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Non-performing loans and house prices: Evidence from Greece

Angeliki Parliarou

August 2021

Abstract

This thesis examines whether shocks in house prices have an impact on the non-performing loan ratios. The analysis presents empirical evidence from the Greek economy, using quarterly basis data over the years 2002-2019, which include the global financial crisis. A vector auto regressive and vector error correction model are used, which capture the interdependencies of the macro-economic variables. The more precise responses of the variables of interest to shocks within the system are presented through the generalized impulse response functions. The findings show that, among multiple macroeconomic factors, housing prices have a significant negative impact on non-performing loans, which importantly confirms international evidence. However, there are spatial deviations within the country. The findings reported could be used by policy makers for scenario analysis, to examine whether forecasting the performance of NPLs at the country or regional level, could provide with specific thresholds that can be useful when determining the lending policy within a bank.

Keywords: non-performing loans, housing prices, macroeconomic determinants, vector autoregressive model, spatial variation

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Document	Master thesis Real Estate Studies
Title	Non-performing loans and house prices: Evidence from Greece
Date	August 31, 2021
Version	Final
Author	Angeliki Parliarou
Student Number	S3999475
E-mail	a.parliarou@student.rug.nl
Supervisor	Michiel Daams
Assessor	Arno van der Vlist

University of Groningen

Faculty of Spatial Sciences

Aknowledgements

Before you lies my master thesis with the title: “Non-performing loans and house prices: Evidence from Greece”. I owe gratitude to my supervisor Michiel Daams for his very useful feedback while writing my thesis. The huge support I received during this process is indisputable. I would also like to thank Mr. Arno van der Vlist, who assessed my thesis, as he provided with very important comments that helped me improve my thesis and knowledge about the topic. In specific, Mr. van der Vlist provided very essential considerations regarding the empirical design of the study which guided me throughout the master thesis process.

Contents

1. Introduction

Economists have often examined financial and banking stability in the context of ex-post-credit risk, or in other words, non-performing loans.[1] The global financial crisis influenced banks, which adopted tighter and more prudent provisions on impaired loans. Consequently, the profits of several banks have been heavily affected during the last decade (Merhbene, 2021). Following credit expansion, towards the business cycle peak, that the interest rates are rising, more relaxed borrowing regulations accompanied with inferior screening processes might lead to higher non-performing loan ratios. Due to changes within the cycle, people, businesses and institutions can face financial difficulties (Konstantakis et al., 2016). Non-performing loans can be triggered from major macroeconomic developments such as; changes in unemployment rates, lower GDP and rising interest rates, which may cause higher rates of default, due to lower income (Messai & Jouini, 2013; Konstantakis et al., 2016). However, the connection of non-performing loans with the housing market has not been covered immensely during the recent decades, although seems relevant when understanding the effects of potential crisis, as this type of asset could affect the NPL fluctuations as well (Wan, 2018).[2] Therefore, this thesis investigates how do the NPLs respond in shocks of the housing prices?

It is well-established that due to future shocks in the macroeconomic determinants and cyclical processes, house prices can decrease and through income fluctuations, people may become unable to re-pay their loans.[3] In particular, when housing prices rise, homeowners can feel safer and richer as Adams and Füss (2010) explain. By this, homeowners believe that they have a crucial opportunity to borrow, as it might bring higher returns. In addition, rising prices can boost banks' capital by increasing the value of properties possessed by the bank or of collateral pledged by borrowers (Koetter & Pogoshyan, 2010). In particular, there are two channels at play; collateral value -the increased value of the assets owned by the bank- and price deviation -which explains the consequences when prices deviate from their fundamental values-, although these might bring to light a joint effect. In more detail, they suggest that

[1]A bank loan is regarded as a non-performing loan (NPL) when the borrower is not able to pay the agreed instalments or interest, for more than 90 days (European Central Bank, 2016).

[2] Recent studies have been either focusing on the macroeconomic determinants of NPLs (GDP growth, inflation, unemployment rates, etc.) or investigating bank specific factors. Little research has been done on the regional-level, connecting the NPL ratios to the housing market, which is essential, as the latter can also exhibit a reaction to changes in the macroeconomy and could be considered as a determinant. Following Koetter and Poghosyan (2010), who observed that there are macroeconomic factors that affect simultaneously the NPLs and housing prices, any bank-specific or other financial factors will not be examined within this thesis.

[3] These processes are additional to more general economic shocks. For instance, a drop in economic indicators such as GDP per capita, income and the increase of unemployment, can cause people being unable to borrow. Consequently, through such shocks, house values fall, usually even lower than the amount of the outstanding mortgage (Stiglitz, 1990). An inactive housing market can be caused, and such house prices shocks can cause higher non-performing loan ratios, as homeowners cannot pay the instalments neither can they sell their houses and so, the bank balance sheet deteriorates. Hence, the real estate market's poorer performance can exacerbate the non-performing loans, due to more strict regulation within banks.

through larger fluctuations of house prices from their fundamental values, the bank's profitability of default can increase further (Koetter & Pogoshyan, 2010).

The aim of the current study is to consider whether changes (shocks), in house prices relate to non-performing loan ratios in Greece, while controlling for established macroeconomic determinants, during the years of 2002 until 2019. Greece is one of the countries that has been affected hugely from the global financial crisis and a consequent sovereign debt crisis.[4] In detail, Greece has experienced a noteworthy rise of non-performing loans and the Greek economy has a relatively high exposure to real estate in aspects of gross national product and bank ratios. In the existing literature, little research has been done on countries that have experienced such continuous crisis as in the case of Greece, regarding the NPLs and housing market. These crises brought to light many issues with a huge impact on the Greek economy, both in individual and national level which makes it an important topic to examine.

The dataset used covers the period of 2002-2019 and consists of quarterly time series data, provided by the Bank of Greece. The method that will be used is a vector auto regressive (VAR) model which, as described by Campbell and Shiller (1987), is a stochastic process model that is used to capture the linear interdependencies among multiple time series. Non-performing loans are examined as the key-dependent variable. The effect of shocks of the house prices and macroeconomic variables on the NPL ratios is expressed through the generalized impulse response functions (GIRFS) that will be explained in a later chapter. By this, we can examine the sign of the relationship between the variables of interest. We find a negative relationship of NPLs with house prices similar to previous studies (Wu et al., 2003; Rinaldi & Sanchis-Arellano, 2006; Koetter & Poghosyan, 2010). Based on these findings, scenario analysis could be used to forecast the NPLs and investigate if or how the banking system can absorb defaults related to their recognition.

As a complementary feature, this thesis considers that the spatial and geographical distribution of bank branches are among the main factors which influence the effectiveness of the credit system and as a result, the non-performing loans (Avetisyan, 2018). Consequently, house price indices for different regions of Athens, Thessaloniki and other large cities, can be used to observe how the non-performing loans respond to shocks in the housing prices in the regional-level in Greece. As Hanink et al. (2010) present, housing prices can vary spatially due to both structural amenities and locational contextual attributes, such as migration. However, observing the reaction of non-performing loans to shocks in the housing prices, while accounting for geographical particularities has not been addressed in the existing

[4] It is well known that Greece in 1981, entered the European Union while adopting the euro as a currency in 2001 (European Commission, 2019). After some years of financial prosperity and a booming economy, during 2001-2010, Greece was affected by the global financial crisis that started in 2007. From 2010, the debt crisis has started and since then, Greece entered a long and rough period of depression and consequent financial crisis. Greece's government implemented a capital control in June 2015 and the effect was that the amount that people could withdraw from banks was restricted (BBC, 2015).

literature. The analysis aims to partial out the effects of the key macroeconomic variables that are related to the house prices and non-performing loans, to capture the spatial relationship between NPLs and housing prices.

The remainder of this thesis is organized as follows. Section 2 examines the literature and discusses theories concerning the non-performing loans and house prices, based on earlier studies' findings. Section 3 describes the empirical approach. Section 4 presents the study area, the dataset and the descriptive statistics. After, section 5 includes the empirical results and some discussion. Lastly, the thesis ends with a conclusion, and recommendations for further research in section 6.

2. Macroeconomic Determinants of Non-Performing Loans and Housing Prices

The literature on non-performing loans and housing markets can be classified into three groups. The first describes the term of non-performing loans and the macroeconomic factors of which they are determined. The second discusses the determinants related to the macroeconomy for the housing prices. Lastly, the relationship of non-performing loans and the key explanatory variable of house prices are discussed.

2.1 Non-performing loans and macroeconomic determinants

First of all, we start by explaining the relationship between non-performing loans and mortgage defaults, using the macroeconomy. Messai and Jouini (2013) claim that the minimization of non-performing loans is essential, in order to improve economic growth and ensure economic efficiency. As the authors explain, many studies illustrate the positive effect of non-performing loans on possible crisis and the importance they have for the prediction of crisis within banks. In addition, NPLs may relate to the conditions of the total loans in an economy (Pesola, 2007; Jappelli et al., 2008; Nkusu, 2011). Hence, non-performing loans are a crucial factor to ensure economic efficiency.

The quality of the banks' loan portfolios was worsened during the recent decades and caused several problems in the banking system, especially in the face of financial crises. There is evidence that show the existence of a strong relationship between NPLs and macroeconomic determinants (Messai & Jouini, 2013; Konstantakis & Michaelides, 2016). In specific, as the authors explain, there are various macroeconomic determinants that can impact the borrowers' ability towards possessing a loan or paying their (loan) installments. These macroeconomic determinants are the gross domestic product (GDP) growth, real exchange rate, inflation, unemployment rates, public debt and more. More specifically, GDP growth rate and employment, are negatively related to NPLs -probably due to a resulted higher level of income- whereas unemployment rate is positively related. In addition, the interest rates affect the amount of bad debt, thus, a rise in NPL ratios can be observed, due to the increase in payments of interest rates (Messai & Jouini, 2013).

