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Banking liquidity and Systemic risk under Panel VAR approach

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Abstract

This paper aims to empirically analyze how changes in systemic risk, measured by the Composite Indicator of Systemic Stress (CISS), can affect banking liquidity and funding. We focus on and provide critical analysis of the maturity mismatch evolution, an indicator of liquidity, which is of integral importance for the well-functioning and stability of the financial system. For that purpose, we use the Panel VAR approach to carry out Impulse Response Functions to compare the effect between stress and non stress countries.

Key Words: maturity mismatch, funding structure, systemic risk, interbank contagion, Panel VAR

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CREi Centre de Recerca en Economia Internacional

1 Introduction

The unprecedented nature of the recent financial crisis has revealed the need to measure systemic risk in order to anticipate and mitigate the adverse effects of another crisis. According to the FSB-IMF-BISS (2009), systemic risk can be defined as a risk of disruption of financial services that is *(i) caused by an impairment of all parts in the financial system and (ii) has the potential to have serious negative consequences for the real economy.* In this context, the role of stress testing becomes essential. As Borio et al.(2012) stated, stress tests before the crisis were "ill-suited as early warning devices" and did not reveal the vulnerabilities of the system, but rather painted a picture of financial resilience (Borio et al., 2012). As shocks to the economy can propagate throughout the system, it is crucial to have a framework that effectively captures the interlinkages between institutions and the effects stemming from their interactions (Gauthier and Souissi, 2012).

The crisis triggered "far-reaching structural changes" and opened up the discussion on macroprudential stress testing, and the need to establish a consensus between different international institutions in order to develop tools and macroprudential policies that are able to mitigate and monitor financial stress levels (European Central Bank Statistical Warehouse). After the inception of the crisis, Hollo et al.(2012) developed a financial stress index in their working paper *A Composite Indicator of Systemic Stress in the Financial System* (henceforth CISS). The main novelty of this index with respect to previous indices is that more weight is given to situations in which the financial strains are materialized across different segments in the financial markets. By modeling the index in this way, the CISS captures the conceptual definition of systemic stress previously defined. We use this index as our proxy for systemic risk throughout our analysis.

Acharya and Mora (2015) find that the crisis of 2007-08 at the core was due to banks failing as liquidity providers. Liquidity has been treated as one of the key elements of the financial system, both as a performance indicator and as a vulnerability if "unable to provide households with insurance against idiosyncratic liquidity shocks" (Freixas and Rochet, 1997:16). One of the fundamental roles of a bank is to offer liquidity to the whole economy. Therefore, if there is a liquidity shortage, and a consequential fire sales of assets (Diamond and Rajan, 2011), this could reduce the value of assets and increase the illiquidity of other banks. For this reason, assessing liquidity is vital for analyzing bank performance and possible contagion effects. Moving forward, we focus our analysis on the interconnection between systemic risk and liquidity risk.

As banks are considered "pools of liquidity," this is a fundamental element to understand for macroprudential regulation. In the aftermath of the crisis, the Basel Committee on Banking Supervision introduced Basel III, seeking reform to "develop a more resilient banking sector" (BIS, 2013). Basel III introduced a new liquidity requirement,the *liquidity coverage ratio*, intended to "promote the

short-term resilience of the liquidity risk profile of banks," ensuring that banks have adequate high-quality liquid assets for depositors' claims (BIS, 2013). Basel III also introduced *net stable funding*, which "requires banks to maintain a stable funding profile in relation to the composition of their assets and off-balance sheet activities" (BIS, 2014). Both of these reforms emphasize the risk stemming from maturity transformation as they emphasize the need for holding enough liquid assets and financing through long term liabilities.

The maturity transformation function of a bank usually means that it must deal with assets that cannot be easily resold. Furthermore, the characteristics of these long term assets are usually quite "different from those of the contracts desired by investors (depositors)" (Freixas and Rochet, 1997:15). When a bank has substantial long-term assets funded by short-term liabilities, the probability of becoming illiquid increases. Funding liquidity risk arises as a consequence. According to the IMF, funding liquidity risk captures liability fragility, or the "inability of a financial intermediary to service their liabilities as they fall due" (2008). Thus, banks are susceptible to liability fragility by construction (Nikolau, 2009). The mismatch between assets and liabilities, the "maturity mismatch", is an indicator for measuring the quality of bank funding and quantifying liquid asset values. Understanding the complex nature of liquidity, and how it evolves after a shock in systemic risk is important for structuring the optimal macroprudential policy for avoiding future liquidity shortfalls arising from wide-scale maturity mismatch. This could involve the implementation of liquidity requirements that act as a buffer, tailored to each bank based on its characteristics.

From a theoretical standpoint, before the crisis banks find it more profitable to invest in long term assets (yielding higher returns), financed by short term liabilities (cheaper way to finance) and consequently, we expect that the maturity mismatch will increase. This implies an increase in funding liquidity risk. In comparison, after the crisis, as liquidity shocks propagate the system, information asymmetries and the devaluation of some assets may cause liquidity to decrease, leading to credit constraints and a "flight to quality." Therefore, we expect the maturity mismatch to decrease after the crisis due to a decrease in access to short term funding, that can be also be motivated by a shock in short-term wholesale markets. We expect both of these effects to be more profound for stressed countries from having a higher risk exposure.

To test our hypothesis, we exploit a Panel VAR methodology, which captures the two dimensions on which macroprudential supervision relies: the cross-sectional dimension and the time dimension. In using this methodology, we can see the interconnectedness and relationship between countries, and how shocks are propagated throughout the system. We believe this will capture how shocks affect bank performance through the liquidity channel. The objective of our research is to see how liquidity evolves when there is an increase in systemic risk.

[Insert Figure 1 and Figure 2]

Looking at the evolution of the year-to-year change of maturity mismatch and CISS we can observe these two variables are following a similar trend through the period of analysis. This evolution is different for each country. The graphs are showing that even if the trends of both variables seem to be related, the movements in CISS and maturity for Greece (Figure 1) seem to be going more in parallel than for Germany (Figure 2). Also, the shifts in the sign of growth are produced in different periods of time, meaning that the response for systemic risk is different for each country.

We want to respond empirically to some questions. Firstly, we would like to know if the trade-off between managing liquidity risk and having higher returns is independent of the level of financial stress. Secondly, we would also like to answer if riskier countries or banks were more affected by a financial shock through liquidity contagion. Finally, we are answering if the liquidity and funding structures of banks are affected by financial stress. We found a positive answer to the first question, but a negative result for the second and the third ones.

Our results confirm that, leading up to the financial crisis, maturity mismatch is increasing for both stressed and non-stressed countries, suggesting that banks have no incentive to hold liquidity when the financial sector seems to be resilient. Following the crisis, we see a decrease in maturity mismatch for both sets of countries. Our hypothesis is confirmed that these effects are larger for stressed countries, suggesting that they were previously taking much riskier positions, making them more vulnerable to situations of financial stress. As a consequence of this, banking institutions are obliged to adapt their sources of funding, and the institutions that are more fragile will might have less discretion to decide their funding structure.

