GDP and credit

Japan presents the GDP reaction of greater magnitude to a shock in credit, despite the negative signal. Which, on its turn, meets with two facts: (i) credit-to-GDP ratio diminished over time and is the second lowest value; (ii) comparing to the other three countries, Japan has the second lowest conceded credit volume to the private non-financial sector. The negative GDP reaction to a credit shock suggests that credit does not have the stimulation effect over the economy. On the other hand, credit responds positively to a positive shock in GDP, which means that only one way of the GDP-credit relation is in accordance with the theory.

The low level of credit and the reduction of credit-to-GDP over time may be a signal of the reduction of the importance of credit in the Japanese economy. On its turn, this may indicate that the BoJ does not use credit to stimulate the economy, as was already suggested by the only one-directional positive relation between credit and GDP.

In the other three countries – the UK, the US and the Euro Area – there is a bidirectional relation between GDP and credit in accordance with the theory: the GDP grows when credit increases and credit grows when the economy is expanding.

Regarding GDP reaction to a credit shock, the UK and the US have similar responses in terms of size and length. The Euro Area appears to have the smaller reaction.

Lastly, Japan presents the smaller credit reaction (in terms of size and length) to a GDP shock, the UK has the longer response and the US have the larger effect.

## 5.4. Short-run Shadow Rate reactions to a GDP shock

The four countries under analysis present a positive SSR reaction following a GDP shock.

The smaller and shorter occurs in Japan. It is known that inflation is a procyclical variable, which means that it tends to follow and/or to magnify the economic cycle. When a positive GDP shock hits the economy, then it would be the case for inflation to increase as well. As stated before, Japanese inflation has been below the target, therefore the BoJ does not tighten monetary policy as much as the other countries, so that inflation can rise and get closer to the target. In the case of Japan, it would be important for the inflation to rise in order to avoid the danger of deflation, which is an identified problem in the Japanese economy over the past decades.

The UK and the Euro Area present similar responses and of larger size. Also, knowing that inflation in both countries has been unstable (as presented in figures A27 and A29), namely in the most recent years, the Central Banks react more aggressively to a GDP shock in order to smooth its cycle. The Bank of England and the ECB would present a more aggressive reaction in order to ensure price stability and to promote a non-inflationary growth.

## 5.5. Forecast Error Variance Decomposition

In Japan, the UK, the US and the Euro Area most of the variables' forecast uncertainty is caused by the own variables. This means that it is the own variables that explain most of their future. Comparing these results with the estimated parameters of the VAR model (presented in tables A6, A11, A16 and A21 in the annexes), it is possible to conclude that, in general, the variables that present larger influence over the dependent variable, i.e., that have a larger parameter estimation do not match with the own dependent variable. The exception appears in the equation where the present value of GDP growth rate is the dependent variable: it is the first lag of this variable that presents the larger estimated parameter.

If the own variables are excluded, the variables that contribute the most to the variables' forecast error variance are summarized in table 5.1. In the four countries, the SSR is the second variable that accounts for most of the forecast error variance of the credit. In three out of the four countries – Japan, US and Euro Area – the GDP is the second most relevant variable for the future uncertainty. Despite the unveiled patterns, the very insignificant contribution of these variables to the forecast uncertainty does not make it possible to assign an economic meaning to it.

It is possible to say that, in the respective forecast error variance analysis, the Short-run Shadow Rate, the credit and the GDP are strongly endogenous, while the other variables exhibit strong exogeneity.

*Table 5.1 – Second most important variables to the forecast error variance of each variable in each country in the 1st, 2nd and 12th step*

| Japan | | | |
|---|---|---|---|
| Influenced Variables / Step | SSR variation | Credit growth rate | GDP growth rate |
| 1 | - | SSR variation | SSR variation |
| 2 | GDP growth rate | SSR variation | Credit growth rate |
| 12 | GDP growth rate | SSR variation | Credit growth rate |
| **UK** | | | |
| Influenced Variables / Step | SSR variation | Credit growth rate | GDP growth rate |
| 1 | - | SSR variation | Credit growth rate |
| 2 | Credit growth rate | SSR variation | Credit growth rate |
| 12 | Credit growth rate | SSR variation | Credit growth rate |
| **US** | | | |
| Influenced Variables / Step | SSR variation | Credit growth rate | GDP growth rate |
| 1 | - | SSR variation | SSR variation |
| 2 | GDP growth rate | SSR variation | SSR variation |
| 12 | GDP growth rate | SSR variation | SSR variation |
| **Euro Area** | | | |
| Influenced Variables / Step | SSR variation | Credit growth rate | GDP growth rate |
| 1 | - | SSR variation | SSR variation |
| 2 | GDP growth rate | SSR variation | SSR variation |
| 12 | GDP growth rate | SSR variation | SSR variation |

CHAPTER 6

# Conclusion

This dissertation studied the relationship between monetary policy credit and economic growth, in Japan, the UK, the US and the Euro Area. To represent monetary policy, this study uses the short-run Shadow Rate since it is a better representative of the unconventional monetary policy.

A monetary policy tightening was found to produce positive responses of GDP and credit in the UK, the US and Euro Area, a result that suggests that the transmission of monetary policy changes to the economy may not happen as theoretically thought.

Besides inflation, which is already targeted by some Central Banks, the proportion of credit to the size of the economies appear to explain the differences in monetary policy responses to shocks in credit and GDP.

In the UK, the US and the Euro Area, was found a positive correlation between credit and economic growth – an increase in credit leads to an economic expansion and during an expansionary phase of the cycle, credit increases. In Japan, the evolution of the credit-to-GDP ratio and the conceded credit volume are explanatory factors of the negative GDP reaction to a credit shock.

This thesis has several limitations that may have contributed to its results. First, it has chosen to use SSR to represent monetary policy. Despite there are some authors that use the SSR as a monetary policy representative (e.g. Wu and Xia (2016) and Damjanovic and Masten (2016)) and claim that this is a good monetary policy representative (e.g. Claus et al. (2014)), there are some limitations with the use of the Short-run Shadow Rate. It is obtained from financial data, therefore it is not directly controlled by central banks and, also, it is not an interest rate at which economic agents can trade or invest (Krippner, 2016).

Besides this inherent limitation with the use of the SSR, two other limitations can be identified in this dissertation.

First, two macroeconomic variables were used in this study. In order to better represent the economy, other macro variables could be added to the VAR model, e.g., unemployment rate and/or inflation. Besides price stability, "full-employment" is also an objective that Central Banks intend to achieve. Therefore, the analysis of how unemployment rate and inflation respond to and influence changes in monetary policy, GDP and credit is also of relative importance. It could also be added to the estimated model other credit related variables, namely the credit-to-GDP ratio and/or the volume of credit conceded by banks or its proportion to total credit. These variables would allow to find how credit evolves relatively to GDP, in the first case, and how much banks would be sought to concede credit, in the latter case.

Secondly, in this study, the Euro Area is treated as one country, while it is constituted by a set of countries that, naturally, present some differences. This limitation could be overtaken by splitting the data between the Euro Area countries, which would increase the number of analyzed countries and would imply the estimation of Short-run Shadow Rates for each country.

The inclusion of the previously suggested variables and the division of the Euro Area data by countries would present leads for future research. Another suggestion would be the employment of the same methodology used here but dividing the time period. This division would be according to whether the ZLB is binding or not or to when unconventional monetary policy is adopted or not. This would allow to study if during conventional policy/non-binding ZLB times, the theoretical perspective of how monetary policy affects economic growth and credit is valid or not. And, if it is valid, if it is the application of unconventional monetary policies that changes these relations.