Similarly, Radivojevic et al. (2019) present that both macroeconomic and microeconomic factors have an impact on the NPL ratios. Firstly, they highlight that most of the researchers find that there is a strong relationship of GDP growth with NPLs. In particular, a negative impact of the former one is observed. However, they identify that several different estimation techniques are being used among the scholars that can lead to biased results due to mis-specification of the models.

To conclude, based on the existing literature non-performing loans are expected to present a negative relationship with GDP growth, inflation and employment, but a positive with unemployment and interest rates.

2.2 House prices and macroeconomic determinants

Furthermore, during the recent decades, literature on housing prices supports that this type of capital market asset is not affected directly by changes in economic fluctuations, as there is a long-term perspective that can influence owners' behavior (Adams & Füss, 2010). Various macroeconomic factors related to the property sector are also incorporated into models that calculate housing prices. For instance, interest rates do not directly affect the demand for housing space, but influence the demand of owning a house. An increase in interest rates can lead to higher proportion of mortgage loans, thus, the demand and the housing prices could decrease (Adams & Füss, 2010). Additionally, an increase in employment, can create further demand for construction as more labour is attracted nearby. However, this can be observed in the long run; construction process is time-consuming.

As Gaspareniene et al. (2016) present, there are three major macroeconomic determinants related to the housing market. More specifically, gross domestic product, inflation and interest rates are connected to an improved economic situation in the economy of a country. Increase in GDP and inflation are both related to higher housing prices, whereas higher interest rates lead to lower market liquidity in the housing sector. According to Gaspareniene et al. (2016), employment is an additional factor that can lead to higher housing prices, as it creates demand for further property purchases, since people feel safer and able to borrow. However, as the authors demonstrate, employment is not an obvious reason for the rise in house prices, as many housing purchases are financed through personal savings of buyers, rather than a loan. Income and consequently wages, do not determine the housing prices per se.

Lastly, Englund and Ioannides (1997), examine macroeconomic variables such as GDP growth and real interest rate, but also specific demographics in order to observe any presence of predictive power of the housing prices. They conclude that, apart from the population variable which did not perform well in their analysis, higher GDP growth leads to higher house price growth in the future. As a result, higher GDP prevents financial deterioration, which is a positively related condition to the existence of bad loans.

To conclude, house prices are affected by changes in the macroeconomy. Also, as Brooks and Tsolacos (2010) mention, in real estate markets there are long-run relationships existing between two or more variables. This is called cointegration[5]; for instance, house prices could in the long run move in proportion with forces determined by economic variables.

2.3 Non-performing loans and house prices

The third section of the literature, focuses on the NPL ratios in relation to the housing prices. As Rinaldi and Sanchis-Arellano (2006) evaluate, the ratio of NPLs of a bank will definitely influence the bank's lending policy, which has an impact on future financial situation and the behavior of these NPL ratios, too. In particular, the ability of an individual to borrow can be restrained from income fluctuations and their ability to post collateral as uncertainty is inherited within financial markets. This could imply that lower income can bring higher probability of default due to inadequate financial resources of the borrower. Existing studies, have used the house price index as a variable to examine the residential borrowing behavior. More specifically, it accounts for the variability in housing wealth as well as the ratio of owner-occupied properties.

Furthermore, as Wan (2018) presents, housing prices have a significant and in particular negative effect on non-performing loans. More specifically, when housing prices increased, the NPLs presented lower ratios, while with decreasing housing prices, the ratio of NPLs was magnified. Similarly, Ogawa (2003) who use micro data and macro city land prices through panel estimations, observe that decreased land prices significantly raised NPLs. The level of non-performing loans does not only affect the performance of real estate, but also banks' profitability; real estate markets and NPLs are closely related (Wu, et al., 2003). As the authors illustrate, a troubled real estate sector could be considered as a contributing factor for NPL ratios to increase.

[5] More specific definition of cointegration can be found in chapter 3.

Accordingly, as Shen and Chang (2002) claim, NPLs affect the lending policy of banks, so a more conservative real estate policy could be expected, since risky loans can cause a bank's crisis. However, due to lending restrictions, a potential crisis could be exacerbated by a poorer performance in the real estate market (Shen & Chang, 2002). Moreover, balance among real estate market and banking sector is highly related to banks' management, as they have a central role as mortgage lenders and the use of real estate as a collateral is very frequent (Koetter & Poghosyan, 2010). The authors present that real estate prices depend on macroeconomic determinants, such as income, GDP growth, wealth and population growth. As a consequence, it can be observed that there are some factors that affect both the housing prices and NPLs.

Moreover, as Kotter and Poghosyan (2010) illustrate, an increase in housing prices can enhance banks' capital through increased value of real estate assets that are owned by the bank and increased value of any collateral promised by the borrowers. They suggest that larger deviations of house prices from their "normal" values, can increase banks' probability of default and result in higher NPL ratios. However, nominal variation concerning the house prices, without accounting for variation in macroeconomic fundamentals or determinants that are related, does not influence bank stability (Koetter & Poghosyan, 2010). Hence, non-performing loans and housing prices are mutually affected by specific macroeconomic fundamental changes.

Table 1. Basic non-performing loans and house price index macroeconomic determinants

Measure	Variables Included	Expected Relationship - Significance
[NPLs][a,b,c]	**GDP growth**, total loans, real exchange rate, **inflation**, **unemployment**, public debt, **interest rates**	Unemployment and interest rates are positively related with non-performing loans whereas GDP growth, inflation and employment are negatively
[HPI][d,e,f,]	**Interest rates**, **employment,** **GDP growth**, **inflation**, income, term spread, population growth	Employment, GDP growth and inflation are positively related with housing prices whereas interest rates are negatively
[NPLs & HPI][g,h,i,j,k,l]	GDP growth inflation unemployment interest rates	Housing prices have a negative effect on non-performing loans. Troubling real estate sector is considered as a contributing factor for NPL ratios increase

[a]Messai and Jouini (2013) [b]Konstantakis & Michaelides (2016) [c]Radivojevic et al. (2019) [d]Adams & Füss (2010) [e]Gaspareniene et al. (2016) [f]Englund & Ioannides (1997) [g]Rinaldi & Sanchis-Arellano (2006) [h]Wan (2018) [i]Ogawa (2003) [j]Wu et al. (2003) [k]Shen & Chang (2002) [l]Koetter & Poghosyan (2010).

3. Methodology

- Vector autoregressive model (VAR)

In this study, the aim is to investigate the relationship between non-performing loans and house prices, based on macroeconomic determinants and observe any differences in the ratios over the studied period, in relation to shocks in the other variables. As Sims (1980) explain, vector auto regressions can be used for forecasting, designing and evaluating economic models and policy making. Hence, we use a vector auto regressive model which is able to capture the interdependencies among the variables used, similar to Konstantakis et al. (2016). More specifically, the variables that have been selected are based on the literature regarding the macroeconomic determinants of non-performing loans but we also implement in the analysis the house price indices.

Non-performing loan ratios variable is assumed to be affected by changes in the gross domestic product growth, the expected inflation, the unemployment rate, the interest rates and the house price indices. As Brooks and Tsolacos (2010, p. 337) define, the vector autoregressive model consists of multiple regressions with more than one dependent variable, of which current values depend on different combinations of lagged values of the variables and also, the error terms. Hence, all the above-mentioned variables will be used as dependent (endogenous) variables, determined from the variables of the system and the lagged values. They define the VAR model in levels, using the notation:

$$y_t = v + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_k y_{t-k} + \delta_0 x_t + \delta_1 x_{t-1} + \cdots + \delta_r x_{t-1} + u_t \quad (1)$$

where v is a kx1 vector of parameters (constants of the regressions), y_t, are the endogenous variables, x_t are the exogenous, the $\beta_{ij,k}$,$\delta_{ij,k}$ indicate the effect of the variable j on variable i with a lag of k, and $u_{i,t}$ is the residual (white noise) of variable i, and lastly the $_{k,r}$ show the duration of the series included (how long back the analysis is going). According to Konstantakis et al. (2016); “the vector term u_t is a white noise, which means that each of these elements from the regressions has a zero mean and a time invariant positive definite covariance matrix”. Autocorrelation in the error terms and across time is assumed to be absent. We will check these restrictions in a later stage. If differences I(1) or I(2) are used, the notion Δ or Δ^2 should be used in front of the variables.

- Unit root test

As most time series models require stationary data, the analysis begins by testing the selected variables, in order to fulfill this condition. As Brooks and Tsolacos (2010) suggest, the use of data that are not stationary can lead to spurious regressions. The Augmented Dickey Fuller (1979) test can provide with information on whether to use the data in levels or if any transformation process is needed. The test is given as:

$$\Delta(x_t) = b_0 x_{t-1} + \sum_{i=1}^{k} a_i \ (\Delta x_{t-i}) + \varepsilon_t \ (2)$$

where Δ is the difference operator, b_0 and a_0 are coefficients, k are the lags used, x_i are the endogenous variables and ε_t is the white noise error term.

- Cointegration test

In addition, if variables used in the model are stationary in differences, cointegration diagnostics need to be performed, since these variables could move together over time as Brooks and Tsolacos (2010) explain. Cointegration refers to the fact that two or more series share a stochastic trend and could be associated in the long run even if their relationship deviated in the short run (Stock & Watson, 2019). Also, Engle and Granger (1987), suggest a two-step process to test for cointegration, both an ordinary least squares regression and a unit root test, following an Augmented Dickey-Fuller (ADF) approach.
Johansen (1988) uses a method that can capture more than one cointegrating relationships. The equation given in the above-mentioned method for second order differences is:

$$\Delta^2 y_t = \Pi \ y_{t-1} - \Gamma\Delta \ y_{t-1} + \sum_{i=1}^{p-1} \Psi i \, \Delta^2 y_{t-i} + e_p \ (3)$$

where the cointegration presence depends on the rank of Π matrix where the likelihood ratio is tested, using a trace test.