The remainder of this paper is organized as follows: In the next section we present the State of Art, specifically considering the role of maturity transformation and non-deposit funding, as well as the Panel VAR methodology used to analyze these variables, and discuss the innovations of our paper. Section 3 and 4 introduce the dataset we construct and the methodology we use. In Section 5 we present our empirical results and offer a theoretical framework to discuss why we see this. In this section, we analyze how banks adjust their balance sheets to changes in systemic risk through the maturity mismatches and the funding channel. We extend our analysis by looking at the cross-country differences between stressed and non-stressed countries. Section 6 provides concluding remarks on the implications for policymakers and ways this research can be improved in the future.

2 Literature Review

2.1 Systemic Risk and Interbank Market

Banks have greatly evolved over time in their tendency to lend and the characteristics of these loans. In the 19th century, bank loans were primarily characterized by having short maturity assets, self-liquidating, and typically not for funding private housing (Goodhart and Perotti, 2015). A major financial innovation occurred in the post-war era in the United States, when banks started lending long-term mortgages intended for returning veterans. This was unprecedented and triggered a radical change in the structure of banking. Banks began to rely on borrowing from wholesale funding markets and "funding liquidity began to increasingly replace asset liquidity" (Goodhart and Perotti, 2015). Over the time frame between the 1970s and 2007, banks reduced the number of liquid assets they held, while financial transactions became increasingly complex. Balance sheets of commercial and investment banks had more and more "toxic" financial instruments on them (Acharya and Mora, 2015:2). The interlinkages between institutions were very opaque, and consequently it became unclear which institutions were more exposed to negative shocks, thus making regulation difficult. The combination of this created a system more sensitive to adverse shocks and possible contagion effects, drastically increasing the "exposure of economically and politically sensitive actors to liquidity needs" (Farhi and Tirole, 2012). The financial ecosystem, described by Farhi and Tirole (2012) as one of "wide-scale" maturity mismatch, was highly exposed to systemic risk.

The risks stemming from maturity transformation in the financial system are a key issue in liquidity risk literature. "Banks exist because they create liquidity and transform risk" (Berger and Bouwman, 2009). These institutions, pair illiquid assets (loans), with liquid liabilities (retail and wholesale deposits) that are subject to runs (Ippolito et al, 2015). As a consequence, it is necessary to hold enough liquid assets to reduce the risk to which they are exposed (Nikolau, 2009). "Liquidity mismatch in banks emerges when the market liquidity of assets is less than the funding liquidity on the liability side of banks' balance sheets" (Brunnermeier et al, 2011). However, there exists a "moral hazard" problem as banks can invest in safe and liquid assets or in higher yielding risky assets like loans (Strahan, 2008).

Berger and Bouwman (2009) take data on US Banks over 1993-2003 to analyse how liquidity creation is related to bank value, how it responds to financial crises and how it is affected by capital. Brunnermeier, Gorton, and Krishnamurthy (2011) develop an index to measure the liquidity position ("the liquidity mismatch index") of a firm in which each asset and liability has a liquidity weight. They also compute the index according to different scenarios, including macroeconomic variables of systemic stress. This index can be aggregated across firms and sectors.

Bai, Krishnamurthy, and Weymuller (2014) use the liquidity mismatch index to measure the relationship between the market liquidity of assets and the funding liquidity of liabilities. They evaluate the liquidity of a given bank under a liquidity stress event. The results showed that banks with a higher liquidity mismatch have more negative stock returns during a crisis and in periods of a liquidity run, while they have more positive returns in a non-crisis period or when there is a government liquidity injection and that banks borrow more from the government during the financial crisis. We also analyze the effects in different time scenarios but we contribute to this previous work with a wider view of how the banking system of a given country is being affected jointly by macroeconomic and financial issues, taking into account a VAR methodology. Our focus is on determining not how the performance or the value of a bank is affected but how risk is managed and affected.

Farhi and Tirole (2012) find that all institutions engaging in maturity mismatch leave central bank authorities with no other option but to intervene, creating "current and deferred social costs," which is an important implication for the need for tighter macro-prudential supervision (Farhi and Tirole, 2012). Our paper builds off of this ideal to suggest which kind of macroprudential policy measures are suitable to ensure the resilience of the financial system as a whole in order to mitigate possible systemic events.

Haan et al.(2016) developed a panel VAR model to see how banks respond in terms of loans growth and loans rates to a shock in wholesale funding. They found that the shock in liquidity decreases credit supply and that the effects are higher in stressed countries than in non-stressed. In that sense, banks decrease the supply of short term funding in the interbank market, at least, just after the time of the shock. This decreases borrowers access to this type of funding. Our contribution relies on the impulse that we take into account to see the effect magnitude. Using the CISS, we are considering not only the shock in one funding market, but how different shocks can be connected. In addition, we do not focus only on the effects on the loan side but also in the liabilities side and the connection between them looking at the maturity transformation.

Segura and Juarez (2016) stated "The Global Financial Crisis turned the attention to inefficiencies associated with maturity transformation," which also brought the attention to macroprudential regulation because of interbank contagion (Rochet Tirole, 1996), (Allen and Gale, 2000) and fire sales that impact asset prices (Diamond and Rajan, 2011). Segura and Juarez (2016) develop a model to measure the value of banks taking into account the positive effect of maturity transformation (as they can benefit from higher returns) without a liquidity crisis, and the negative effect of excess refinancing costs. They find that increasing maturity could have a positive effect on social efficiency.

Acharya and Mora (2013) show that banks can only maintain their role as liquidity providers because of large government intervention. According to capital requirements and regulation, Berger and

Bouwman (2009) find that larger banks present a positive relationship between capital and liquidity creation and that large banks create 81% of the total liquidity. Our work has the objective of measuring the effect on liquidity stemming from a situation of financial stress in order to determine optimal macroprudential measures, such as liquidity provisions that could reduce liquidity risk in times of non-financial stress.

Previous literature does not solely study maturity, but also the different sources of obtaining funds for banks and the effect of a financial crisis. During the past decades, the composition of bank funding has evolved due to an increase in the interconnection in financial markets, the rapid growth of investment banking activity, the importance of wholesale markets (specially short-term) and the growth of international finance (Rixtel and Gasperini, 2013). In the same way, banks increasingly use short-term funds to supplement traditional retail deposits. The problem arises when wholesale financiers have lower incentives to conduct costly monitoring (Huang and Ratnovski, 2010). This change in pattern has an effect on maturity mismatch and funding liquidity risk.