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Bank for International Settlements (BIS), Organization for Economic Co-operation and Development (OECD) and Reserve Bank of New Zealand (RBNZ).

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# Annexes

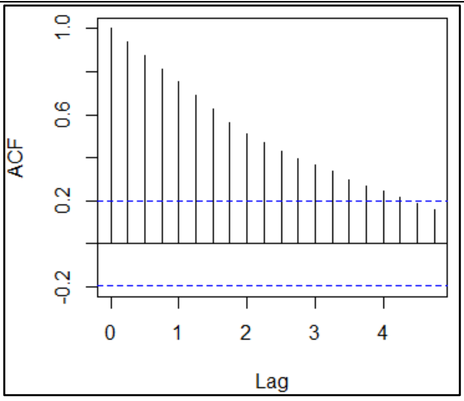


*Figure A1 – Autocorrelation function of the Japanese shadow rate*

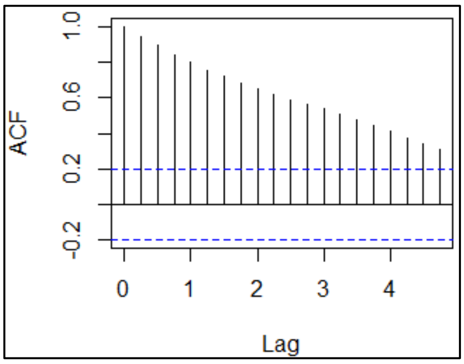


*Figure A2 – Autocorrelation function of Japan's GDP*

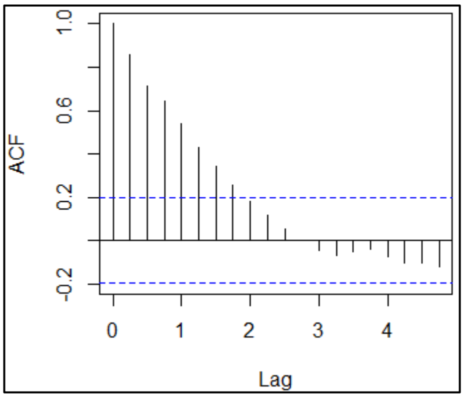


*Figure A3 – Autocorrelation function of Japan's total credit to the private non-financial sector*

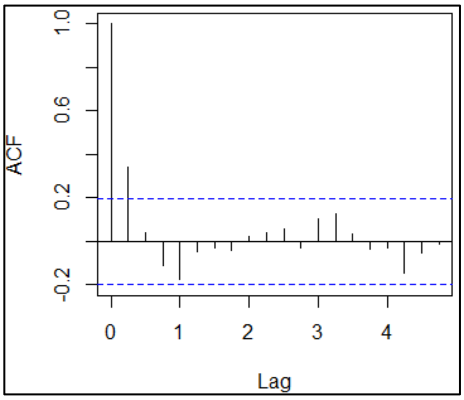


*Figure A4 – Autocorrelation function of the Japanese Short-run Shadow Rate first difference*

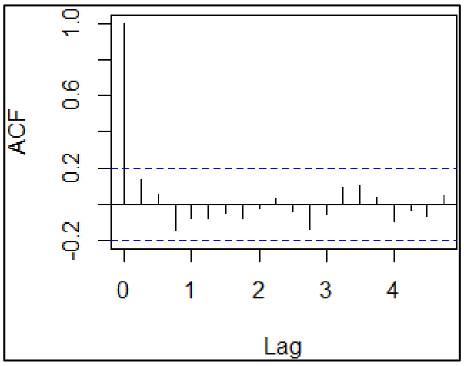


*Figure A5 – Autocorrelation function of Japanese GDP log-difference*

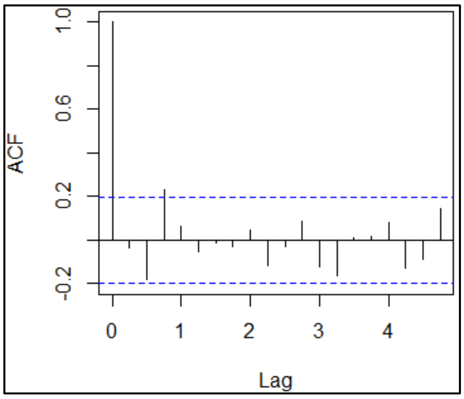


*Figure A6 – Autocorrelation function of the Japanese total credit growth rate*

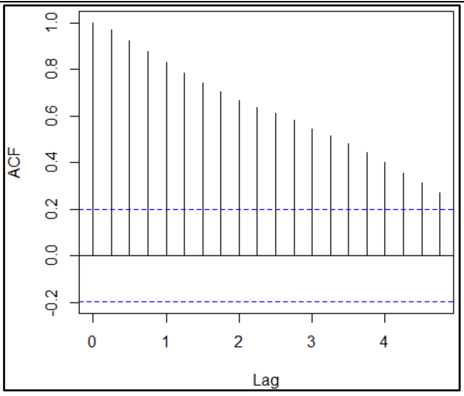


*Figure A7 – Autocorrelation function of UK's shadow rate*

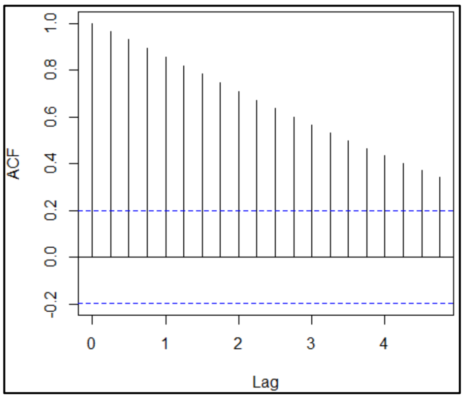


*Figure A8 – Autocorrelation function of UK's GDP*

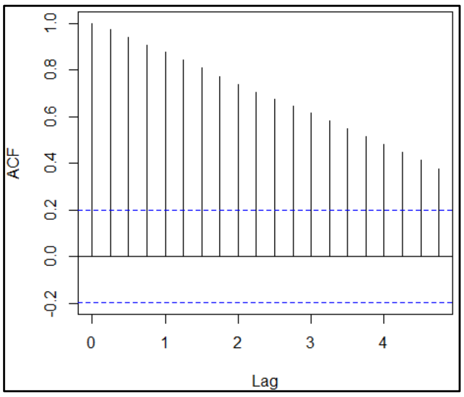


*Figure A9 – Autocorrelation function of UK's total credit to the private non-financial sector*

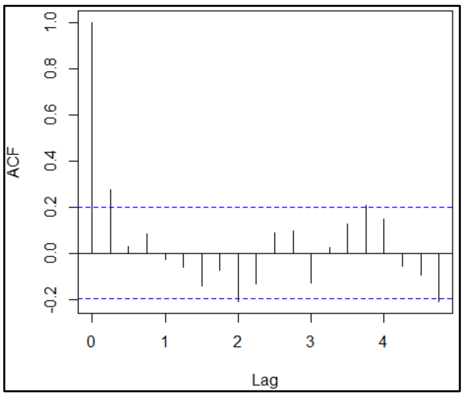


*Figure A10 – Autocorrelation function of UK's Short-run Shadow Rate first difference*