In case that cointegration is present, a vector error correction model needs to be implemented, which is a restricted vector auto regression model that involves the cointegration restrictions into the model specification in order to use these non-stationary series that are cointegrated. More specifically, the VEC model imposes the existing long-run relationship of the variables to turn into their cointegrating relationships while at the same time recognizing short-run relationships. The model is changing to an error correction model by allowing these short-run adjustments. Results can be found in the next chapter.

- Lag length selection

The lag length of the model is being selected based on the Akaike's information criteria[6]. Brooks and Tsolacos (2010) support that including too few lags will not remove the autocorrelation which can bias the results, but using too many can increase the coefficients' standard errors. Hence, it is important to include other criteria in order to derive to the most efficient result. More specifically, as Lütkepohl (2005) explains, such information criteria measure the distance between the observations and model classes. The AIC (Akaike) criteria is denoted as:

$$AIC_{(P)} = -2\left(\frac{LL}{T}\right) + \frac{2t_p}{T} \ (4)$$

[6] Schwarz's Bayesian information criterion (SBIC) and the Hannan-Quinn information criterion (HQIC) are the other two most popular used in order to choose the number of lags for the model.

where t_p is the total number of the variables, LL is the log likelihood and T is the number of observations.

- VAR – VECM

Following the above-mentioned suggestions, the vector auto regression for the key-interest variable of non-performing loan ratios is given as:

$$\Delta^2 npl_t = v + \sum_{i=1}^{k-1} B\, i\Delta^2 gdpg_{t-1} + \sum_{j=1}^{k-1} \Phi j\, i\Delta^2 infl_{t-1} + \sum_{m=1}^{k-1} \Gamma\, m\Delta^2 unem_{t-1} + \sum_{n=1}^{k-1} Z\, n\Delta^2 intrate_{t-1} + \sum_{o=1}^{k-1} \eta\, i\Delta^2 hpi_{t-1} + u_{1t} \quad (5a)$$

where *npl* denotes the ratio of mortgage non-performing loans to total mortgage loans for Greece at time *t*. The *gdp* is gross domestic product growth, *infl* for the inflation rate, *unemp* accounts for the unemployment rate, which relates to the uncertainty of the future income of a borrower and finally *intrate* captures the real interest rates given for the same period. The house price index for Greece in country level but also in regional level at time *t* is expressed as *hpi*. The term u_t is a white noise as stated in equation (3). Δ^2 is the second order difference I(2) of the variables, which responds to the stationary data condition.

The aforementioned macroeconomic variables are the core variables of the model and as based on the literature, they are considered as the most relevant when investigating non-performing loan ratios and house prices. In case a vector error correction model is applicable, the inclusion of the appropriate error terms to account for the long-run relationships is crucial.

The VECM model is used as a restricted vector auto regressive model, which is applicable for nonstationary series that have one or more cointegrating vectors (Clayton et al., 2009). With a VECM model equal to equation (8a) and an additive error correction term of $\lambda\Delta^2 u_{t-1}$where λ is the coefficient (which is negative) regarding the correction of the disequilibrium period *t-1* which takes place in period *t.* Also, $\Delta^2 u_{t-1}$ is the magnitude in difference by which *y* was below or above the long-run equilibrium value in the previous period. As this allows to correct for the error and let the variables move together over time, it is similar to a VAR model. What the error correction term implies, is that the deviation from the long-run equilibrium is reformed by allowing short-run dynamics (Konstantakis et al., 2016). Hence, the VEC model for the non-performing loans is given as:

$$\Delta^2 npl_t = \sigma + \sum_{i=1}^{k-1} \beta\, i\Delta^2 gdpg_{t-1} + \sum_{j=1}^{k-1} \varphi j\, i\Delta^2 infl_{t-1} + \sum_{m=1}^{k-1} \gamma\, i\Delta^2 unem_{t-1} + \sum_{n=1}^{k-1} \zeta\, i\Delta^2 intrate_{t-1} + \sum_{o=1}^{k-1} \eta\, i\Delta^2 hpi_{t-1} + \lambda\Delta^2 u_{t-1} + u_{1t} \quad (5b)$$

- Generalized impulse response functions

An important step of the var/vec model is to detect the sign of the relationship between the variables. In particular, the aim is to present how specific shocks in the variables affect the key-interest variable of the analysis. Shocks in the variables (impulses) are being investigated with their impact on the variable that is called response variable. In this study, the non-performing loans is the response variable. This can be performed through the generalized impulse response functions (GIRF) which is expressed as:

$$I_{l(n)} = \sigma_{ll}^{-\frac{1}{2}} + B_n \Sigma e_l \forall n = 1, 2, \dots \ (6)$$

As described in Konstantakis et al. (2016), $I_{l(n)}$ is the impulse response function at period n after a positive standard error unit shock, σ_{ll} are the rows and columns of the covariance matrix of Cholesky decomposition, which follows a normal distribution, B are the coefficients and e_l is the column vector of a unity matrix. With IRFs the effect of a shock on the behavior of a time series can be estimated. In particular, IRF presents how much a variable change at a specific moment in time, consider $t+h$, if another variable from the system changes at the time t. The magnitude of the shock corresponds to one-unit standard deviation for a horizon set in the process. The horizon in the current analysis is set to 20 quarters, i.e. 5 years. In the next chapter, the dataset used will be presented.

4. Data

The dataset is sourced from the Bank of Greece and covers time series data, of a period of 18 years, from q4 2002 to q4 2019. Non-performing loan ratios are obtained from the Bank of Greece, regarding all Greek commercial and cooperative banks. The ratios are calculated as the non-performing gross residential loans divided with the gross residential total loans and is expressed in percentages. The aim is to examine the relationship between non-performing loan ratios and housing prices; hence, consumer and business non-performing loans will not be taken into consideration in the ongoing analysis. Important to mention is that balance changes between some quarters could be affected by the restructuring of the Greek banking system. Due to the consequent crisis banking system regulations change throughout the studied period. For instance, the resolution of banks or sale of foreign branches could be such restructuring policies.

To continue with, house price indices are based on data collected by the credit institutions and weighted index according to the stock of houses in Athens and in other urban areas. They are provided from the Bank of Greece in cooperation with research done by dominant real estate firms. Cases that contained incomplete or missing information were removed from the dataset. An additional dataset collected from the Bank of Greece includes the mortgage interest rates through the same period. The sum of individual amounts may be slightly different from the total amounts due to rounding and new deposits exist only in the case of deposits with agreed maturity, while for loans only in the case of loans with a defined maturity.

In addition, the dataset that includes GDP growth, inflation and unemployment rates, is created from the OECD, Eurostat and World Bank. Some data were available for longer time periods, but due to other variables' missing observations during larger time periods, only the period of 2002q4-2019q4 is included in this study. Based on the literature review regarding the non-performing loans and house prices and the methodology, a selection of the variables was made. A summary of the selected variables and data sources is given in table 2.

Table 2. Variables Description

Variable	**Description**	**Source**
Non-performing loans	The ratio of mortgage non-performing loans to total mortgage loans per quarter	Bank of Greece
House price index	Index that measures the price changes of residential housing as a percentage change from a specific start date	Bank of Greece
Gross Domestic Product growth	Total market value growth of all the finished goods and services produced within a country's borders per quarter	OECD, Eurostat
Inflation	The inflation rate is the percentage change in consumer prices	OECD, World Bank
Unemployment	Unemployment Rate	OECD
Interest rates	Real interest rates of all Greek commercial banks given in quarters	Bank of Greece

Notes: The description of the variables is based on information from global financial sources, for the country of Greece given in quarters

Figure 1 presents the percentage of the non-performing residential loans in Greece through the studied period. As can be seen, the highest non-performing loan ratios are observed during the time period of 2014-2019. In addition, up until 2019, the ratios were still rising. This period is strongly related to the Greek debt crisis that followed after the global financial crisis in 2007.

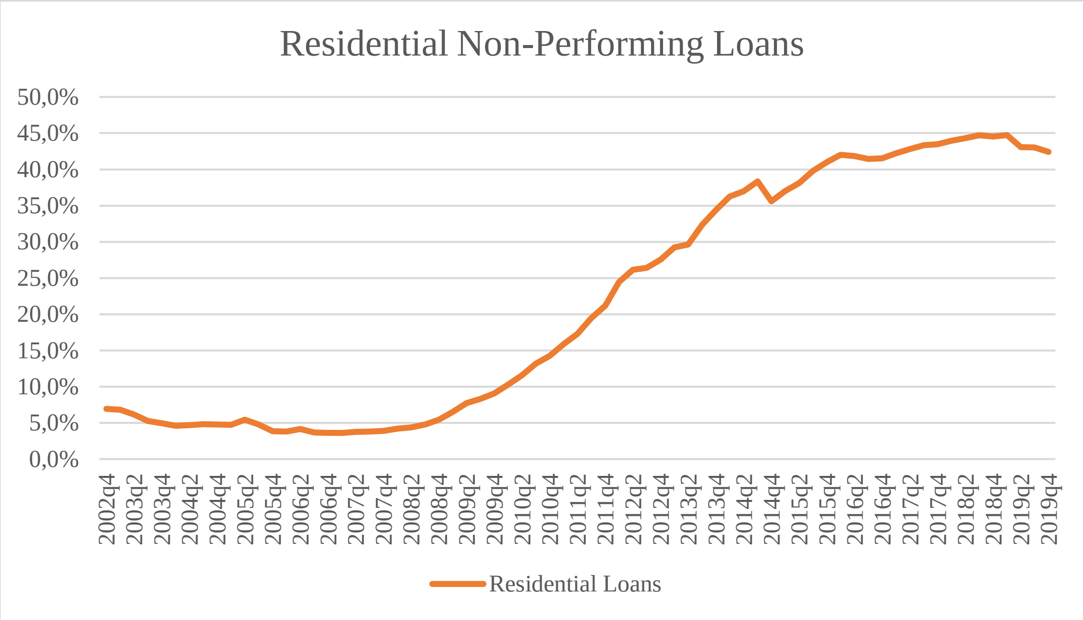

Figure 1 Non-Performing Residential Loan during the study period of 2002-2019.
Source: Bank of Greece

The descriptive statistics of the dataset are shown in table 3. On average, the non-performing loan ratios are 21.7% during the studied period. The house price index has an average of 198.8 and presents fluctuations through the studied period. Gross Domestic Product growth has a mean of approximately -0.2%. This negative growth rate is experienced due to consequent crisis in Greece. Inflation has an average of 1.7%, unemployment was on average 16.4%, which is considered as a very large percentage rate in Europe and interest rates have an average of 3.7%, from 2002 to 2019.