As Haan et al.(2016) stated "wholesale funding (or non deposit funding) refers to the use of deposits and other liabilities from institutions such as banks, pension funds, money market mutual funds and other financial intermediaries. When a bank relies on short-term wholesale funds to support long-term illiquid assets it becomes vulnerable to runs by wholesale creditors" (Haan et al, 2016:2). In that case, maturity mismatch and non wholesale funding become extremely related, especially when using the latter in the short term. In addition, since the start of the financial crisis in 2007, and due to liquidity constraints, banks responded by reducing maturity mismatch, using alternatives sources of finance and deleveraging.

The interbank market arises as a source of potential contagion in the case of liquidity shortages. As Franklin et al.(2009:1) stated "interbank markets allow liquidity to be readily transferred from banks with a surplus to banks with a deficit". In normal times, the interbank market is one of the most liquid markets in the financial sector (Heider, 2009). However, liquidity dried up when the crisis started, as banks preferred hoarding liquidity instead of lending. In that sense, Franklin et al.(2009) analyze the performance of the interbank market during a period of liquidity constraints and see how the Central Bank can intervene, revealing another important issue to consider regarding macroprudential regulation.

Another approach to see how shocks to individual banks can affect liquidity in the market is shown in Alfonso et al.(2011). Credit constraints coming from an increase in riskier borrowers increase asymmetric information but also, some banks are not willing to lend even to high-quality borrowers as they prefer to have more liquidity for precautionary reasons.

As Ippolito et al.(2015:1) stated "The financial crisis that started in 2007 was centered on wholesale

liquidity problems at financial institutions". Additionally, banks that are more reliant on interbank funding suffer when there is a severe funding liquidity shock. Interbank funding can be seen as a source of fragility for banks (Ippolito et al, 2015).

Peydró and Iyer (2010) test the extent to which interbank exposure and the fear of financial contagion affect liquidity provision among banks. The authors exploit a sudden shock in the interbank market arising from a large-bank failure, and find that "higher interbank exposure to the failed bank leads to large deposit withdrawals" (Peydró and Iyer, 2010:5). Furthermore, they find that the interbank linkages helped to "further propagate the shock," suggesting that interbank linkages can "act as an important channel for contagion," which is directly related to systemic risk (Peydró and Iyer, 2010:5).

Ippolito et al.(2015) found that after the crisis, banks with higher interbank funding, reduced more the supply of credit to new applicants than other banks. Not only was the supply of credit reduced, but drawdowns in credit lines (which increases the demand of cash for banks) were higher for banks more exposed to interbank funding. This is the double effect, which damages liquidity for the overall economy. Liquidity tensions, systemic stress and contagion thus become highly interrelated. Haan et al.(2016) found that banks responded to shocks in the wholesale market by increasing interest rates because of the reduction in wholesale funding growth. It also led to a change in risk-taking behaviour by banks, shifting to investment in long term assets instead of short term. This response is bigger for stressed countries than for non-stressed.

At the beginning of the crisis, banks saw aggregate deposits decrease, and consequently their "loan-to-deposit shortfalls widened" (Acharya and Mora, 2015:3). Acharya and Mora find that banks affected the most by undrawn commitments offered higher rates to attract deposit inflows. The authors suggest that the "mechanism whereby the banking system as a whole provides backup liquidity to the market by experiencing deposit inflows broke down" (Acharya and Mora, 2015:3). Deposit funding pressure was affecting all banks as liquidity providers, a fact documented and confirmed by Acharya, Schnabl and Suarez (2013).

Taking past literature into consideration, it is clear that the financial environment and maturity mismatch are important for understanding liquidity shortages and their implications for the inter-bank market. The evolution of maturity mismatch can be explained by how banks are obtaining their sources of funding. For that reason, our empirical analysis focuses on determining an impulse response function of the effect of an increase in systemic stress in the Euro area on the degree of maturity mismatch and the funding structure, taking into account possible heterogeneities between different countries. Our main contribution resides in implementing a unique specification model, with panel VAR approach, to relate directly a measure of systemic stress, interbank linkages, liquidity

shortages and funding structure taking into account also macroeconomic variables.

2.2 Panel VAR Methodolody

Following a Panel VAR, we exploit this methodology in order to see how a systemic risk shock, measured by the CISS , affects the evolution of the maturity mismatch. In order to perform our analysis, we take advantage of a Stata package developed by Abrigo and Love (2015).[1].

Through this approach, we are able to capture both static and dynamic interdependencies, while simultaneously taking into account the cross sectional dynamic heterogeneity between countries in the Euro area. As far as we know, this methodology has been used to address a variety of issues of interest of macroeconomists and policymakers. There are several trends that have been analysed through this methodology, mainly focused in applied macroeconomics. In the Real Business Cycles: Canova et al.(2007) study the similarities and convergences among G7 cycles. Moreover, Canova and Altug (2012) analyse the cross sectional dynamics of Mediterranean business cycles. Canova et al.(2013) have studied how shocks to the U.S. interest rates are propagated to european economies. Grauwe and Karas (2012) exhibit how the dynamics of deposits and interest rates of "good" and "bad" banks differ in response to bank run shocks. With a different approach, Cicarrelli et al.(2013), demonstrate how financial fragility may induce a different transmission mechanism of monetary policy across different groups of countries in the recent crisis. We build off of Cicarrelli's approach, but instead of looking at the monetary policy transmission mechanism, we analyze the liquidity channel and how it transmits to the real economy. Recently, Han et al.(2016) have also exploited a p-VAR methodology to see how banks with different characteristics respond to wholesale funding shocks, also relating their analysis to liquidity. To the best of our knowledge, there is a diverse range of issues in the area of systemic risk and interbank market lending which the p-VAR methodology can be implemented, and we exploit this in our analysis. One way our analysis contributes to the state of the art is that, rather than looking at these issues from the bank-level (micro-perspective), we use bank aggregate country-level data in order to look at the system as a whole, in order to have a more global perspective, incorporating the different characteristics of countries. We look at the EU as one unit, and treat every country as an individual agent to understand the interconnection between countries.

[1]This methodology has been cited in a wide variety of publications (445 research papers). Some examples are contained in the American Economic Review (Head et al, 2014), Applied Economics (Mora and Logan, 2012), Journal of Macroeconomics (Carpenter and Demiralp, 2012), and The Journal of Economic History (Newman et al, 2010). We build our analysis from this

3 Data

We construct our sample by collecting data starting from January 1997 to December 2016, using the following sources: i) European Central Bank Statistical Data Warehouse; ii) OECD; and iii) Eurostat. We utilise aggregated bank data at the country level, which is measured as the "sum of the harmonized balance sheets of all the Monetary Financial Institutions residing in the Euro area" (ECB Statistical Data Warehouse). The data is collected as the average of observations through the period we are analysing. The statistics from the ECB are obtained from different datasets, mainly including variables from the *Risk Assessment Indicators Dataset* (monthly). For the datasets obtained daily, we apply a monthly transformation. Using this frequency gives us more observations and an increase in variability, which we exploit in our analysis.

