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ABSTRACT

We utilize a new set of macroeconomic and regulatory data to analyze the evolution of loan loss provisioning practices in the Greek banking system over the period 2005-2015. We explore the determinants of the aggregate loan loss reserves to total loans ratio, which reflects the accumulation of provisions net of write-offs, and constitutes an important metric of the credit quality of loan portfolios. Our results suggest that domestic credit institutions respond relatively quickly to macroeconomic shocks, though the latter's effects on the provisioning behavior of the domestic banking system show significant persistence. Furthermore, the impact of macroeconomic shocks on the loan loss reserves ratio has become stronger (both in terms of magnitude and statistical significance) following the outbreak of the Greek sovereign debt crisis. From a macro policy perspective, this result indicates that a sustainable stabilization of macroeconomic conditions is a key precondition for safeguarding domestic financial stability. For a regulatory standpoint, it suggests that the possibility of macroeconomic regime-related effects on banks' provisioning policies should be taken into account when macro prudential stress tests of the banking system are designed and implemented.

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The Determinants of Loan Loss Provisions: An Analysis of the Greek Banking System in Light of the Sovereign Debt Crisis

1. Introduction

Non-performing loans (NPLs) and loan loss provisions (LLPs) have generally been considered to be the main transmission channels of macroeconomic shocks to banks' balance sheets. Provisions represent an important quantitative indicator of the credit quality of loan portfolios. Banks take them in anticipation of potential losses and they are a key contributor to fluctuations in bank earnings and capital (Hoggarth and Pain, 2002). In effect, loss provisions constitute a tool for adjusting the historical value of loans to reflect their true value (Dinamona, 2008). Numerous empirical studies have examined the behavior of provisioning practices based on data for individual banks or aggregate data for one or more countries. Some of the issues and testable hypotheses examined in these contributions include: procyclicality of provisioning policies, the role of provisioning in the broader context of capital regulation and the use of provisions for managing earnings.

Using a new set of macroeconomic and regulatory data this study looks at the evolution of provisioning practices in the Greek banking system over the period 2005-2015. This is performed by examining the determinants of the aggregate (industry-wide) loan loss reserves to total loans ratio, which reflects the accumulation of provisions net of write-offs and constitutes an important metric of the credit quality of loan portfolios. Our empirical findings make several contributions to the literature. While in other periphery economies (e.g. Ireland, Spain and Cyprus) the outbreak of the recent crisis was mainly concentrated in over-levered domestic banking systems, in Greece's case it was the outcome of a huge fiscal derailment that eventually mutated to a severe domestic recession and a full-blown financial sector crisis. Between Q1 2008 and Q4 2015, the ratio of non-performing loans to total bank loans in Greece increased by 30.9ppts (and by 38.4ppts if restructured loans are also accounted for), hitting 35.6 percent (and 43.5 percent, respectively) at the end of that period[2]. In addition, the unprecedented (in size and scope) restructuring of privately-held Greek pubic debt in early 2012 completely wiped out the capital base of major Greek banks, necessitating a major recapitalization of the domestic banking system in the following year. Two additional recapitalizations of the systemic banks followed (in 2014 and in late 2015) to address severe liquidity and solvency problems faced by these institutions due to the sizeable drawdown of deposits and the sharp increase of bad loans[3]. In this

[2] Monokroussos, Thomakos and Alexopoulos (2016a) argue that the primary cause of the sharp increase of non-performing loans in Greece following the outbreak of the sovereign debt crisis can be mainly attributed to the unprecedented contraction of domestic economic activity and the subsequent rise in unemployment. In addition, their findings offer no empirical evidence in support of a range of examined hypotheses assuming overly aggressive lending practices by major Greek banks or any systematic efforts to boost current earnings by extending credit to lower credit quality clients.

[3] The last capital raising exercise of Greece's four systemic banks was successfully completed in December 2015. Total financing from official sources (i.e., the ESM through the Hellenic Financial Stability Fund) to recapitalize these banks was limited to just €5.43bn as two of them, Eurobank and Alpha Bank, managed to fully cover their respective capital shortfalls (under both the baseline and the adverse scenario) exclusively through internal capital raising means (LME) and private-sector funds injection. This was below the amount committed (up to €25bn) in the context of Greece's new bailout programme for recapitalization and resolution purposes. Greece's systemic banks have been exempted from the EU-wide stress testing exercise that was launched in late February 2016, on the basis that they have been adequately recapitalized quite recently.

context, it is of primary importance to analyze the provisioning policies of domestic credit institutions, especially as Greece remains a crucial factor influencing macroeconomic and financial system stability in the common currency area.