Table 3. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
NPLs (%)	69	21.655	16.444	3.611	44.742
HPI	69	198.822	39.536	149.49	261.397
GDP growth (%)	69	-.170	1.673	-5.744	3.258
Inflation (%)	69	1.687	2.077	-2.378	5.534
Unemployment (%)	69	16.437	7.056	7.533	27.867
Interest Rates (%)	69	3.659	.795	2.497	5.223

Notes: NPLs and HPI are acronyms for the non-performing loan ratios and the house price indices. All variables are expressed in percentages, except from hpi which is an index.

5. Results and Discussion

5.1 VARM-VECM Application

The empirical analysis begins by investigating whether the variables are stationary, otherwise they should be used in differences when introducing the model. Hence, the Dickey Fuller (1979) test is being performed, considering all variables in the system. The result, provides that the null hypothesis of a unit root can be rejected, for all second order differences of the variables, thus, second order differences I(2) are used in the model.[7]

As can be seen in table 4, for all variables their second order differences are stationary as the test statistics provided by the ADF test are higher than the critical values for the 1% level. The graphs illustrating the pattern that the variables follow in levels, first and second order differences (correcting for unit roots) are given in Appendix II.

Table 4. Augmented Dickey Fuller - Unit root test results

Constant and trend						
Variables	p-value levels	Stationarity	p-value I(1)	Stationarity	p-value I(2)	Stationarity
npls	0.71	NO	0.29	NO	0.00	YES
hpi	0.29	NO	0.77	NO	0.00	YES
gdpg	0.34	NO	0.00	YES	-	-
inflation	0.11	NO	0.00	YES	-	-
unemployment	0.67	NO	0.78	NO	0.00	YES
interest rates	0.17	NO	0.00	YES	-	-

Notes: *** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level. Critical values given by MacKinnon (2010). Null Hypothesis is that the series are non-stationary. "–" is representing that the variable is stationary at first differences. Several robustness checks were performed in the model, by using the logarithm of the variables and testing the unit roots. The transformed variables did not provide with any differences in the results, second order differences I(2) were present.

Moreover, as a next step, cointegration tests of Johansen (1988) were performed, since some variables are integrated of order I(1) and others are I(2). Cointegration implies that there is a long-run relationship and the series can be combined in a linear function. Moreover, if there are shocks in the short run which can affect the movement in the individual series, they would converge with time (in the long run). As shown in table 5, two cointegration equations were found and results from Johansen (1988) test are given below. There are two cointegration equations as given in the maximum rank. Hence, we need to estimate both long run and short run models. Therefore, we have to use a vector autoregressive - vector error correction model (Equation 5b).

[7] Variables in levels and their first differences are not stationary for all variables simultaneously, which is a condition to implement a VAR model (Brooks and Tsolacos, 2010).

Table 5. Johansen test for cointegration results

Maximum rank	Log likelihood	Eigenvalue	Trace statistic	5% critical value	Cointegration
0	-424.57835	.	125.6627	94.15	
1	-402.2997	0.48574	81.1054*	68.52	
2	-384.4219	0.41355	45.3498	47.21	**YES**
3	-373.12748	0.28620	22.7609	29.68	
4	-364.71872	0.22198	5.9434	15.41	
5	-362.27352	0.07039	1.0530	3.76	
6	-361.74701	0.01559			

Notes: *Denotes statistical significance at 5% or higher. The value 45.3498 shows that this estimator has selected the number of cointegrating equations corresponding to the table as two (since the trace statistic is smaller than the critical value we cannot reject the null hypothesis that there is no cointegration). Critical values for the trace and maximal eigenvalue test are given by Osterwald-Lenum (1992). The variables included are the non-performing loans, the gross domestic product growth, the inflation, the unemployment, the interest rates and the house price index.

Additionally, table 6, shows that the AIC and BISC value for the system is minimized at the second and first lag accordingly. As Brooks and Tsolacos (2010) explain, SBIC is consistent but not efficient while AIC is not consistent but more efficient. In general, there is not a clear choice on whether to choose the AIC or SBIC criterion. Following Konstantakis et al. (2016), we proceed with the AIC criterion, choosing 2 lags and based on the sample size and our large model, we consider the result of SBIC (1 lag) as less optimal.

Table 6. VAR lag length selection

Endogenous variables	Lags	AIC value	SBIC value
	0	29.7879	29.9886
	1	13.4835	**14.8885***
npls, gdpg, infl, unempl, intrate, hpi	**2**	**13.1676***	15.7769
	3	13.6212	17.4347
	4	13.6968	18.7146

Notes: * Provides the optimal lag length selection based on the Akaike's and Schwarz's values

When implementing vector auto regressive - vector error correction models we have to perform some diagnostic checks for the system's stability. Hence, after running the VAR - VEC models following equations (1 and 5a), several postestimation model diagnostics are performed, to proceed on the impulse response functions in the next subsection and reveal the impact of the above-mentioned variables' shocks on the non-performing loan ratios. The standard diagnostics (Brooks & Tsolacos, 2010; Konstantakis et al., 2016) regarding autocorrelation, and stability of the model can be found in appendix IV.

Table 7. VAR results

	Equation in VAR	
	$\Delta^2 NPLs_t$	$\Delta^2 HPI_t$
Constant	0.009	0.023
	(0.090)	(0.07)

$\Delta^2 NPLs_{t-1}$	-0.613	-0.677
	(-4.8)	(-1.70)
$\Delta^2 NPLs_{t-2}$	-0.195	0.024
	(-1.480)	(-0.06)
$\Delta^2 HPI_{t-1}$	-0.06	-0.482
	(-1.500)	(-3.77)
$\Delta^2 HPI_{t-2}$	-0.015	-0.229
	(-0.39)	(-1.85)
R^2	0.305	0.233

Notes: The above model includes the non-performing loans and the house price index. Coefficients are presented, indicating the negative relationship among the two variables. Sample period is October 2002 to October 2019. Numbers in parenthesis are t-ratios, two lags are included.

Table 7 presents the results of the VAR estimation with two lags and the two main interest variables. These are the non-performing loans and house prices. As mentioned above, the house prices are considered as a very important factor for the NPLs and are thought of as the key-variable of interest. We can observe a negative relationship between non-performing loans and house prices, as expected based on the existing literature (Shen & Chang, 2002; Ogawa, 2003; Wu et al., 2003; Rinaldi & Sanchis-Arellano, 2006; Koetter & Poghosyan, 2010; Wan, 2018). Additionally, as Brooks and Tsolacos (2010) explain, some coefficients in the VAR equations might not be significant or take the expected signs but if the model has the correct "shape", this is not a problem. Following a VAR estimation including all variables from table 2, we create the impulse response functions which are presented in the next section.

5.2 Generalized Impulse Response Functions (GIRF)

Within a VAR system, the F-tests will only suggest which variables present significant impact on the values of each variable within the system. However, the sign of the relationship cannot be explained through such tests, neither how long an effect or a shock requires to take place. Impulse response functions detect how the dependent variables in the model respond to shocks to each of the variables of the system (Brooks & Tsolacos, 2010). The response of the dependent variables of the vector autoregressive model to shocks to each of the other variables, with regards to the time that it takes for the variable to return back to its equilibrium position after the shock, are captured through the impulse response functions. Hence, the time that each shock takes to be absorbed is important, since some shocks are more difficult to 'die away' as Brooks and Tsolacos (2010) mention.

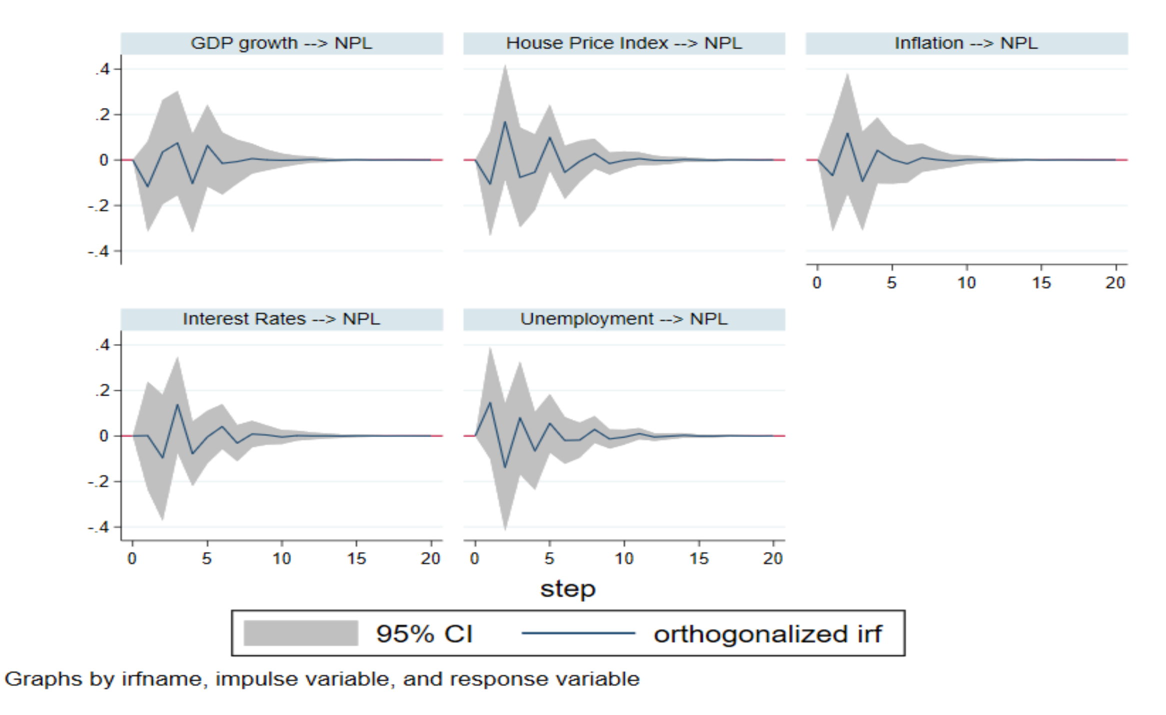

Figure 2. Response of NPLs to shocks in GDP growth, House Price Index, Inflation, Interest Rates and Unemployment Rates

This subsection focuses on capturing whether possible shocks in the value of a given variable has a positive or negative effect on others within the system, focusing on the key-interest variable of non-performing loans. The dynamic responses of non-performing loans to shocks in GDP growth, house prices, inflation, interest rates and unemployment, through a period of 20 quarters, are presented in figure 2 (Appendix V presents the robustness checks, using the transformed variables in the model). We first consider the response of NPLs to shocks in the several macro-level factors which are considered in this analysis, before turning to our focal point, the response of NPLs to house prices.