We have constructed a panel consisting of data for 12 different EU countries, classified as stressed or unstressed based on the risk premium rate. We measure as the spread between the 10 year government bond between each country and the benchmark, which we define to be the 10 year German government bond[2]. We separate between stressed and non-stressed countries by whether or not the risk premium exceeds 5 (points), that gives us a sample of stressed countries that exactly coincides with the list classified by the ECB. This includes the GIIPS: Greece, Italy, Ireland, Portugal and Spain. We classify the following countries as non-stressed: Netherlands, Luxembourg, Austria, Belgium, Finland, Germany and France. Our dataset contains both macroeconomic and financial data which provide information about the economic environment, systemic stress, liquidity and solvency, and both interbank and wholesale markets and country exposure to them.

To identify how economic performance responds to changes in systemic risk we use the Industrial Production Index (henceforth, IPI) as a proxy for GDP. The IPI refers to the output of industrial establishments and covers sectors such as mining, manufacturing and public utilities (electricity, gas and water). This indicator is measured as an index based on a reference period that expresses changes in the volume of production output. We use this index, for a measure of the performance of the economies of interest. The IPI is collected on a monthly frequency and is measured with respect to the 2010 base level of 100 (points).

Additionally, as a way to introduce the evolution of the overnight interbank market, we use the weighted rate for the overnight maturity on unsecured overnight lending in the Euro area provided by banks (Eonia). The data is obtained in percentages with a daily frequency, that we transform to a monthly frequency using a simple average.

[2]The risk premium for the 10 year German government bond is calculated as the spread between the 10 year German government bond and the US 10 year government bond

In order to determine the response of a bank's performance (liquidity and non-deposit funding exposure) to the macroeconomic indicator (IPI) and the evolution of interbank market (Eonia) we use the CISS, a measure of systemic stress in the Euro area. It comprises a set of 15 stress indicators which capture the main features of a financial crisis: asymmetric information (adverse selection and moral hazard), an increase in uncertainty, an increase in disagreement among investors and a reduced preference for holding risky assets (flight-to-quality) and/or illiquid assets(flight-to-liquidity). These individual stress indicators belong to the main segments of the financial markets: money market, bond market, equity, financial intermediaries and foreign exchange. Therefore, it captures the propagation of stress across the financial system as a whole. The authors standardized the indicators between [0,1] following a Cumulative Density Function (CDF). Afterwards, they aggregate each one of the individual indicators by taking the simple average of the stress indicators. Once they have 5 subindices indicators for each of the markets, they aggregate all of them into a single indicator, taking into account the cross-correlation between subindices across time. We use the index available y from the Statistical Data Warehouse and transform it into a monthly frequency by taking the simple average of weekly observations.

To see the heterogeneous performance of the financial system in different countries of the Euro area, we analyze the growth rate of the degree of maturity mismatch and non-deposit funding, an evolution that is connected on the liability side of the balance sheet (short term sources of funding). As stated in Rixtel and Gasperini (2003), banks fund themselves through a wide range of financial instruments, from both retail and wholesale sources. The latter includes funding from private markets, used to supplement customer deposits. In the short run, banks can fund themselves through interbank loans, and other short term debt, such as repurchase agreements (repos) and commercial paper (CP) or certificates of deposits. In the long run, banks issue medium-term notes (MTNs) and bonds. Banks also have access to Central bank funds and can raise liquidity (equity).

Maturity Mismatch arises when banks hold more short term liabilities than short term assets. Here, we use the degree of maturity mismatch (in points) that increases when short term liabilities increase compared to short term assets. Thus, the maturity mismatch increases if either short term liabilities increase or long term assets increase. For that reason, it is a good proxy for understanding both the liquidity and funding structure of the banking system. It is initially measured in points (taking values from 0 to 100). We use the year-to-year transformation (as a percentage change) directly from the ECB Data Warehouse in order to see evolution and growth over time.

Non-deposit funding refers to the sources of banking funds not obtained from retailers. It provides information about the debt structure of an institution or a country. When it increases, banks are obtaining more funds from other wholesale sources of funding such as the interbank market, central bank funds, repurchase agreements (repos) or other sources. We use this as a proxy for interbank

(and other sources of wholesale funding) exposure. In this case, we apply the first difference to see the evolution of this source of funding.

4 Methodology

In this analysis, we utilise the Panel VAR methodology, which captures both static and dynamic interdependencies between stressed and non-stressed countries. The advantage of using this approach is that we can incorporate time variations and account for cross-sectional dynamic heterogeneities. The model fundamentally has the same structure as the VAR framework implemented by Sims (1980) in the sense that all variables are assumed to be endogenous and interdependent, but a cross-sectional dimension is added.

We consider a k-variate Panel VAR of order p with panel fixed effects specification, represented by the following system of linear equations:

$$Y_{it} = A_{0i}(t) + A_i(l)Y_{t-1} + u_{it} + e_{it} \tag{1}$$

$$i \in [1, 2, ..., N], t \in [1, 2, ...T_i]$$

where Y_{it} is a vector of endogenous variables, comprising of four variables: (i) IPI (seasonally adjusted), (ii) EONIA, (iii) Maturity Mismatch/Non deposit funding and (iv) CISS (see section 3 for a description of the variables). All variables are at the country level, except for the CISS and EONIA which are common across all countries. u_{it} is a vector of specific fixed-effects and e_{it} is a vector of idiosyncratic errors. The model is estimated recursively, and the first estimation is run over the sample January 1997 to January 2005. In the subsequent estimations, we add one year at a time, using a moving window approach until we cover the full sample, following the methodology used by Ciccarelli et al.(2013).

The parameters in the model could be jointly estimated with fixed effects or after a differences-in-differences transformation, using in each equation an ordinary least squares (OLS) approach. However, with the presence of lagged variables on the right-hand side of the equation, this approach would lead to a biased estimation (Nickell, 1981) since we have a small sample size for T (time) and fixed N (countries). In order to tackle this caveat, several authors have proposed the Generalized Method of Moments (GMM) as a way to get consistent and unbiased estimators, even with small samples. Arellano and Bover (1995) proposed using lagged instruments and levels as instruments. Therefore, system GMM has one set of instruments to deal with the endogeneity of the regressors and another set to deal with the correlation between lagged dependent variables and the error terms.

The software package developed by Abrigo and Love (2015), incorporates this instrument.