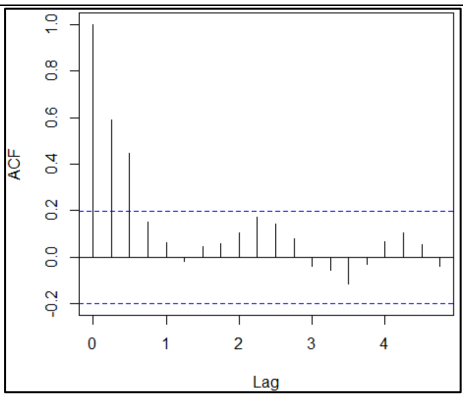


*Figure A11 – Autocorrelation function of the UK GDP log-difference*

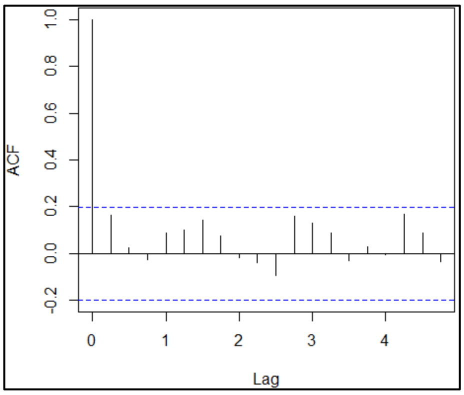


*Figure A12 – Autocorrelation function of UK's total credit growth rate*

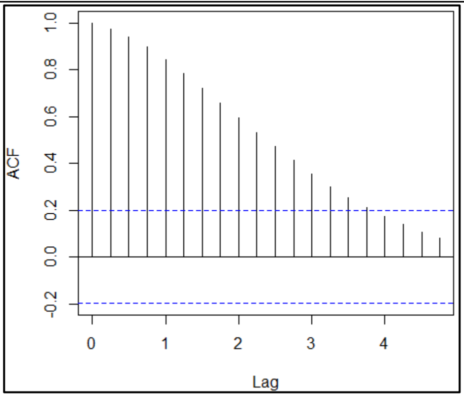


*Figure A13 – Autocorrelation function of US' shadow rate*

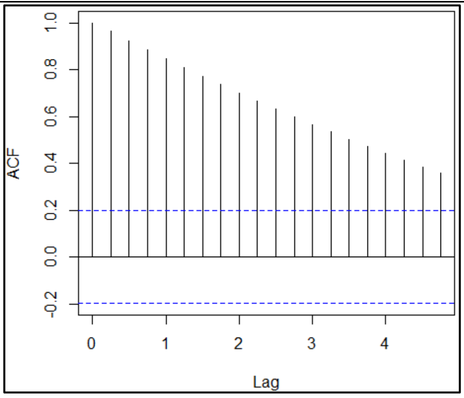


*Figure A14 – Autocorrelation function of US' GDP*

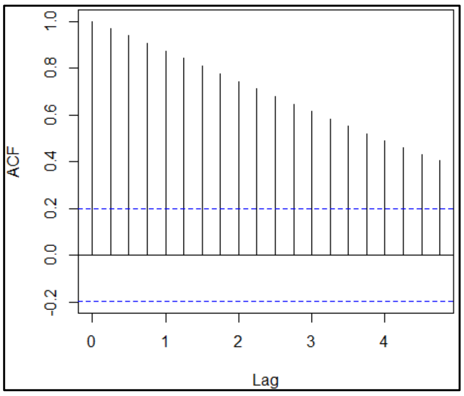


*Figure A15 – Autocorrelation function of US' total credit to the private non-financial sector*

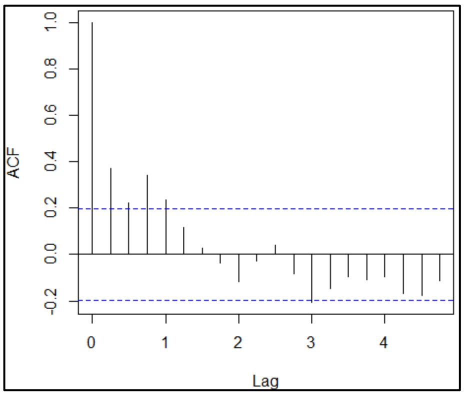


*Figure A16 – Autocorrelation function of the US' Short-run Shadow Rate first difference*

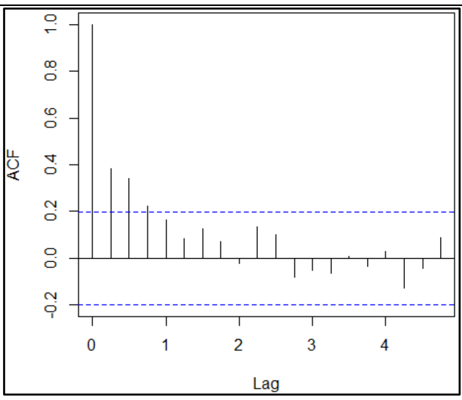


*Figure A17 – Autocorrelation function of the US GDP log-difference*

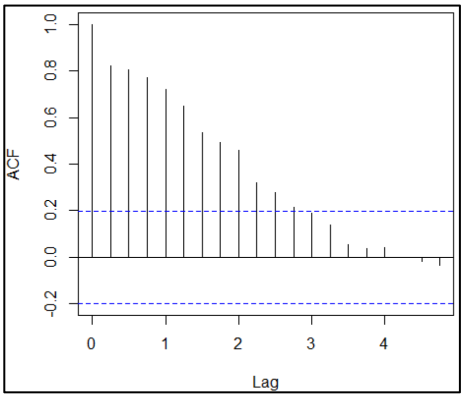


*Figure A18 – Autocorrelation function of US' total credit growth rate*

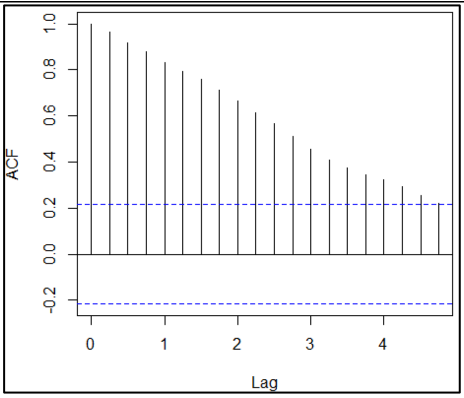


*Figure A19 – Autocorrelation function of EA's shadow rate*

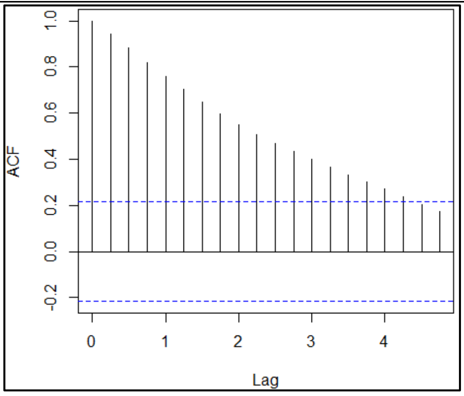


*Figure A20 – EA's GDP autocorrelation function*

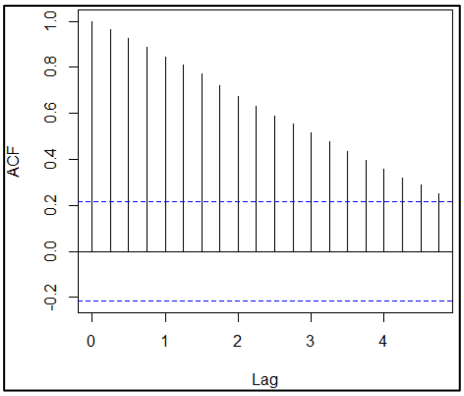


*Figure A21 – Autocorrelation function of EA's total credit to the private non-financial sector*