As can be seen, the response of non-performing loans to a shock in gross domestic product growth is negative during the first three quarters. In specific, the direction of the line at the first moment of the shock is indicating the sign of the relationship. Also, the moment up until the line is presenting fluctuations, provides with the duration of the shock. In the long run, the non-performing loan ratios return back to the equilibrium conditions approximately after the 10^{th} quarter. As provided in the international literature, gross domestic product growth is related to a higher level of income which can increase the ability of the borrower to pay their loan installments, thus, contributes to reduce NPLs (Messai and Jouini, 2013). In Greece, a negative impact can be observed during the studied period, as the global financial crisis and a consequent debt crisis has created financial difficulties to people who had a lower level of income.

A shock in inflation affects negatively the NPLs in the short run, whereas in the long run the NPLs return back to their equilibrium condition, not long after the 6th quarter. As Rinaldi & Sanchis-Arellano (2006) explain, rising inflation can worsen the financial conditions, especially in the long-run. However, inflation is an ambiguous factor, as it can act both as a positive and negative influence on non-performing loan ratios (Ptasica, 2018). For example, high inflation rates can reduce the purchasing power of people, as their income is used for consumption. When there are high inflation rates, the cost of business is higher and can lead to less returns for the business. Hence, the ability to repay the loans might be reduced.

A shock in interest rates also affects negatively the NPLs in the short run, until the second quarter, while in the mid-run the shock in interest rates affects positively the NPLs. However, in the medium term, the non-performing loan ratios return back to the equilibrium conditions, after approcimately the 8th quarter. The results for the interest rates are supported by Wu et al. (2003), who observe that lower interest rates cause non-performing loans to rise. A possible explanation is that interest rates have a positive effect on the amount of bad debt, especially because borrowers are adversely affected due to changes in interest rates.[8] However, Messai and Jouini (2013) find that interest rates have positive long-term impact on non-performing loans.

Finally, a shock in unemployment affects positively the NPLs in the short run and for about 3 quarters. However, in the medium-run and especially until the 6th quarter there are fluctuations that provide with a shock having negative effect on the NPLs. In the long-run, after the 12th quarter the NPLs return back to their equilibrium conditions. As Konstantakis et al. (2016) explain, higher unemployment rates, lead to the borrowers not being able to pay their installments, which leads to a rise in non-performing loans. This is consistent with Messai and Jouini (2013) who support that unemployment is positively related to non-performing loans due to a lower level of income.

We now focus on the main variable of interest, the responses of NPLs to shocks in house prices. As can be seen, a shock in house prices, affects negatively the NPL ratios in the short-term for about 2 quarters, which confirms our hypothesis.[9] However, after some quarters, in the mid-term, the shock in house prices affects positively the NPL ratios, but in the long-term NPLs return back to their equilibrium conditions. However, this is observed after the 12th quarter, which is a longer duration of the shock in comparison with most of the macro-variables of the analysis. These findings are consistent with Wu et al. (2003), Rinaldi & Sanchis-Arellano (2006) and Wan (2018) who observed that there is a negative relationship between real estate markets and non-performing loans, thus, housing prices are negatively

[8] Other variables which have not been taken into account, such as bank specific factors, could affect this relationship.

[9] The first study hypothesis is that there is a negative relationship between non-performing loans and housing prices, as found in the papers of Wu et al. (2003), Rinaldi & Sanchis-Arellano (2006), Koetter & Poghosyan (2010) and Wan (2018).

affecting the latter. Before the global financial crisis, house prices had risen and supported the collateral of the firms and entrepreneurs who secured loans on their houses. Simultaneously, due to the financial strength, banks have been lending aggressively (Minsky, 1963). However, after the crisis, collateral values drop and banks needed to rebalance additionally because of that. Hence, the lending policies were tightened and as a consequence the ability of firms and individuals to obtain loans was worsened. Additionally, due to financial difficulties and large fluctuations of house prices the bank's profitability of default can be increased, amplifying the non-performing loans (Koetter & Pogoshyan, 2010).

5.3 Spatial Patterns of non-performing loans in Greece

We now turn to examine the effect of changes of house prices on the non-performing loans in regions across Greece. Louzis et al. (2012), investigate specific type of non-performing loans, in order to observe if there are differences among business, mortgage and consumer categories. Here, we only focus on the mortgage loans, which are clearly the most closely related to the housing market, in comparison with the other type of loans. However, it is interesting to examine if spatial patterns exist and observe regional-scale fluctuations as observed in previous studies (Hanink et al., 2010; Avetisyan 2018). The main reason is that there are geographical particularities that affect each location in multiple levels. For instance, most big banks are located in Athens but not all borrowers are operating in Athens. As Petach et al. (2021) explain, home prices can be more resilient in regions that have high concentration of local capital in terms of community banks. By this, changes in the house prices in different regions that have not such concentration of capital could be affecting the borrowers' ability to repay their loans and location patterns might be observed.

In particular, we support that house prices can be thought of as primarily local measures and could provide with further insights. Therefore, we investigate whether shocks in house prices in Greece, and specifically in Athens, Thessaloniki and other big cities, present variations on the response of the non-performing loans. We follow the same analysis as before, but now using regional specific house price indices provided by the Bank of Greece. Table 8 presents the descriptive statistics of the house price indices.

Table 8. Descriptive statistics of the house price index percentage change per region in Greece

Variable	Obs	Mean	Std. Dev.	Min	Max
hpiAth	69	.77	.159	.561	1.014
hpiTh	69	.723	.172	.541	1.027
hpiUrbCi	69	.79	.144	.615	1.026

Notes: Ath is used for the mean house price change in Athens, Th for Thessaloniki and UrbCi for the other urban centers excluding Athens and Thessaloniki.

We perform the analysis as followed in the previous chapter. In specific we check for stationarity and perform the Augmented Dickey Fuller test, the Lag Length Selection tests and the Johansen's Cointegration test (following equations 2, 3 and 4). The results can be found in Appendix II – Stationarity and Appendix III – Unit Root Test, Lag Length Selection and Cointegration test (city-level). Finally, we create the impulse response functions of the new model. The results provided for different regions are presented below. The figures present the GIRFs, which incorporate the variables of house price indices for Athens, for Thessaloniki and finally for all other big urban centers in Greece (excluding Athens and Thessaloniki). All other macroeconomic variables are structured similar to the model that includes the house prices for Greece, in other words, we assume that they are held constant. The reasoning behind this is that the macroeconomic variables were not available for the city-level. We are therefore able to explain any differences observed in the response of the NPLs on the city-level, based on the shocks in house prices.

As can be seen in figure 3, a shock in the house prices of Athens, affects negatively the non-performing loans in the short run, for about two quarters. This result is similar to the response for Greece including all locations. This can be explained by the fact that Athens is the capital of Greece, hence, the house prices in Greece can largely follow, or be affected, by the house prices in this major local economy. In the long run, after the 8th quarter, the NPLs return back to their equilibrium conditions. Hence, the group of Athens, in terms of house prices shocks, does not present any variations in the NPLs in comparison with the pattern observed in Greece, holding all other control variables equal.

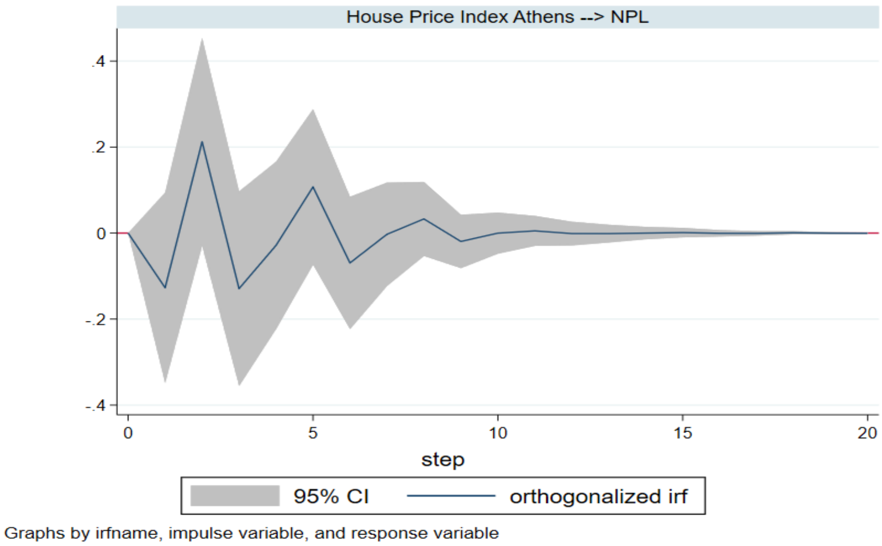

Figure 3. Response of NPLs to shocks in House Price Index of Athens

Figure 4 presents the shock in house prices in Thessaloniki, where a positive effect on non-performing loans can be observed. More specifically, a positive effect can be detected in the short run, while in the mid run, and before the 5th quarter, the shock in house prices affects negatively the non-performing loans. In the long run however, the NPLs return back to the equilibrium situation, right after the 8th quarter, earlier than in other cities.