4.1 Model selection

In order to perform our analysis, we need to exploit the properties of a time-series. Frequently, time series models are characterised by the presence of unit roots, which is a certain feature that does not allow us to exploit the dynamic properties of the data. In this scope, the work of Granger and Newbold (1974) was determinant in the development of understanding unit roots. Several authors have proposed different approaches to deal with the presence of unit root which make our series non-stationary. After differencing or cointegrating, our series can become stationary. In this sense, Engle and Granger (1987) and Johansen (1988) exploited the use of cointegration time-series applied to VAR models (Johansen, 1991).

Our analysis relies on the contribution of Sims, Stock & Watson (1990), who concluded that the presence of unit roots in p-VAR models would be biased since the IRF is built upon the parameters estimated in the regressions. Therefore, the outcomes that we obtain from a panel with unit root would be spurious. In order to avoid an erroneous estimation we proceed in the following form: First, we check the order of integration of the set of variables that we have used (IPI, EONIA, maturity mismatch and CISS) through Dickey-Fuller test (1979) adapted to panel data; and second, we take differences of those variables which are integrated in levels in order to make them covariance stationary. To keep p-VAR models estimable, we restrict the number of variables for each model to four and then estimate two separate models, replacing consecutively the variable identifier of a bank's liquidity (maturity mismatch/non-deposit funding).

4.2 Identification strategy

Starting from the Impulse Response Functions (IRF), we obtain the effect of a one standard deviation shock for each of the present and future innovations in the vector of endogenous variables Y_{it}. If the variables are uncorrelated, the IRF can be directly interpreted, however, the innovations tend to be correlated, since they have a component in common which cannot be jointly associated to a specific variable. In order to solve this problem, we draw upon Cholesky's decomposition.

$$\begin{pmatrix} \eta_t^{IPI} \\ \eta_t^{eonia} \\ \eta_t^{maturity} \\ \eta_t^{CISS} \end{pmatrix} = \begin{pmatrix} a & 0 & 0 & 0 \\ b & c & 0 & 0 \\ d & e & f & 0 \\ g & h & i & j \end{pmatrix} \times \begin{pmatrix} u_t^1 \\ u_t^2 \\ u_t^3 \\ u_t^4 \end{pmatrix}$$

Following this method, we proceed to orthogonalize the errors with a covariance diagonal matrix. At the time of using this tool, we have to take into account that the order in which we introduce our variables in the vector of endogenous variables can change the results of the IRF. In order to determine a logical order, we consider the economic sense of each of the variables included in the equation. In our case, the representative variable of the real economy (IPI) will be included in the first position, since it does not respond contemporaneously to shocks in a bank's balance sheet and systemic risk. Subsequently, we include EONIA, maturity mismatch and CISS since they respond in a contemporaneously way to one shock. Therefore, according with the above equation for a single country, a shock in the CISS will not affect the IPI, since u_t^4 is multiplied by 0 in η_t^{IPI} equation. But the opposite is not true, since u_t^1 is not multiplied by 0, but by g. In general, the above matrix sum the IRF that we are going to carry out. As a result of our p-VAR estimation, we obtain 16 IRF.

Once we obtain the IRF for each of the equations estimated, we focus on those which can help us to disentangle how the degree of maturity mismatch and non-deposit funding is changing against a shock in systemic stress. Furthermore, we analyze how the real economy reacts to changes in systemic stress. Our results are presented in the next section.

5 Results

Using the specification presented in Section 4, we present the results following a change in systemic risk. First, we present the reaction of maturity mismatch across different periods of time. Second, we analyze how sources of financing change through non-deposit funding. Third, we examine how the liquidity channel transmits to the real economy, looking at the evolution of the industrial production index. Throughout this section, we exploit the different characteristics of countries to see the different responses between stressed and non-stressed countries.

5.1 The impact of systemic risk on liquidity and non-deposit funding

Figure 3.(a) reports the results for the dynamic response of maturity mismatch to a 100 basis points increase in systemic risk, captured by the CISS for all EU countries. It is possible to observe two distinct phases: an increase in maturity mismatch during the periods before the financial crisis, followed by a decrease after the crisis. These effects are more profound for stressed countries. The evolution observed confirms our hypothesis that leading up to the crisis, banks were increasing their exposure to liquidity risk.

[Insert Figure 3.(a)]

Even if these clearly differentiated stages exist, there is also some variation across the subperiods. In our results, for the analysis including all European countries, maturity mismatch growth was increasing and became more noticeable after 2006, and peaked considering the period until 2007, previously to the beginning of financial problems in the subprime market. The deeper point was produced in 2009, responding to the Lehman's fall. Finally, during the last years of our analysis, it seems to start recovering, following the sovereign debt crisis that lead to government intervention and central bank policy actions (Ciccarelli et al, 2013) Therefore, we need to take into account that liquidity and debt structure are responding not only to systemic stress but also monetary policy response.

The tendency to increase maturity mismatch before the crisis could be driven by both an increase in short term liabilities or a decrease in short term assets held (compared to long term), so that we cannot isolate what is the effect of each of them. In good times, we can find economic explanations for both cases. Increasing exposure to liquidity risk is a profitable strategy because "short-term funding is much cheaper" while long-term, illiquid assets are higher yielding (Perotti and Suárez, 2012).

First of all, we will focus on understanding the decrease in short term assets. Thus, "banks face a trade-off between holding short-term, liquid assets that are low-yielding, and using them to invest in longer term, illiquid assets" (Strahan, 2008). For that reason, in a positive economic scenario with no credit constraints or liquidity frictions, institutions are not as concerned about holding enough liquid assets and credit supply seems to be completely accessible. This result can also be related with the economic performance of banks. It is consistent with the findings of Bai, Krishnamurthy, and Weymuller, (2014) who demonstrate that banks with higher maturity mismatch have more positive returns in a non-crisis environment. This result, as observed by other institutions, can create incentives to take riskier positions.

Secondly, the increase in maturity mismatch is also motivated by a shift to other sources of funding that has been observed during the last decades (Rixtel and Gasperini, 2013). As stated in Gobat et al. (2014:3), "this in part reflected banks' increasing reliance on short-term wholesale funding as a means to grow their balance sheets over the past 20 years". This behaviour can provide an explanation for the event preceding the origins of the financial bubble: banks' asset and liability structures proved to be highly vulnerable to market shocks, investor runs and breakdowns in wholesale funding markets (Gobat et al, 2014). Therefore, we can suppose that countries with higher maturity mismatch or high risk have more exposure to risk and will be more damaged.

In the phase following the crisis, we observe that the maturity mismatch is decreasing. Once again,

this effect could be explained both by the asset or the liability side. In the aftermath of a crisis, liquidity may dry up. Needs for cash start increasing, which also makes asset values go down in a context of financial constraints for the whole economy. In a time of funding liquidity risk, coordination problems can lead to bank runs due to both an increase in deposit withdrawals (normally with long term maturity) and an increase in the demand for cash through credit lines (increasing need for liquid assets). This effect is higher for banks with higher liquidity risk or more exposure as stated in Ippolito et al.(2015). For that reason, we can think on two reasons motivating this response.