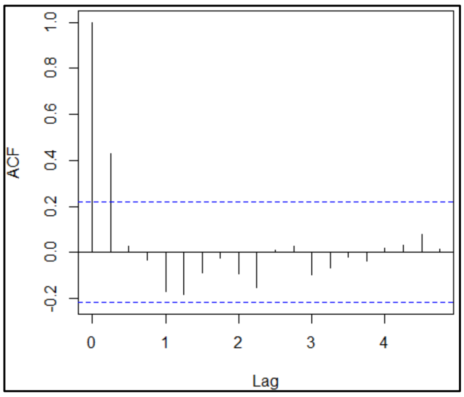


*Figure A22 – Autocorrelation function of the EA's Short-run Shadow Rate first difference*

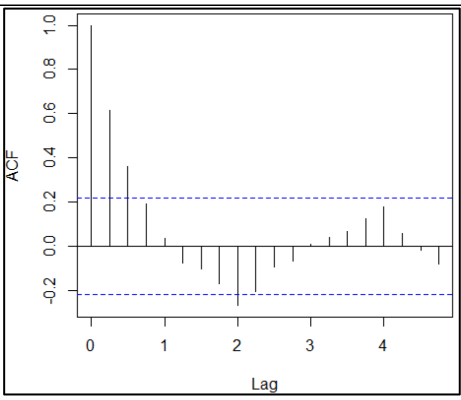


*Figure A23 – Autocorrelation function of the EA GDP log-difference*

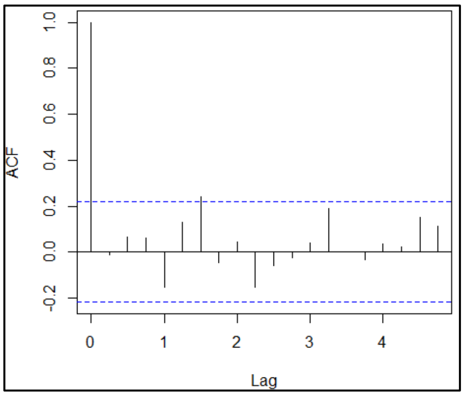


*Figure A24 – Autocorrelation function of EA's total credit growth rate*

| | Tau1 | Tau2 | Tau3 | Phi1 | Phi2 | Phi3 |
|---|---|---|---|---|---|---|
| 1% | -2.6 | -3.51 | -4.04 | 6.70 | 6.50 | 8.73 |
| 5% | -1.95 | -2.89 | -3.45 | 4.71 | 4.88 | 6.49 |
| 10% | -1.61 | -2.58 | -3.15 | 3.86 | 4.16 | 5.47 |

*Table A1 – Critical values for Augmented Dickey-Fuller test*

| | | Tau1 | Tau2 | Tau3 | Phi1 | Phi2 | Phi3 |
|---|---|---|---|---|---|---|---|
| Japan | SSR | 0.9349 | -0.0886 | -1.374 | 1.0414 | 1.7329 | 1.5329 |
| | GDP | 1.4968 | -0.8296 | -2.6733 | 1.5208 | 3.2499 | 3.6109 |
| | Credit | -0.7297 | -2.7152 * | -2.5756 | 3.8117 | 2.6168 | 3.8009 |
| UK | SSR | -1.962 ** | -1.8472 | -1.8563 | 1.927 | 1.5177 | 2.0565 |
| | GDP | 2.7859 | -1.0308 | -2.0077 | 4.8692 ** | 4.4299 * | 2.1715 |
| | Credit | 0.4494 | -2.1762 | -1.6417 | 2.8274 | 1.8598 | 2.3364 |
| US | SSR | -2.8105 *** | -2.7663 * | -2.4517 | 3.9494 | 2.6418 | 3.8408 |
| | GDP | 4.0967 | 0.3923 | -1.3468 | 8.2956 *** | 6.3159 ** | 1.1321 |
| | Credit | 1.1775 | -0.6247 | -2.8094 | 1.2644 | 3.4135 | 3.9561 |
| EA | SSR | -0.7298 | -0.86 | -3.3126 * | 0.7631 | 4.1297 | 5.736 * |
| | GDP | 1.5193 | -0.7966 | -2.1769 | 1.5283 | 2.4604 | 2.4136 |
| | Credit | 0.7948 | -2.3972 | -2.2617 | 3.5761 | 2.548 | 3.1246 |

*Table A2 – ADF test statistics (Note: the null hypothesis is rejected at: *** 1%, ** 5% and *10%)*

| | | Tau1 | Tau2 | Tau3 | Phi1 | Phi2 | Phi3 |
|---|---|---|---|---|---|---|---|
| Japan | SSR variation | -5.1178*** | -5.3862*** | -5.5466*** | 14.5257*** | 10.2687*** | 15.3825*** |
| | GDP growt h rate | -5.2089*** | -5.8327*** | -5.7874*** | 17.0111*** | 11.1899*** | 16.7841*** |
| | Credit growth rate | -4.321*** | -4.3003*** | -7.3802*** | 9.2613*** | 18.1644*** | 27.2337*** |
| UK | SSR variation | -5.4171*** | -5.4333*** | -5.4777*** | 14.7607*** | 10.0036*** | 15.0053*** |
| | GDP growth rate | -3.2306*** | -4.4377*** | -4.5205*** | 9.857*** | 6.8387*** | 10.2477*** |
| | Credit growth rate | -5.5248*** | -5.7446*** | -6.3182*** | 16.5003*** | 13.3215*** | 19.9822*** |
| US | SSR variation | -2.9569*** | -2.9739** | -3.2481* | 4.4421* | 3.5622 | 5.3229 |
| | GDP growth rate | -3.0433*** | -4.3989*** | -4.3787*** | 9.7053*** | 6.4987** | 9.718*** |
| | Credit growth rate | -1.5924 | -2.0031 | -1.893 | 2.1074 | 1.4076 | 2.0115 |
| EA | SSR variation | -4.5807*** | -4.6933*** | -4.6756*** | 11.07*** | 7.3854*** | 11.0226*** |
| | GDP growth rate | -3.0585*** | -3.416** | -3.3968* | 5.84** | 3.8535 | 5.775* |
| | Credit growth rate | -5.0373*** | -5.2181*** | -5.4186*** | 13.6152*** | 9.788*** | 14.6809*** |

*Table A3 – ADF test statistics (Note: the null hypothesis is rejected at: *** 1%, ** 5% and *10%)*

| | 10% | 5% | 2.5% | 1% |
|---|---|---|---|---|
| Intercept | 0.347 | 0.463 | 0.574 | 0.739 |
| Trend | 0.119 | 0.146 | 0.176 | 0.216 |

*Table A4 – Critical values for KPSS test*

| | Intercept | | | Trend | | |
|---|---|---|---|---|---|---|
| | nil | short | long | nil | short | long |
| US SSR variation | 0.3895* | 0.1999 | 0.1338 | 0.1828*** | 0.0961 | 0.0671 |
| US Credit growth rate | 3.324**** | 0.9709**** | 0.4024* | 0.6033**** | 0.1868*** | 0.0876 |
| EA GDP growth rate | 0.3813* | 0.1602 | 0.1583 | 0.2815**** | 0.1189 | 0.1188 |