This result contrasts the findings of the shock of house prices for Greece, as the effect in Thessaloniki follows a reversed trend than the one supported from the literature of Wu et al. (2003), Rinaldi & Sanchis-Arellano (2006) and Wan (2018). This could reflect 'omitted' variables on regional processes that relate to spatial spillovers, in terms of unemployment rates, risk premium and rental growth, but also migration (Zhang et al., 2017; Avetisyan, 2018). For instance, due to the consequent crisis that Greece experienced, many people who worked in Athens were forced to return back to their hometowns, in order to find a job, because the competition in Athens was constantly rising. Hence, the unemployment rates in Thessaloniki, could be lower than in Athens for specific time periods.[10]

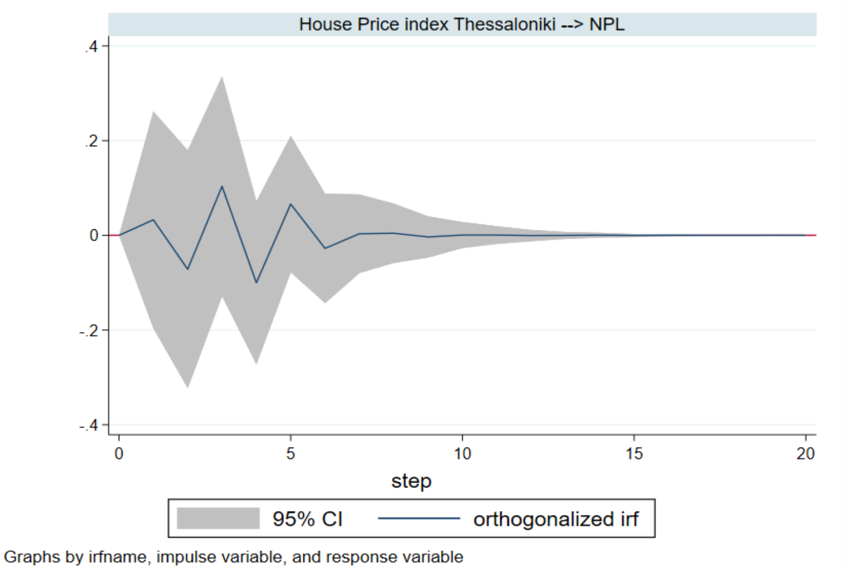

Figure 4. Response of NPLs to shocks in House Price Index of Thessaloniki

[10] We … ment rates in Thessaloniki, the effect …

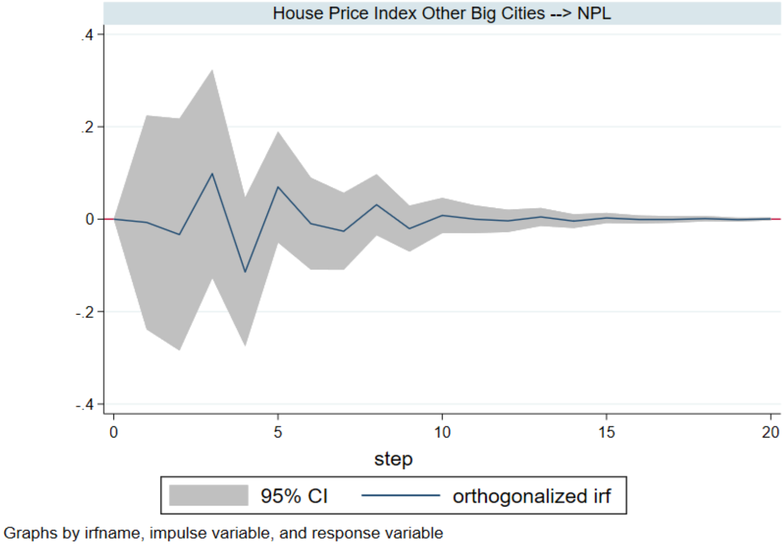

Figure 5. Response of NPLs on shocks in House Price Indices of other big urban centers in Greece

Finally, as can be seen in figure 5, a shock in house prices in other big urban centers in Greece, excluding the locations of Athens and Thessaloniki affected negatively the non-performing loans in the short run, until the 3th quarter. However, in the long run, after the 15th quarter, the NPLs return back to their equilibrium conditions. The effect of the shock seems to have longer duration, than in the previous two situations. In addition, the house prices in other cities than Athens and Thessaloniki present the highest fluctuations (mean house price index percentage change is equal to 0.79%, as can be seen in table 8). Hence, the positive impact could be again related to other omitted variables, such as migration rates (Avetisyan, 2018) or bank specific determinants that are not being addressed in this thesis.

As can be observed the city of Athens and Thessaloniki restore the fastest, until the 8th quarter whereas in other smaller -but still big- urban centers in Greece, we see a longer duration of the effect which dies away after the 15th quarter. Important to mention is that Athens and Thessaloniki are the safest places, the most well-known as they are the biggest two cities, so it is very likely that they have the most agglomeration in terms of entrepreneurship and firm activity. Hence, the strongest rebound might be expected mostly there. These results suggest that there might be locational attributes, such as migration and unemployment rates, risk premiums and rental growth which can affect the house prices. In addition, Athens and Thessaloniki can be thought of as the centers of agglomeration, thus, absorb any impact of house price changes faster than other urban centers. Hence, the relationship of house prices with non-performing loans is not only affected by the macroeconomic variables used, but the results provide with contradicting spatially observed patterns.

Finally, from the above analysis provided, we can support that the group of the urban areas presents heterogeneity, in comparison with the reference group which is the country level of Greece. Our model thus, cannot capture the effect completely when focusing in the country level, since the sign of the relationship between non-performing loans and house prices changes among regions.

6. Conclusions

This thesis explored the relationship between non-performing loans (NPLs) and house prices. In particular, the focus was on whether a shock in the house prices can have an impact on the key-dependent variable of non-performing loans. For a sample of an 18-year period, by means of vector auto regression (VAR) and vector error correction (VEC) model, the impact of house prices and other macroeconomic factors on the non-performing loan ratios is examined. According to the findings, house prices, besides more general macroeconomic factors, have an impact on the non-performing loan ratios.

In particular, in the Greek context it appears that a positive shock in house prices, which dies out after 13 quarters, has a negative effect on the non-performing loans, consistent with previous literature for other countries (Shen & Chang, 2002; Ogawa, 2003; Wu et al., 2003; Rinaldi & Sanchis-Arellano, 2006; Koetter & Poghosyan, 2010; Wan, 2018). However, the Greek economy is relatively volatile in comparison with other economies and despite the broader waves of shock, the housing market still remained strong compared to other broader macro-level influences. In addition, as a result of the complementary approach, we find that the effect presents variations in terms of location. In Athens the effect of negative impact remains same as in the country level model, both in terms of sign and duration. However, in Thessaloniki and other big cities the results present either an opposite effect or longer duration; a positive impact of a shock in house prices on the non-performing loans can be observed for Thessaloniki and a negative impact but with longer duration for other big-urban centers.

This thesis could be further extended by investigating a structural break that could change the interactions between the factors used and the non-performing loans, as Greece has experienced a financial crisis and a consequent debt crisis during the studied period. However, a structural break would require to split the sample in sub-periods. These periods would be short, thus including the number of variables used in this model might not provide with correct estimates, as the degrees of freedom would drop quickly. There are already several variables included and the degrees of freedom are already very low, thus any forecasts could be of low accuracy[12]. In particular, this model requires very complex application which, if not implemented correctly, could result in large standard errors and unstable estimates (Brooks & Tsolacos, 2010).

[12] The degrees of freedom are 78 ($g+kg^2$) as we have 6 variables (g) and 2 lags (k) (Brooksb & Tsolacos, 2010).

Moreover, it would be interesting to estimate results given from different variables, that might provide with additional insights. For instance, the use of financial, bank specific and institutional variables such as debt, real exchange rates, quality of management and performance or efficiency, could be worthy of study. However, it would not be wise to incorporate too many variables in the model, due to possible large errors in the estimations, as we now have a relatively small sample for a VAR-VEC model and it could lead to biased coefficient estimates. Lastly, another process that could be followed in the analysis would be to decompose the series into trends, cycles and seasonality, in order to achieve stationarity, without implementing the complex second order differences in the model, which could provide distinctive results, such as locating the turning points of the series.

A limitation of this analysis, which may be addressed in future studies is that the non-performing loans are given at a country level, thus, the spatial distribution of such loans cannot be detected in the regional level. Hence, while we can observe local differences in the house prices, we cannot examine the effect one by one for the house prices and non-performing loans, ceteris paribus. Hence, we have macro-level observations for the key-dependent variable whereas micro-level data are given for the house prices. However, it is very important to mention that using vector autoregressive models is considered very effective for forecasting purposes. As Brooks and Tsolacos (2010) mention, due to the fact that on the right-hand side only the lagged values of the variables are used, the forecasts are being calculated using the information that already exists in the system.

Finally, this study has multiple implications for spatial policy as the results can be used to forecast the expected non-performing loan fluctuations, based on the variables that have been found to be significant. For instance, simulation analysis could be based on the variables chosen, to examine the response of non-performing loans and whether the banking system can predict defaults related to their recognition both at a country and regional level.