First of all, a decrease in the maturity mismatch could be driven by a decrease in short term liabilities, as access to short term funding decreases[3]. Secondly, as for the asset side, were are going to focus on the type of loans banks prefer to hold. When a liquidity shortage overcomes the financial system, information asymmetries play a crucial role in determining the supply of credit, and banks could then prefer to lend long than short term. Institutions or individuals who as for short term funding following a crisis may be signalling their liquidity problems. Banks will then be less willing to finance this type of risky borrowers. As more and more of this type appear in the whole system, banks with excess liquidity must either require higher interest rates or provide a lower amount to the borrower when lending (Alfonso et al, 2012).

[Insert Figure 3.(b) and Figure 3.(c)]

Looking at Figure 3.(b) and Figure 3.(c) we observe that the maturity mismatch evolves in the same direction for both stressed and non-stressed countries, but the magnitude of the year-to-year change is much greater for stressed countries. Thus stressed countries are more affected to changes in systemic risk. We see that before the financial crisis, stressed countries show a higher degree of growth in maturity mismatch than non-stressed countries.[4][5] Moreover, as entities or countries with high maturity mismatch have worse liquidity positions, the probability of a failure can be high.[6]

The maturity mismatch relates to non-deposit funding in terms of short term liabilities. Up until the crisis, we observe a trend to increase reliance on short-term wholesale funding. This increased bank's maturity mismatch, and also increased the proportion of non-deposit funding, leaving banks highly

[3]This result is consistent with the work of Haan et al.(2016), who find that in response to the financial crisis, as banks become liquidity constrained, they reduced their maturity mismatches using other sources of funding.

[4]Notice that stressed countries are, by definition more riskier so that they could be in worse liquidity positions than the non-stressed. As an example, if we look at the maturity level for Greece, one of the most affected, it was particularly high before the crisis.

[5]This result is coherent with the research of Gobat et al.(2014:5) who stated, "studies have shown that excessive maturity transformation risk can be a major source of bank failure."

[6]This conclusion is also found in the research of Vázquez and Federico (2012), who state that banks with weaker structural liquidity and higher leverage before the crisis, were more likely to fail. Also, they show that the probability of failure increases for higher risk-taking institutions.

exposed to a liquidity shock, and a consequential interbank market freeze. We focus now on an impulse response function to see how a change in systemic risk affects the proportion of non-deposit funding. Both Figures 4 and 5 report the evolution of non-deposit funding against a 100 basis points increase in the CISS indicator for both stressed and non-stressed countries. Clearly, the evolution of the share of non-deposit funding can be interpreted from the blue line in the Figures.

[Insert Figure 4 and Figure 5]

The IRF for stressed countries shows a decrease in the short term, and after a few periods, it starts to rise again just above zero. It continues being positive, even in the long run. Confidence bands at 90% illustrate that this effect is significant. For non-stressed countries, the graph follows a similar pattern of movement. However, in this case, zero is included in the confidence intervals that, more or less, are smaller than for the stressed countries. Although we can expect a similar movement for both countries, falling in the short run and quickly increasing after, the effect of the shock in stressed countries is significantly greater. This finding demonstrates that stressed countries are more affected by systemic risk. Additionally, in terms of funding structure there is also a clear difference between the short and long term.

In the short run, an increase in the CISS leads to a significant decrease in non-deposit funding. This variable can be affected by a decrease in the wholesale market, an increase in the deposit funds or by both of them jointly. We can provide some theoretical explanations to this empirical results that can affect at different moments in time.[7]

However, in the long run, banks are able to obtain alternative sources of funding since the uncertainty between market participants has decreased. Furthermore, central bank intervention can contribute to an efficient allocation of liquidity, alleviating negative effects. As an example, when the European Central Bank started providing public liquidity or long-term refinancing operations (LTROs), lending conditions and liquidity were recovered (Ciccarelli et al, 2013). In addition, the behaviour of retail depositors may magnify this effect, so that when they suffer the financial constraints, two forces arises. They tend to start doing deposit withdrawals as they need more liquidity. Also, it tend to increase as a contagion effect response.

[7] In line with our results, Peydró and Iyer (2010) find that in times of financial distress, participants in the interbank market are reluctant to lend, and tend to hoard liquidity. As banks increasingly relied on short-term wholesale funding, this left many highly exposed to an interbank market freeze. We can understand this effect to be more important in the short run as mostly of the transactions are overnight, so that the effects of the dry up can just be seen the day after.

5.2 The impact of systemic risk in the real economy

How do changes in systemic risk transmit to the real economy? We present the reaction of the industrial production index as a proxy for the economic performance of the EU countries. Funding liquidity shocks can propagate to the real economy if there is a decrease in the level of bank lending. In the aftermath of a crisis, as banks become more conservative in lending, this means that households and firms will have less access to funding, which translates into lower levels of consumption, investment, and income. The results of the analysis are reported in Figures 6.(a), 6.(b) and 6.(c), where we compare the dynamic responses of the first differences of IPI to a 100 basis points increase in CISS. The figures show the evolution of twelve IRF estimated for the different periods.

[Insert Figure 6.(a), Figure 6.(b) and Figure 6.(c)]

In Figure 6.(c) showing the response for non-stressed countries, we observe that the economy moves in a similar way before and after the crisis. However, during the crisis years (2008-2010), in the short run, the shock in the IPI is much larger, as the economy goes into a recession. It recovers in the long run, reaching similar levels as before. For stressed countries, seen in Figure 4.(b) we observe a similar pattern of movement as non-stressed countries. However, it is significantly different for the crisis years. In those years, the economy falls, but it does not recover from the shock as non-stressed countries do. It foretells what is going to happen in the following years. The impact of the crisis is seen in all the countries but non stress ones recovered rapidly, while stressed nations remain depressed in the medium-long run.

6 Conclusions

In this paper we have analyzed how changes in systemic risk affect bank performance, particularly through the liquidity channel and the funding structure. We then looked at how this transmits to the real economy. We analyze the effects of systemic risk in the (i) pre-crisis and (ii) post-crisis times, for countries with different degrees of stress. We find that, before the crisis, banks were increasing greatly their maturity mismatch, increasing their exposure to funding liquidity risk.

Our results have important implications for future policy making on macroprudential regulation and supervision. Regulatory measures should be taken in order to ensure the resilience of the financial system as a whole, mitigating possible propagation of systemic stress. In order to encourage banks to hold liquid assets ex-ante, we must introduce incentives to do so. From this perspective, we should focus on those policies which increase bank's incentive to hold liquid assets among the business cycle. In this sense, macroprudential policies oriented in tackling time and cross-sectional dimensions of

systemic stress, such as countercyclical capital buffers, could help to dampen the procyclical nature of the financial system. Nevertheless, one should take into account the existence of a trade-off between a possible detriment in banks profitability with excessive regulatory actions, which could affect the overall performance of the economy.