*Table A5 – KPSS test statistics (Note: the null hypothesis is rejected at: **** 1%, *** 2.5%, ** 5% and *10%)*

| VAR Estimation Results: | | | | |
|---|---|---|---|---|
| Sample size: 96 | | | | |
| Log likelihood: 405.491 | | | | |
| Roots of characteristic polynomial: 0.27007671; 0.22200002; 0.04607597 | | | | |
| Estimation results for equation $ssr_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$ | | | | |
| | Estimate | Standard Error | t test value | P-value |
| $ssr_{t-1}$ | 0.34318 | 0.09541 | 3.597 | 0.000521 |
| $credit_{t-1}$ | -0.23202 | 0.71963 | -0.322 | 0.747873 |
| $gdp_{t-1}$ | 3.22487 | 4.33518 | 0.744 | 0.458843 |
| $c_1$ | -0.07127 | 0.04395 | -1.622 | 0.108295 |
| Residual standard error: 0.04059 on 92 degrees of freedom | | | | |
| Multiple R-Squared: 0.1301; Adjusted R-Squared:0.1017 | | | | |
| F-Statistic: 4.585 on 3 and 92 degrees of freedom; p-value: 0.004886 | | | | |
| Estimation results for equation $credit_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$ | | | | |
| | Estimate | Standard Error | t test value | P-value |
| $ssr_{t-1}$ | 0.010384 | 0.013791 | 0.753 | 0.453 |
| $credit_{t-1}$ | -0.036554 | 0.104013 | -0.351 | 0.726 |
| $gdp_{t-1}$ | 0.014053 | 0.626594 | 0.022 | 0.982 |
| $c_2$ | -0.003753 | 0.006352 | -0.591 | 0.556 |
| Residual standard error: 0.05867 on 92 degrees of freedom | | | | |
| Multiple R-Squared: 0.00733; Adjusted R-Squared: -0.02504 | | | | |
| F-statistic: 0.2265 on 3 and 92 degrees of freedom; p-value: 0.8778 | | | | |
| Estimation results for equation $gdp_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$ | | | | |
| | Estimate | Standard Error | t test value | P-value |
| $ssr_{t-1}$ | -0.001269 | 0.002187 | -0.580 | 0.5631 |
| $credit_{t-1}$ | -0.042022 | 0.016492 | -2.548 | 0.0125 |
| $gdp_{t-1}$ | 0.139376 | 0.099350 | 1.403 | 0.1640 |
| $c_3$ | 0.001573 | 0.001007 | 1.562 | 0.1218 |
| Residual standard error: 0.009303 on 92 degrees of freedom | | | | |
| Multiple R-Squared: 0.08713; Adjusted R-Squared: 0.05736 | | | | |
| F-statistic: 2.927 on 3 and 92 degrees of freedom; p-value: 0.03788 | | | | |

*Table A6 – Japan's VAR model estimation results*

| |
|---|
| ARCH test (multivariate):<br>Chi-squared: 190.51; Degrees of freedom: 180; p-value: 0.2814 |
| Jarque-Bera test (multivariate):<br>Chi-squared: 72.176; Degrees of freedom: 6; p-value: 0.0000000000001462 |
| Skewness only (multivariate):<br>Chi-squared: 18.152; Degrees of freedom: 3; p-value: 0.0004092 |
| Kurtosis only (multivariate):<br>Chi-squared: 54.024; Degrees of freedom: 3; p-value: 0.00000000001109 |
| Portmanteau test (asymptotic):<br>Chi-squared: 113.67; Degrees of freedom: 135; p-value: 0.9086 |
| Portmanteau test (adjusted):<br>Chi-squared: 124.52; Degrees of freedom: 135; p-value: 0.7305 |
| Breusch-Godfrey LM test:<br>Chi-squared: 50.069; Degrees of freedom: 45; p-value: 0.2792 |

*Table A7 – Results of diagnostic tests on Japan's estimated model*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 1.0000000 | 0.000000000 | 0.000000000 |
| 2 | 0.9941717 | 0.001004139 | 0.004824198 |
| 3 | 0.9923606 | 0.001774658 | 0.005864706 |
| 4 | 0.9920933 | 0.001900074 | 0.006006614 |
| 5 | 0.9920628 | 0.001915136 | 0.006022098 |
| 6 | 0.9920597 | 0.001916667 | 0.006023592 |
| 7 | 0.9920595 | 0.001916809 | 0.006023726 |
| 8 | 0.9920594 | 0.001916821 | 0.006023737 |
| 9 | 0.9920594 | 0.001916822 | 0.006023738 |
| 10 | 0.9920594 | 0.001916822 | 0.006023738 |
| 11 | 0.9920594 | 0.001916822 | 0.006023738 |
| 12 | 0.9920594 | 0.001916822 | 0.006023738 |

*Table A8 – Forecast error variance decomposition of Japan's SSR variation*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.0000158018 | 0.9999842 | 0.000000 |
| 2 | 0.0051432182 | 0.9948519 | 0.000004912368 |
| 3 | 0.0056322996 | 0.9943325 | 0.00003524547 |
| 4 | 0.0056839380 | 0.9942752 | 0.00004087814 |
| 5 | 0.0056887046 | 0.9942697 | 0.00004159571 |
| 6 | 0.0056891203 | 0.9942692 | 0.00004167084 |
| 7 | 0.0056891550 | 0.9942692 | 0.00004167792 |
| 8 | 0.0056891578 | 0.9942692 | 0.00004167854 |
| 9 | 0.0056891580 | 0.9942692 | 0.00004167859 |
| 10 | 0.0056891580 | 0.9942692 | 0.00004167860 |
| 11 | 0.0056891580 | 0.9942692 | 0.00004167860 |
| 12 | 0.0056891580 | 0.9942692 | 0.00004167860 |

*Table A9 – Forecast error variance decomposition of Japan's credit growth rate*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.004122432 | 0.000002353128 | 0.9958752 |
| 2 | 0.005840112 | 0.06443039 | 0.9297295 |
| 3 | 0.007667593 | 0.06485093 | 0.9274815 |
| 4 | 0.007975679 | 0.06483245 | 0.9271919 |
| 5 | 0.008012969 | 0.06483079 | 0.9271562 |
| 6 | 0.008016773 | 0.06483081 | 0.9271524 |
| 7 | 0.008017126 | 0.06483083 | 0.9271520 |
| 8 | 0.008017157 | 0.06483083 | 0.9271520 |
| 9 | 0.008017159 | 0.06483083 | 0.9271520 |
| 10 | 0.008017159 | 0.06483083 | 0.9271520 |
| 11 | 0.008017159 | 0.06483083 | 0.9271520 |
| 12 | 0.008017159 | 0.06483083 | 0.9271520 |