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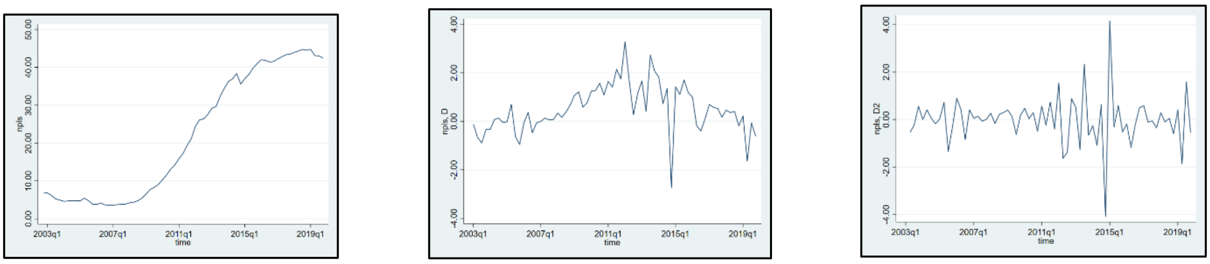
Appendix I – Correlation

Appendix Table i. Correlation of the variables used in the model

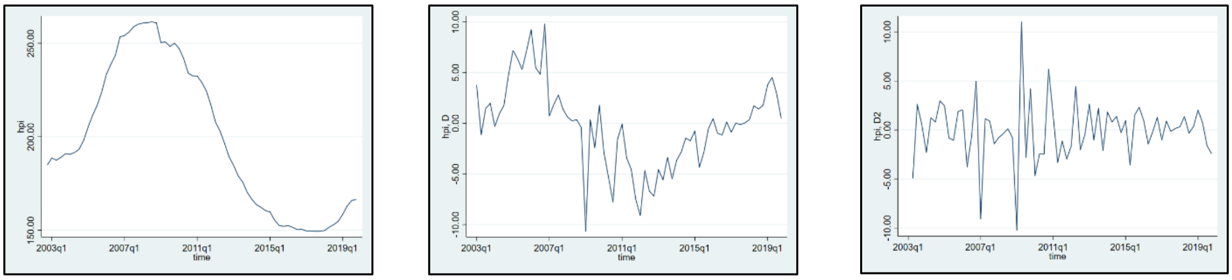
Variables	npls	hpi	gdpg	inflation	unemployment	interestrate
npls	1.000					
hpi	-0.849	1.000				
gdpg	-0.019	-0.217	1.000			
inflation	-0.784	0.712	-0.121	1.000		
unemployment	0.848	-0.743	-0.115	-0.799	1.000	
interestrate	-0.885	0.731	0.064	0.835	-0.869	1.000

Appendix II – Stationarity

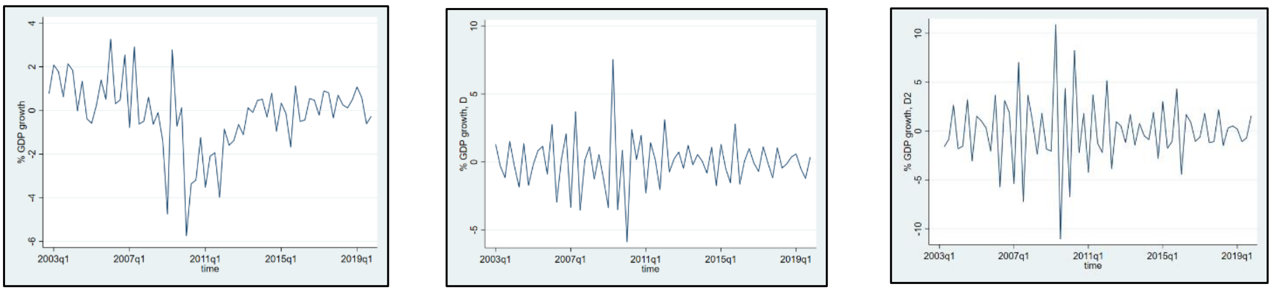
Appendix figure 1. Non-performing loans in levels, first and second order differences



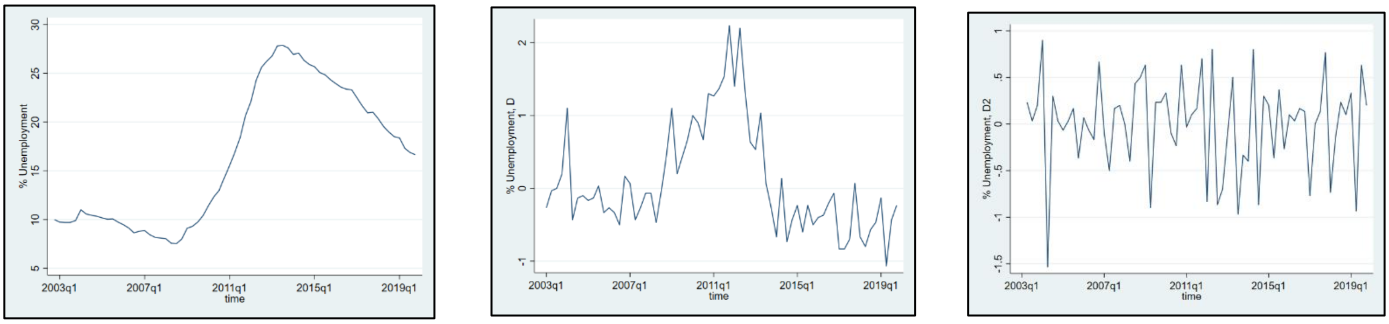
Appendix figure 2. House price indices in levels, first and second order differences



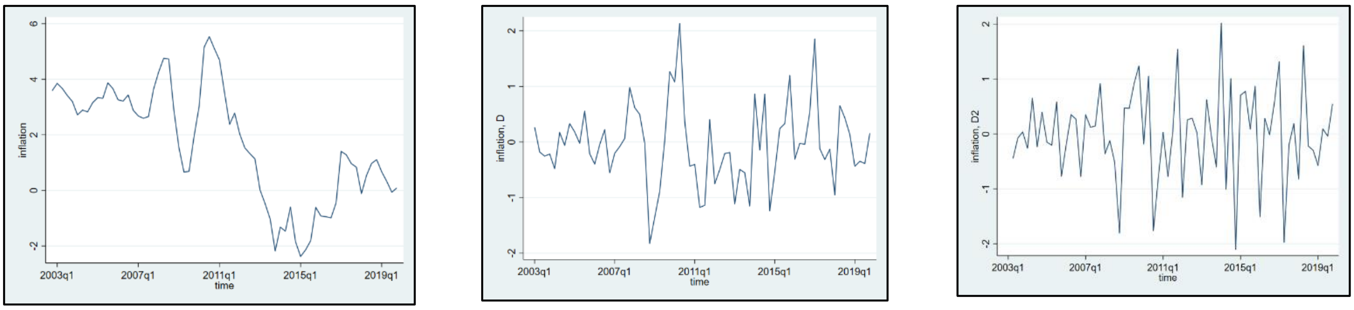
Appendix figure 3. Gross Domestic Product growth in levels, first and second order differences



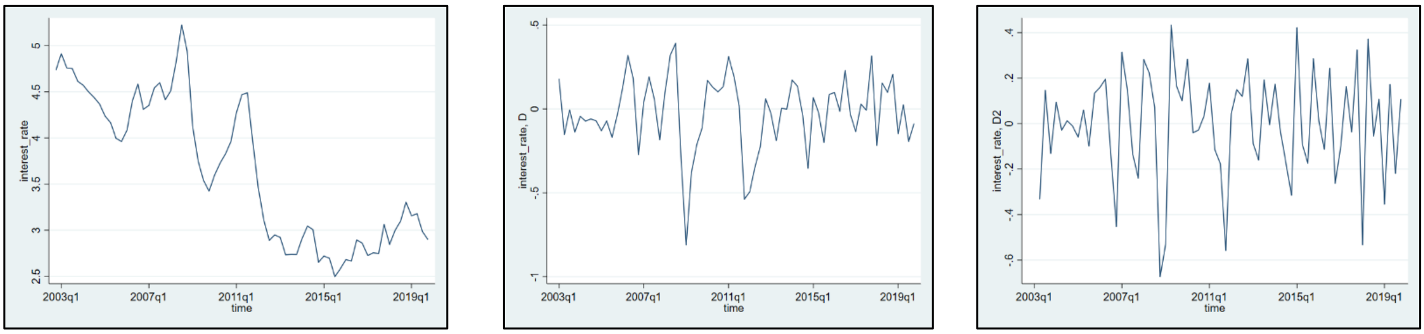
Appendix figure 6. Unemployment in levels, first and second order differences



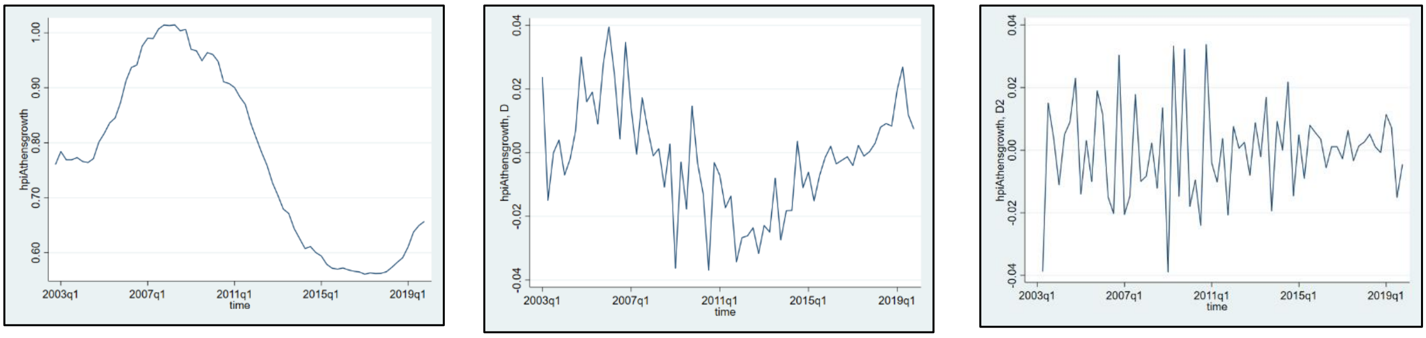
Appendix figure 5. Inflation in levels, first and second order differences