From another perspective, as the financial crisis has shown, a good understanding and coordination between adequate central bank intervention and regulatory policies, such as, macroprudential and microprudential policies are essential to ensure a suitable recovery of liquidity in order to fight against potential sources of liquidity risk, which could trigger new systemic episodes. From a microprudential perspective, there should be a clear and consistent way of determining value of assets and, indeed, ensure that liquidity indicators are well defined. Fair value should be used as the main accounting principle. In addition, it is crucial to establish a clear separation between solvency and liquidity problems, in order to avoid giving the wrong incentives when "injecting money" in the economy. Moreover, for securitization or other complex transactions, transparency is crucial to understand which collateral is related in order to have an adequate measure of the risk associated.

In this analysis, we have observed the importance of structural breaks in the behaviour of some variables, especially those related with the banking system. It is essential to take this into account for future analysis. From a methodological view, parameters estimated in many models can experiment even sign changes that will affect the quality of forecasts. In addition, it will also be interesting for future lines of research to check how the CISS is affected by other variables, and finding out where this shift comes from. We could also consider some analysis based on the predictability of systemic risk, which could help policymakers determine adequate ratios of banking indicators at each point in time. Building off of our analysis, it would be useful to try to create a model to forecast the CISS. From a macroprudential perspective, the appropriate level and conditions in which such capital buffers should be implemented is still to be determined and will be crucial for moving forward. More analysis is needed.

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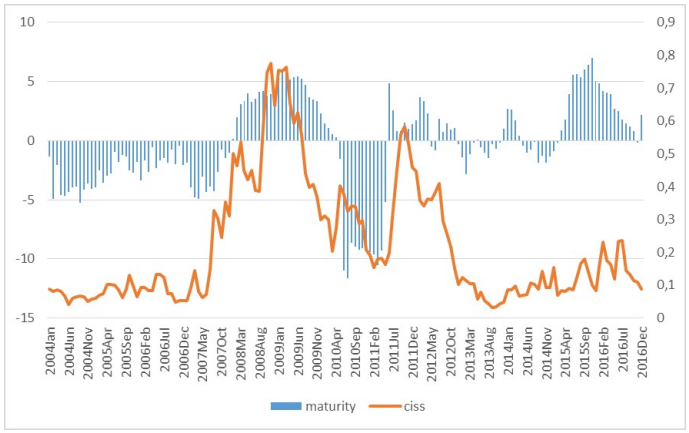
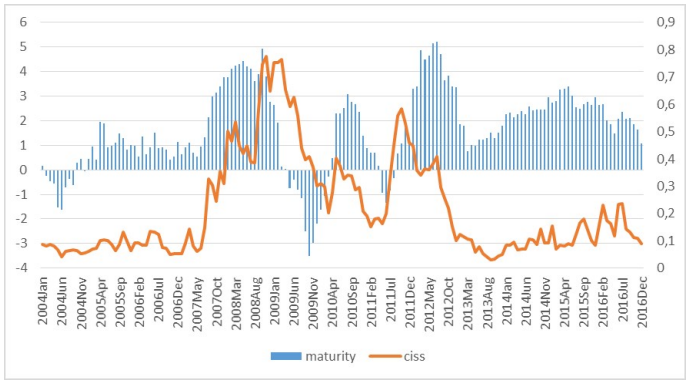
Appendix

Figure 1: CISS vs Maturity mismatch (year to year change) Greece. Jan2004-Dec 2016



In the the left axis is shown the year- to-year percentage change in maturity (see blue points). The value for CISS is shown in the right side (see orange line).

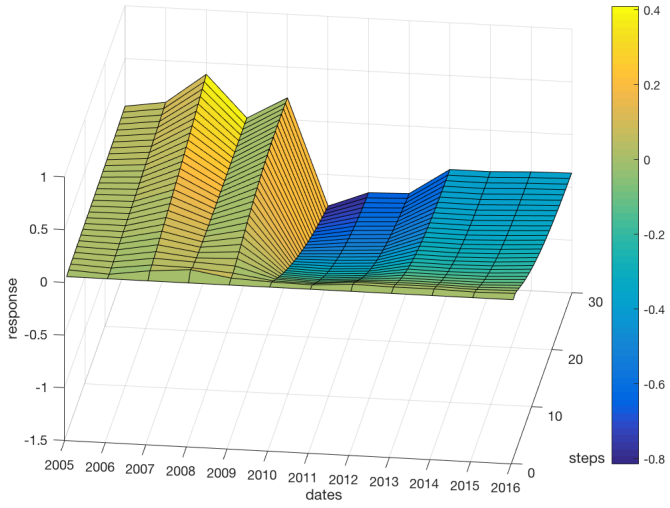
Figure 2: CISS vs Maturity mismatch (year to year change) Germany. Jan 2004-Dec 2016



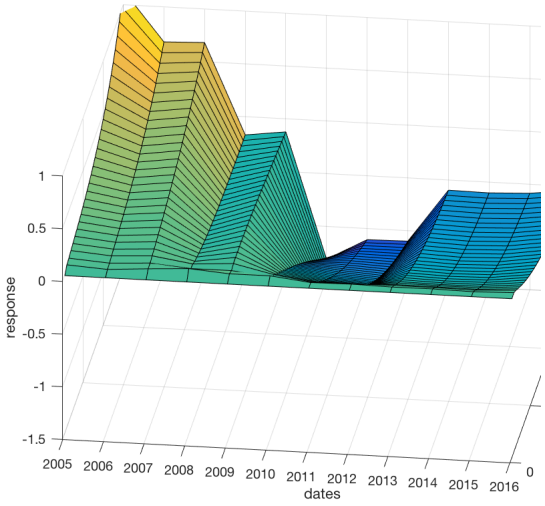
In the the left axis is shown the year- to-year percentage change in maturity (see blue points). The value for CISS is shown in the right side (see orange line.