*Table A10 – Forecast error variance decomposition of Japan's GDP growth rate*

| VAR Estimation Results: | | | | |
|---|---|---|---|---|
| Sample size: 96 | | | | |
| Log likelihood: 456.446 | | | | |
| Roots of characteristic polynomial: 0.6055816; 0.1071699; 0.1071699 | | | | |
| Estimation results for equation $ssr_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$ | | | | |
| | Estimate | Standard Error | t test value | P-value |
| $ssr_{t-1}$ | 0.1599 | 0.1025 | 1.560 | 0.1223 |
| $credit_{t-1}$ | 3.0239 | 1.8114 | 1.669 | 0.0984 |
| $gdp_{t-1}$ | 26.3044 | 13.7773 | 1.909 | 0.0593 |
| $c_1$ | -0.2239 | 0.1002 | -2.235 | 0.0279 |
| Residual standard error: 0.6981 on 92 degrees of freedom | | | | |
| Multiple R-Squared: 0.1598; Adjusted R-Squared: 0.1324 | | | | |
| F-Statistic: 5.833 on 3 and 92 degrees of freedom; p-value: 0.001079 | | | | |
| Estimation results for equation $credit_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$ | | | | |
| | Estimate | Standard Error | t test value | P-value |
| $ssr_{t-1}$ | -0.001799 | 0.006308 | -0.285 | 0.7761 |
| $credit_{t-1}$ | 0.093364 | 0.111453 | 0.838 | 0.4044 |
| $gdp_{t-1}$ | 1.652673 | 0.847685 | 1.950 | 0.0543 |
| $c_2$ | 0.001645 | 0.006165 | 0.267 | 0.7902 |
| Residual standard error: 0.04295 on 92 degrees of freedom | | | | |
| Multiple R-Squared: 0.06591; Adjusted R-Squared: 0.03545 | | | | |
| F-statistic: 2.164 on 3 and 92 degrees of freedom; p-value: 0.09763 | | | | |
| Estimation results for equation $gdp_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$ | | | | |
| | Estimate | Standard Error | t test value | P-value |
| $ssr_{t-1}$ | 0.0001647 | 0.0006873 | 0.240 | 0.81111 |
| $credit_{t-1}$ | 0.0148887 | 0.0121425 | 1.226 | 0.22327 |
| $gdp_{t-1}$ | 0.5486588 | 0.0923530 | 5.941 | 0.00000005 |
| $c_3$ | 0.0021335 | 0.0006716 | 3.177 | 0.00203 |
| Residual standard error: 0.004679 on 92 degrees of freedom | | | | |
| Multiple R-Squared: 0.3639; Adjusted R-Squared: 0.3432 | | | | |
| F-statistic: 17.54 on 3 and 92 degrees of freedom; p-value: 0.000000004346 | | | | |

*Table A11 – UK's VAR model estimation results*

| |
|---|
| ARCH test (multivariate):<br>Chi-squared: 244.47; Degrees of freedom: 180; p-value: 0.0009861 |
| Jarque-Bera test (multivariate):<br>Chi-squared: 301.57; Degrees of freedom: 6; p-value: <2.2e-16 |
| Skewness only (multivariate):<br>Chi-squared: 6.9705; Degrees of freedom: 3; p-value: 0.07284 |
| Kurtosis only (multivariate):<br>Chi-squared: 294.6; Degrees of freedom: 3; p-value: <2.2e-16 |
| Portmanteau test (asymptotic):<br>Chi-squared:157.77; Degrees of freedom: 135; p-value: 0.08773 |
| Portmanteau test (adjusted):<br>Chi-squared:174.77; Degrees of freedom: 135; p-value: 0.01202 |
| Breusch-Godfrey LM test:<br>Chi-squared: 46.144; Degrees of freedom: 45; p-value: 0.4247 |

*Table A12 – Results of diagnostic tests on UK's estimated model*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 1.0000000 | 0.00000000 | 0.00000000 |
| 2 | 0.9286954 | 0.04622558 | 0.02507905 |
| 3 | 0.9007165 | 0.05547021 | 0.04381331 |
| 4 | 0.8904923 | 0.05787592 | 0.05163177 |
| 5 | 0.8867794 | 0.05867041 | 0.05455020 |
| 6 | 0.8854250 | 0.05895470 | 0.05562029 |
| 7 | 0.8849294 | 0.05905840 | 0.05601219 |
| 8 | 0.8847478 | 0.05909638 | 0.05315580 |
| 9 | 0.8846812 | 0.05911031 | 0.05620846 |
| 10 | 0.8846568 | 0.05911541 | 0.05622777 |
| 11 | 0.8846479 | 0.05911729 | 0.05623485 |
| 12 | 0.8846446 | 0.05911797 | 0.05623744 |

*Table A13 – Forecast error variance decomposition of UK's SSR variation*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.05857826 | 0.9414217 | 0.00000000 |
| 2 | 0.05600692 | 0.9157994 | 0.02819368 |
| 3 | 0.05548449 | 0.9062492 | 0.03826634 |
| 4 | 0.05537077 | 0.9029337 | 0.04169551 |
| 5 | 0.05533748 | 0.9017421 | 0.04292038 |
| 6 | 0.05532593 | 0.9013077 | 0.04336641 |
| 7 | 0.05532174 | 0.9011486 | 0.04352969 |
| 8 | 0.05532021 | 0.9010902 | 0.04358955 |
| 9 | 0.05531964 | 0.9010689 | 0.04361149 |
| 10 | 0.05531944 | 0.9010610 | 0.04361954 |
| 11 | 0.05531936 | 0.9010581 | 0.04362249 |
| 12 | 0.05531933 | 0.9010571 | 0.04362357 |

*Table A14 – Forecast error variance decomposition of UK's credit growth rate*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.01288360 | 0.07458524 | 0.9125312 |
| 2 | 0.01991858 | 0.11276340 | 0.8673180 |
| 3 | 0.02166568 | 0.12394430 | 0.8543900 |
| 4 | 0.02220093 | 0.12759166 | 0.8502074 |
| 5 | 0.02238522 | 0.12886783 | 0.8487470 |
| 6 | 0.02245143 | 0.12932785 | 0.8482207 |
| 7 | 0.02247555 | 0.12949551 | 0.8480289 |
| 8 | 0.02248438 | 0.12955687 | 0.8479588 |
| 9 | 0.02248761 | 0.12957935 | 0.8479236 |
| 10 | 0.02248880 | 0.12958759 | 0.8479236 |
| 11 | 0.02248923 | 0.12959061 | 0.8479202 |
| 12 | 0.02248939 | 0.12959172 | 0.8479189 |

*Table A15 – Forecast error variance decomposition of UK's GDP growth rate*

VAR Estimation Results:

Sample size: 96

Log likelihood: 670.996

Roots of characteristic polynomial: 0.8032704; 0.3973254; 0.1812769

Estimation results for equation $ssr_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$

| | Estimate | Standard Error | t test value | P-value |
|---|---|---|---|---|
| $ssr_{t-1}$ | 0.34267 | 0.10571 | 3.242 | 0.00166 |
| $credit_{t-1}$ | 0.22968 | 6.47217 | 0.035 | 0.97177 |
| $gdp_{t-1}$ | 6.6616 | 11.08172 | 0.602 | 0.54896 |
| $c_1$ | -0.06774 | 0.10391 | -0.652 | 0.51608 |

Residual standard error: 0.5391 on 92 degrees of freedom

Multiple R-Squared: 0.1425; Adjusted R-Squared: 0.1145

F-Statistic: 5.095 on 3 and 92 degrees of freedom; p-value: 0.002626

Estimation results for equation $credit_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$

| | Estimate | Standard Error | t test value | P-value |
|---|---|---|---|---|
| $ssr_{t-1}$ | 0.0004896 | 0.0010647 | 0.460 | 0.647 |
| $credit_{t-1}$ | 0.7798842 | 0.0651894 | 11.963 | <2e-16 |
| $gdp_{t-1}$ | 0.1266646 | 0.1116181 | 1.135 | 0.259 |
| $c_2$ | 0.0020875 | 0.0010466 | 1.995 | 0.049 |

Residual standard error: 0.00543 on 92 degrees of freedom

Multiple R-Squared: 0.684; Adjusted R-Squared: 0.6737

F-statistic: 66.38 on 3 and 92 degrees of freedom; p-value: < 2.0e-16

Estimation results for equation $gdp_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$

| | Estimate | Standard Error | t test value | P-value |
|---|---|---|---|---|
| $ssr_{t-1}$ | 0.001513 | 0.001062 | 1.424 | 0.15788 |
| $credit_{t-1}$ | 0.089574 | 0.065047 | 1.377 | 0.17183 |
| $gdp_{t-1}$ | 0.259318 | 0.111374 | 2.328 | 0.02208 |
| $c_3$ | 0.003405 | 0.001044 | 3.261 | 0.00156 |