Second, a thorough understanding of the determinants and the behavior of bank provisioning policies is key for designing countercyclical provisioning policies that aim to alleviate the amplifying macroeconomic effects of bank lending practices along the business cycle. This is particularly relevant not only for the periphery economies but also for the euro area as a whole, given the primary role of the regulated banking system as a provider of liquidity to the real economy. The existence of provisioning policies that encourage credit institutions to behave in a more forward-looking way by providing for lean years during good years is also important from a systemic stability standpoint. In this context, it is not a surprise that in the case of Greece domestic financial stability constitutes a key pillar of the current stabilization programme, with particular emphasis on the management of bad loans and reforms to the domestic regulatory and legal framework in dealing with private sector insolvency.

Third, the behavior of provisioning policies in the Greek banking system is a topic that has not been thoroughly analyzed in the past. Furthermore, our study features some novel aspects relative to a (pretty limited) number of earlier contributions. For instance, compared to the data panel estimation methods that have been mostly used in earlier studies, we estimate a number of vector autoregession (VAR) models that relate loans loss reserves to a range of macroeconomic and banking system-specific drivers. This gives us the additional advantage of addressing potential endogeneity issues and allows us to fully capture the dynamic interactions between different types of determinants. As a robustness check, we also run a series of single equation models that express loss reserves as a function of macro- and bank-related variables that have been found to be significant in the VAR equations.

Fourth, our study utilizes a fully-updated set of macroeconomic and banking-sector quarterly data spanning the period 2005-2015. This time horizon covers a significant part of the high growth period that followed the country's euro area entry as well as the years after the outbreak of the Greek sovereign debt crisis in late 2009/early 2010.

Finally, in addition to examining the robustness of some earlier empirical findings in the context of our extended data set, we test a number of new hypotheses that appear to have important macroeconomic and policy-related implications. Among others, we empirically document that, at an aggregate level, Greek banks generally behave in line with the stylized facts of provisioning policy procyclicality, taking higher provisions (and increasing their loan loss reserves) when domestic macroeconomic conditions deteriorate. International experience shows that the pro-cyclical behavior of bank provisioning practices can be potentially mitigated by the impact of bank earnings. That is, provided that banks provision considerably more when earnings are high (and vice versa). Such a behavior contributes to banks' financial soundness and implies a positive association between loan loss provisions and earnings (income smoothing hypothesis). Since our study lacks income statement data, we cannot directly test the latter hypothesis. However, the data at hand do allow us to test the so-called capital management hypothesis, which postulates that banks with low regulatory capital are inclined to take more general provisions in order to keep their capital ratios adequate. Our empirical findings do not support the latter hypothesis. Furthermore, they are in general agreement with the view that the unprecedented domestic recession is the primary cause of the credit quality deterioration witnessed in the portfolios of major Greek banks in recent years.

Separately, our estimates show that domestic banks respond relatively quickly to macroeconomic shocks, with the peak quarterly change in the loan loss reserves ratio (i.e., the flow of provisions net of write offs) being realized within two quarters. Yet, the effects of such shocks on the provisioning behavior of the domestic banking system show significant persistence. For instance, the impact of GDP shocks on loss reserves dies out in about 10 quarters, while the impact of shocks on the unemployment rate persists for a considerably longer period. In terms of quantitative impacts, our bi-variate VAR estimates show that a 1 percentage point (ppt) decline (increase) in real GDP growth leads to an increase (decline) of 0.11ppts in the quarterly change of the loss reserves ratio after a quarter, with the corresponding long-run effect being around 0.18ppts.

Another interesting finding of our analysis is that the impact of macroeconomic shocks on the loan loss reserves ratio has become stronger (both in terms of magnitude and statistical significance) following the outburst of the Greek sovereign debt crisis. From a macro policy perspective, this result indicates that a sustainable stabilization of macroeconomic conditions is a key precondition for safeguarding domestic financial stability. For a regulatory standpoint, it suggests that the possibility of macroeconomic regime-related effects on banks' provisioning policies should be taken into account when macro prudential stress tests of the banking system are designed and implemented.

As a final note to this section, we emphasize that our analysis does not explicitly account for the three major bank recapitalizations that took place in the Greek banking system over the period 2012-2015. Naturally, these recapitalizations facilitated the effort of domestic banks to reach adequate provisioning levels for their loan portfolios. In any case, we note that the main aim of our study is to decipher the long-term macro and bank-specific determinants of the provisioning behavior of Greek credit institutions, regardless of such one-off events as the aforementioned recapitalizations. Furthermore, as it will be shown in the empirical part of our analysis, our formal statistical tests do not identify any structural breaks around the relevant bank recapitalization dates.