Figure 3: IRF: Shock CISS- Response Maturity

(a) All countries



(b) Stress countries



(c) Non-stress countries

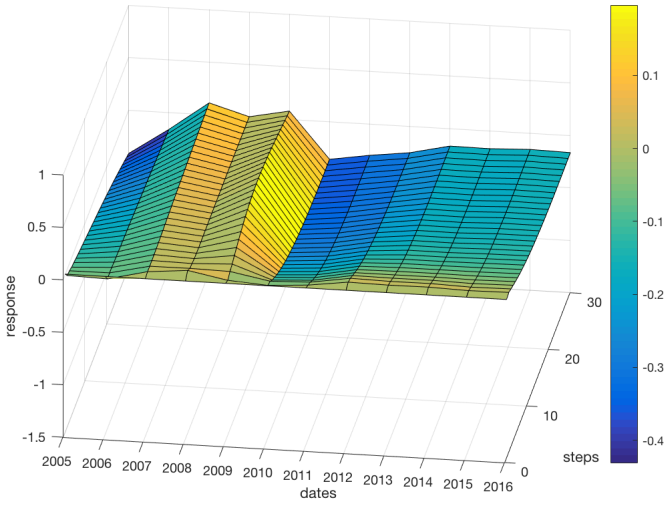


Figure 4: IRF:Shock CISS - Response Non Deposit Funding (First differences) (Stress countries)

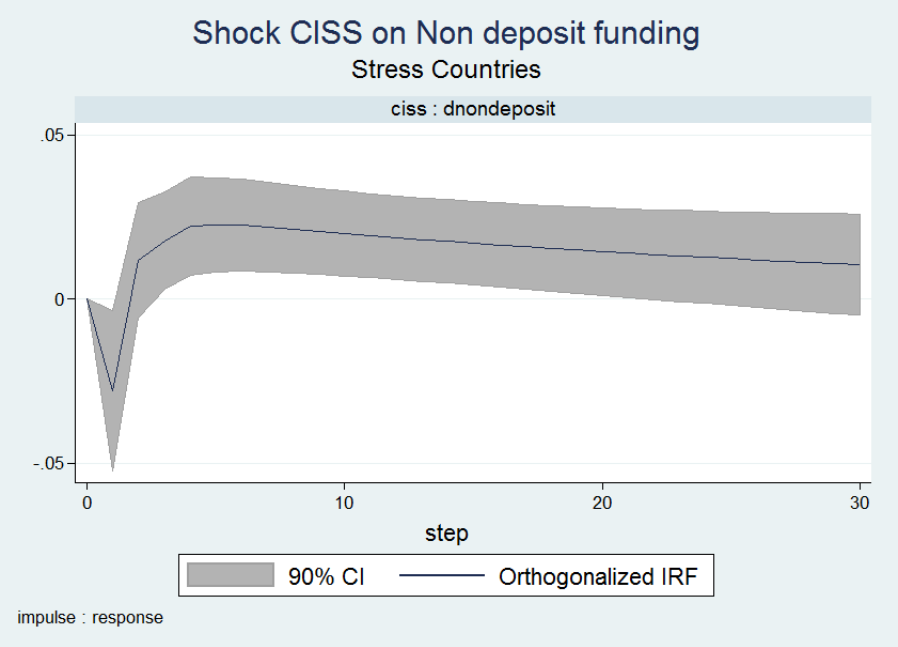


Figure 5: IRF:Shock CISS - Response Non Deposit Funding (First differences) (Non-stress countries)

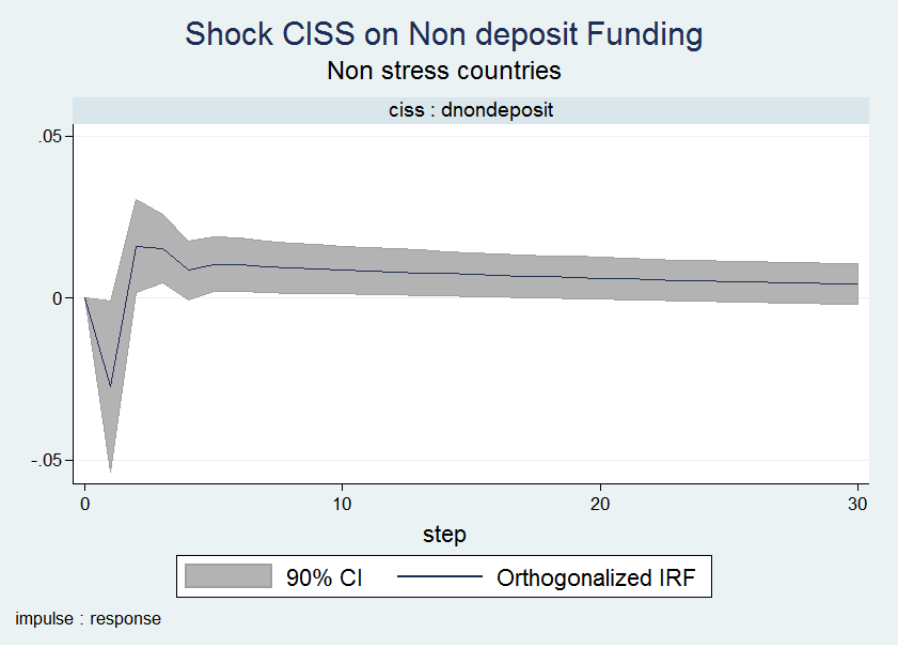
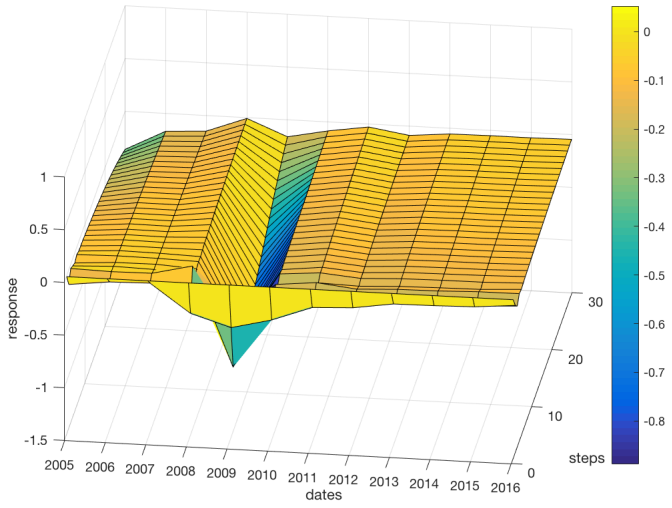
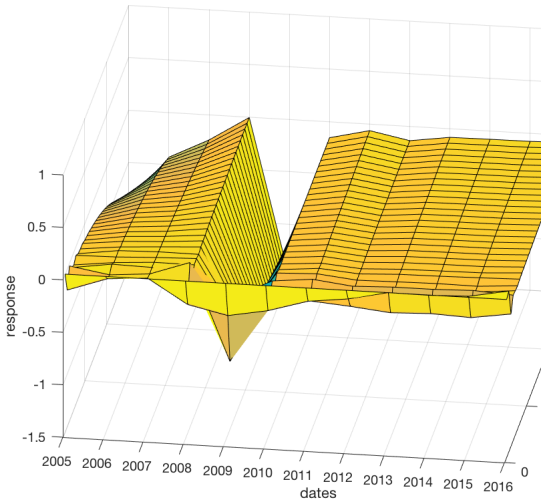


Figure 6: IRF: Shock CISS- Response First differences IPI

(a) All countries



(b) Stress countries



(c) Non-stress countries