Residual standard error: 0.005419 on 92 degrees of freedom

Multiple R-Squared: 0.1837; Adjusted R-Squared: 0.1571

F-statistic: 6.9 on 3 and 92 degrees of freedom; p-value: 0.0003051

*Table A16 – US' VAR model estimation results*

| |
|---|
| ARCH test (multivariate):<br>Chi-squared: 222.91; Degrees of freedom: 180; p-value: 0.01627 |
| Jarque-Bera test (multivariate):<br>Chi-squared: 54.52; Degrees of freedom: 6; p-value: 0.0000000005794 |
| Skewness only (multivariate):<br>Chi-squared: 2.938; Degrees of freedom: 3; p-value: 0.3926 |
| Kurtosis only (multivariate):<br>Chi-squared: 51.526; Degrees of freedom: 3; p-value: 0.00000000003779 |
| Portmanteau test (asymptotic):<br>Chi-squared: 154.17; Degrees of freedom: 135; p-value: 0.1239 |
| Portmanteau test (adjusted):<br>Chi-squared: 168.68; Degrees of freedom: 135; p-value: 0.02616 |
| Breusch-Godfrey LM test:<br>Chi-squared: 73.827; Degrees of freedom: 45; p-value: 0.004316 |

*Table A17 – Results of diagnostic tests on US' estimated model*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 1.0000000 | 0.0000000000 | 0.000000000 |
| 2 | 0.9964119 | 0.0003669609 | 0.003221146 |
| 3 | 0.9949950 | 0.0006839786 | 0.004321059 |
| 4 | 0.9945122 | 0.0008966278 | 0.004591178 |
| 5 | 0.9943102 | 0.0010330397 | 0.004656779 |
| 6 | 0.9942047 | 0.0011202295 | 0.004675030 |
| 7 | 0.9941426 | 0.0011761306 | 0.004681281 |
| 8 | 0.9941040 | 0.0012120713 | 0.004683931 |
| 9 | 0.9940795 | 0.0012352181 | 0.004685261 |
| 10 | 0.9940639 | 0.0012501390 | 0.004686009 |
| 11 | 0.9940538 | 0.0012597619 | 0.004686458 |
| 12 | 0.9940473 | 0.0012659694 | 0.004686737 |

*Table A18 – Forecast error variance decomposition of US' SSR variation*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.05763424 | 0.9423658 | 0.000000000 |
| 2 | 0.07851820 | 0.9138842 | 0.007597618 |
| 3 | 0.09324951 | 0.8941552 | 0.012595270 |
| 4 | 0.10267178 | 0.8818777 | 0.015450514 |
| 5 | 0.10852125 | 0.8743755 | 0.017103215 |
| 6 | 0.11213960 | 0.8697730 | 0.018087439 |
| 7 | 0.11439068 | 0.8669215 | 0.018687828 |
| 8 | 0.11580240 | 0.8651370 | 0.019060611 |
| 9 | 0.11669439 | 0.8640106 | 0.019294976 |
| 10 | 0.11726144 | 0.8632950 | 0.019443590 |
| 11 | 0.11762356 | 0.8628381 | 0.019538380 |
| 12 | 0.11785559 | 0.8625453 | 0.019599078 |

*Table A19 – Forecast error variance decomposition of US' credit growth rate*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.1099127 | 0.07368465 | 0.8164026 |
| 2 | 0.1539681 | 0.08593101 | 0.7601009 |
| 3 | 0.1667851 | 0.09408064 | 0.7391343 |
| 4 | 0.1703067 | 0.09952298 | 0.7301703 |
| 5 | 0.1713384 | 0.10309239 | 0.7255693 |
| 6 | 0.1716723 | 0.10540902 | 0.7229187 |
| 7 | 0.1717938 | 0.10690593 | 0.7213002 |
| 8 | 0.1718443 | 0.10787161 | 0.7202841 |
| 9 | 0.1718682 | 0.10849430 | 0.7196375 |
| 10 | 0.1718810 | 0.10889581 | 0.7192232 |
| 11 | 0.1718884 | 0.10915474 | 0.7189569 |
| 12 | 0.1718929 | 0.10932174 | 0.7187854 |

*Table A20 – Forecast error variance decomposition of US' GDP growth rate*

VAR Estimation Results:

Sample size: 80

Log likelihood: 385.934

Roots of characteristic polynomial: 0.66684923; 0.22946840; 0.04241164

Estimation results for equation $ssr_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$

| | Estimate | Standard Error | t test value | P-value |
|---|---|---|---|---|
| $ssr_{t-1}$ | 0.33085 | 0.11520 | 2.872 | 0.00528 |
| $credit_{t-1}$ | 0.5476 | 1.24580 | 0.436 | 0.66373 |
| $gdp_{t-1}$ | 24.70160 | 11.06850 | 2.232 | 0.02858 |
| $c_1$ | -0.15713 | 0.07503 | -2.094 | 0.03958 |

Residual standard error: 0.5352 on 76 degrees of freedom

Multiple R-Squared: 0.2482; Adjusted R-Squared: 0.2186

F-Statistic: 8.366 on 3 and 76 degrees of freedom; p-value: 0.00007094

Estimation results for equation $credit_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$

| | Estimate | Standard Error | t test value | P-value |
|---|---|---|---|---|
| $ssr_{t-1}$ | 0.006708 | 0.010829 | 0.619 | 0.5375 |
| $credit_{t-1}$ | -0.28751 | 0.117106 | -0.246 | 0.8067 |
| $gdp_{t-1}$ | 0.059114 | 1.040444 | 0.057 | 0.9548 |
| $c_2$ | 0.013446 | 0.007053 | 1.906 | 0.0604 |

Residual standard error: 0.05031 on 76 degrees of freedom

Multiple R-Squared: 0.006771; Adjusted R-Squared: -0.03244

F-statistic: 0.1727 on 3 and 76 degrees of freedom; p-value: 0.9145

Estimation results for equation $gdp_t = ssr_{t-1} + credit_{t-1} + gdp_{t-1} + c_1$

| | Estimate | Standard Error | t test value | P-value |
|---|---|---|---|---|
| $ssr_{t-1}$ | 0.001566 | 0.001038 | 1.509 | 0.1354 |
| $credit_{t-1}$ | -0.002677 | 0.011225 | -0.238 | 0.8122 |
| $gdp_{t-1}$ | 0.551802 | 0.099730 | 5.533 | 0.000000429 |
| $c_3$ | 0.001676 | 0.000676 | 2.479 | 0.0154 |

Residual standard error: 0.004822 on 76 degrees of freedom

Multiple R-Squared: 0.3971; Adjusted R-Squared: 0.3733

F-statistic: 16.69 on 3 and 76 degrees of freedom; p-value: 0.00000002011

*Table A21 – Euro Area's VAR model estimation results*

| |
|---|
| ARCH test (multivariate):<br>Chi-squared: 276.04; Degrees of freedom: 180; p-value: 0.000005386 |
| Jarque-Bera test (multivariate):<br>Chi-squared: 114.34; Degrees of freedom: 6; p-value: < 2.2e-16 |
| Skewness only (multivariate):<br>Chi-squared: 12.671; Degrees of freedom: 3; p-value: 0.005405 |
| Kurtosis only (multivariate):<br>Chi-squared: 101.67; Degrees of freedom: 3; p-value: <2.2e-16 |
| Portmanteau test (asymptotic):<br>Chi-squared: 99.197; Degrees of freedom: 135; p-value: 0.991 |
| Portmanteau test (adjusted):<br>Chi-squared: 110.2; Degrees of freedom: 135; p-value: 0.942 |
| Breusch-Godfrey LM test:<br>Chi-squared: 50.94; Degrees of freedom: 45; p-value: 0.2514 |