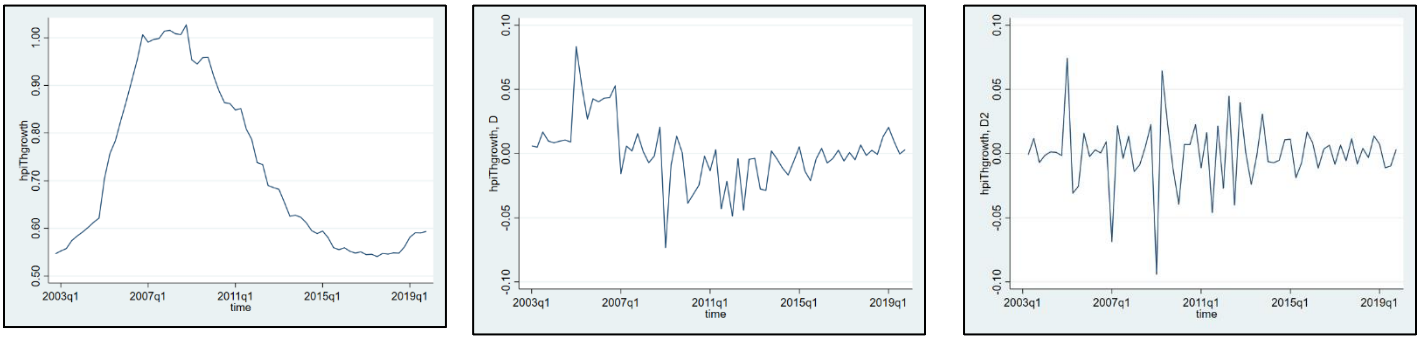
Appendix figure 4. Interest rates in levels, first and second order differences



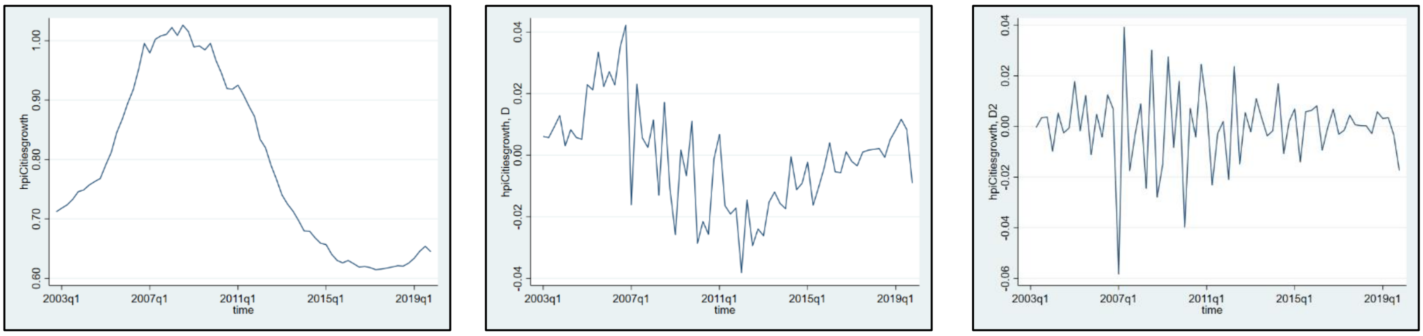
Appendix figure 7. House Prices in levels, first and second order differences for Athens



Appendix figure 8. House Prices in levels, first and second order differences for Thessaloniki



Appendix figure 9. House Prices in levels, first and second order differences for other big urban centers, excluding Athens and Thessaloniki



Appendix III – Unit Root Test, Lag Length Selection and Cointegration test (city-level)

Appendix figure 10. Augmented Dickey Fuller test

			Constant and trend			
Variables	p-value levels	Stationarity	p-value I(1)	Stationarity	p-value I(2)	Stationarity
hpiAth	0.85	NO	0.50	NO	0.00	YES
hpiTh	0.42	NO	0.06	NO	0.00	YES
hpiCi	0.50	NO	0.30	NO	0.00	YES

Notes: *** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level. Critical values given by MacKinnon (2010). Null Hypothesis is that the series are non-stationary.

Appendix figure 11. Lag Length Selection

		HPI Athens		**HPI Thessaloniki**		**HPI Urban Centers**	
Endogenous variables	Lags	AIC value	SBIC value	AIC value	SBIC value	AIC value	SBIC value
	0	6.4053	6.60601	7.52887	**7.72958***	6.37668	**6.57739***
	1	5.1483	**6.55482***	**6.36716***	7.77215	**5.23535***	6.64034
	2	**5.04108***	7.65034	6.55171	9.16097	5.38956	7.99882

Notes: * Provides the optimal lag length selection based on the Akaike's and Schwarz's values

Appendix figure 12. Johansen Cointegration test: Athens

Maximum rank	Log likelihood	Eigenvalue	Trace statistic	5% critical value	Cointegration
0	-69.623864	.	127.5605	94.15	
1	-46.124018	0.50415	80.5608	68.52	
2	-28.399675	0.41086	45.1121*	47.21	**YES**
3	-16.845392	0.29171	22.0036	29.68	
4	-8.2607966	0.22606	4.8344	15.41	
5	-5.8444298	0.06959	0.0016	3.76	
6	-5.8436075	0.00002			

Notes: *Denotes statistical significance at 5% or higher. The value 45.1121 shows that this estimator has selected the number of cointegrating equations corresponding to the table as two (since the trace statistic is smaller than the critical value we cannot reject the null hypothesis that there is no cointegration). Critical values for the trace and maximal eigenvalue test are given by Osterwald-Lenum (1992). The variables included are the non-performing loans, the gross domestic product growth, the inflation, the unemployment, the interest rates and the house price index of Athens.

Appendix figure 13. Johansen Cointegration test: Thessaloniki

Maximum rank	Log likelihood	Eigenvalue	Trace statistic	5% critical value	Cointegration
0	-107.82485	-.	139.6060	94.15	
1	-84.664763	0.49910	93.2858	68.52	
2	-64.055061	0.45948	52.0664	47.21	
3	-52.179506	0.29847	28.3153*	29.68	**YES**
4	-42.027648	0.26143	8.0116	15.41	
5	-39.528646	0.07188	3.0136	3.76	
6	-38.021866	0.04398			

Notes: *Denotes statistical significance at 5% or higher. The value 28.3153 shows that this estimator has selected the number of cointegrating equations corresponding to the table as three (since the trace statistic is smaller than the critical value we cannot reject the null hypothesis that there is no cointegration). Critical values for the trace and maximal eigenvalue test are given by Osterwald-Lenum (1992). The variables included are the non-performing loans, the gross domestic product growth, the inflation, the unemployment, the interest rates and the house price index of Thessaloniki Region.

Appendix figure 14. Johansen Cointegration test: Other big urban centers

Maximum rank	Log likelihood	Eigenvalue	Trace statistic	5% critical value	Cointegration
0	-67.980416	-	142.4765	94.15	
1	-44.269404	0.50727	95.0544	68.52	
2	-23.583313	0.46071	53.6823	47.21	
3	-11.620699	0.30029	29.7570	29.68	
4	-1.2438958	0.26637	9.0034*	15.41	**YES**
5	1.7841185	0.08641	2.9474	3.76	
6	3.2578162	0.04304			

Notes: *Denotes statistical significance at 5% or higher. The value 9.0034 shows that this estimator has selected the number of cointegrating equations corresponding to the table as four (since the trace statistic is smaller than the critical value we cannot reject the null hypothesis that there is no cointegration). Critical values for the trace and maximal eigenvalue test are given by Osterwald-Lenum (1992). The variables included are the non-performing loans, the gross domestic product growth, the inflation, the unemployment, the interest rates and the house price index of other big-urban centers.

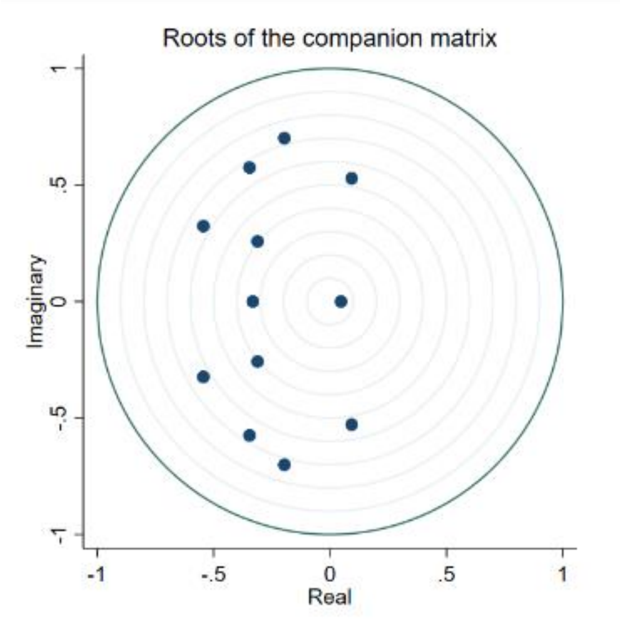
Appendix IV – Basic Model Postestimation Diagnostics (country-level)

Appendix Table ii. Lagrange multiplier test - Autocorrelation test

lag	Chi2	df	Prob> chi2
1	31.5182	36	0.68166
2	32.7294	36	0.62495
3	33.4046	36	0.59266
4	57.0302	36	0.01429
5	39.2259	36	0.32726
6	31.3994	36	0.68710

Notes: H0: No autocorrelation at lag order

Appendix figure 15. Stability of the VEC model (All eigenvalues lie inside the unit circle)



Appendix V - Robustness checks

Appendix figure 16. GIRFs of the model using the transformed variables of lnnpls and lnhpi