*Table A22 – Results of diagnostic tests on Euro Area's estimated model*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 1.0000000 | 0.000000000 | 0.00000000 |
| 2 | 0.9565508 | 0.005401876 | 0.03804736 |
| 3 | 0.9302015 | 0.006087099 | 0.06371136 |
| 4 | 0.9173510 | 0.006282212 | 0.07636682 |
| 5 | 0.9115087 | 0.006352495 | 0.08213879 |
| 6 | 0.9089004 | 0.006381304 | 0.08471832 |
| 7 | 0.9077407 | 0.006393729 | 0.08586554 |
| 8 | 0.9072254 | 0.006399192 | 0.08637536 |
| 9 | 0.9069964 | 0.006401611 | 0.08660195 |
| 10 | 0.9068946 | 0.006402685 | 0.08670267 |
| 11 | 0.9068494 | 0.006403162 | 0.08674746 |
| 12 | 0.9068293 | 0.006403374 | 0.08676737 |

*Table A23 – Forecast error variance decomposition of Euro Area's SSR variation*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.03252453 | 0.9674755 | 0.00000000000 |
| 2 | 0.03688365 | 0.9630868 | 0.00002958763 |
| 3 | 0.03760590 | 0.9620376 | 0.0003564739 |
| 4 | 0.03780529 | 0.9616190 | 0.0005756797 |
| 5 | 0.03787781 | 0.9614357 | 0.0006864888 |
| 6 | 0.03790773 | 0.9613544 | 0.0007378738 |
| 7 | 0.03792069 | 0.9613183 | 0.0007610511 |
| 8 | 0.03792640 | 0.9613022 | 0.0007714079 |
| 9 | 0.03792894 | 0.9612950 | 0.0007760211 |
| 10 | 0.03793006 | 0.9612919 | 0.0007780738 |
| 11 | 0.03793056 | 0.9612905 | 0.0007789867 |
| 12 | 0.03793078 | 0.9612898 | 0.0007793927 |

*Table A24 – Forecast error variance decomposition of Euro Area's credit growth rate*

| Step | SSR variation | Credit growth rate | GDP growth rate |
|---|---|---|---|
| 1 | 0.05482889 | 0.01871123 | 0.9264599 |
| 2 | 0.10460549 | 0.01530450 | 0.8800900 |
| 3 | 0.12808542 | 0.01478141 | 0.8571332 |
| 4 | 0.13843488 | 0.01462931 | 0.8469358 |
| 5 | 0.14296373 | 0.01457381 | 0.8424625 |
| 6 | 0.14495460 | 0.01455100 | 0.8404944 |
| 7 | 0.14583401 | 0.01454116 | 0.8396248 |
| 8 | 0.14622369 | 0.01453683 | 0.8392395 |
| 9 | 0.14639666 | 0.01453492 | 0.8390684 |
| 10 | 0.14647352 | 0.01453492 | 0.8389924 |
| 11 | 0.14650768 | 0.01453369 | 0.8389586 |
| 12 | 0.14652287 | 0.01453353 | 0.8389436 |

*Table A25 – Forecast error variance decomposition of Euro Area's GDP growth rate*

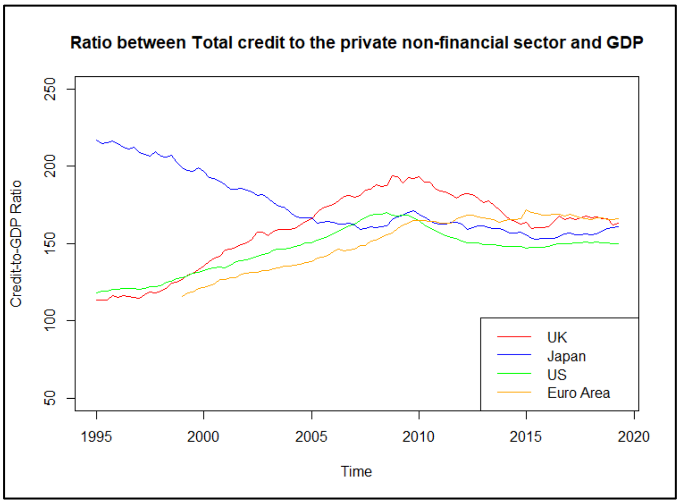


*Figure A25 – Quarterly ratio of Total credit to the private non-financial sector to the GDP in the UK, Japan, US (1995Q1 - 2019Q2) and Euro Area (1999Q1 - 2019Q2)*

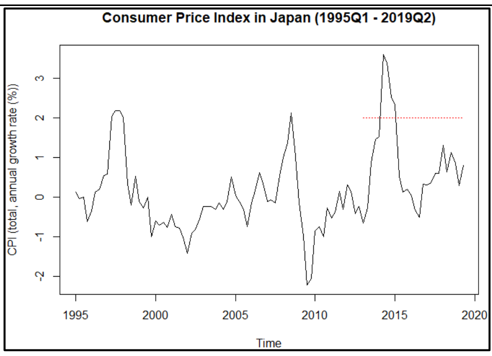


*Figure A26 – Quarterly consumer price index in Japan (Source: OECD)*

*(Note: the red dotted line represents the 2% inflation target adopted in 2013)*

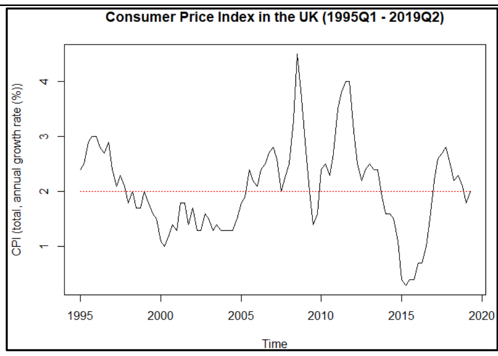


*Figure A27 – Quarterly consumer price index in the UK (Source: OECD)*

*(Note: the red dotted line represents the 2% inflation target adopted in 1992)*

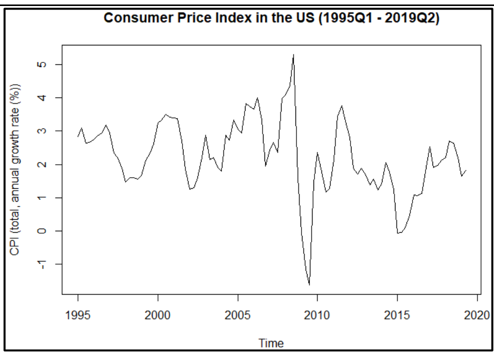


*Figure A28 – Quarterly consumer price index in the US (Source: OECD)*

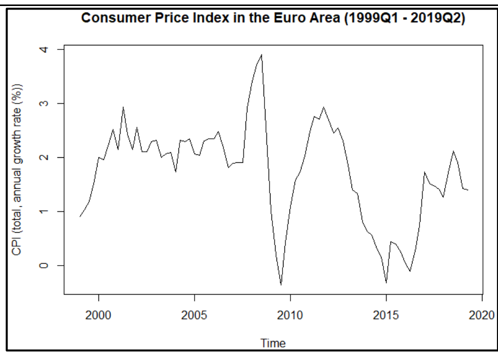


*Figure A29 – Quarterly consumer price index in the Euro Area (Source: OECD)*