The rest of this document is structured as follows: Chapter 2 includes a literature review of the macro- and micro-related determinants of banks' loan provisioning practices; Chapter 3 provides a bird's eye view on the evolution of problem loans and bank provisioning policies in Greece in the years before and after the outbreak of the global crisis; Chapter 4 discusses our data and empirical methodology; Chapter 5 presents our empirical results and discusses their policy implications; and Chapter 6 concludes.

2. What determines banks' provisioning practices?

Many banking-sector variables are potentially able to convey signals about the evolution of banks' riskiness over the business cycle; however, non-performing loans and loan loss provisions have generally been considered to be the main transmission channels of macroeconomic shocks to banks' balance sheets (Quagliariello, 2007). Provisions represent an important quantitative indicator of the credit quality of banks' portfolios. Banks take them in anticipation of potential loan losses. In addition, provisions constitute a key contributor to fluctuations in earnings and capital (Hoggarth and Pain, 2002). In effect, loan loss provisions constitute a tool for adjusting the historical value of loans to reflect their true value (Dinamona, 2008).

In the beginning of a typical expansionary phase corporate profits improve, collateral values rise and households form optimistic expectations about their future finances. These dynamics eventually lead to an acceleration of banks' lending activities, which are often accompanied by a gradual loosening of credit standards and a reduction of provisions for future losses (see e.g. Keeton, 1999 and Fernandez De Lis et al., 2000). The literature identifies a number of causes for such a behavior on the part of bank managers. These include, among others, disaster myopia (Guttentag et al., 1986), herding behavior (Rajan, 1994), lack of institutional memory (Berger and Udell, 2003), principal-agent problems (Perez et al, 2006) and signaling (Ahmed et al., 1996). The latter is on the basis that higher provisions are interpreted by stakeholders as a signal of lower quality portfolios.

International experience suggests that banks' increasingly liberal credit practices during the more advanced stages of an economic upturn may take the form of "negative NPV" strategies, involving lower interest charges and/or increased lending to low-credit quality borrowers (Rajan, 1994). Such strategies usually backfire during recessionary phases, when credit risks actually materialize. In an economic recession, the rise of unemployment and the decline in household and corporate incomes hinder the debt servicing capacity of borrowers. The incipient rise in problem loans and the decline in collateral values lead to a serious tightening of credit conditions as banks become increasingly unwilling to extend new credit in an environment characterized by increased information asymmetries with respect to the actual credit quality of borrowers. The whole situation is exacerbated by a notable deterioration in banks' balance sheets due to the incipient rise in non-performing exposures at a time when additional capital is either more costly to acquire or simply nonexistent. Banks react by scaling back lending, a course of action that contributes to an acceleration of the economic downturn (procyclicality). The feedback effect from bank credit to the real economy may be particularly pronounced in economies where the biggest share of private sector financing takes place through the domestic banking system and direct access to wholesale credit markets is not an option for many firms.

Perez et al. (2006) argue that in economic upturns banks increase loan growth due to principal-agent problems, herd behavior and short-term objectives. For instance, with a view to obtain a reasonable return on equity for their shareholders, managers may engage in riskier activities and put more emphasis on their own rewards, which may be based more on growth objectives than on profitability targets. In such situations, managers may have incentives to increase loans growth, even in periods of declining profitability. Herd behavior may be another reason for higher loan growth volatility. During boom periods, many banks are encouraged to increase loans volume in order to preserve their market share. Another reason may relate to banks' focus on short-term objectives. Looking at some of these issues from another angle, Cavallo and Majnoni (2001) rely on an agency approach to explain the difficultly faced by the regulation of banks' provisioning practices. The authors suggest that the imperfect control and monitoring ability of insiders (bank managers and majority shareholders) by outsiders (minority shareholders or the fiscal authority) is for banks as for non-financial corporations a source of agency problems. However banks, due to the safety net, may face a very specific set of agency costs.

The literature has extensively studied the causes of the procyclical (and, in some instances, backward-looking) behavior of banks' credit policies and provisioning practices. As regards the latter, Borio et al. (2001) demonstrate that provisions increase during the recession, reaching their maximum one year after the real deceleration of the economy. The procyclical behavior of provisions constitutes an important challenge for banks and regulatory authorities alike. From a regulatory standpoint, it is of great importance to design countercyclical provisioning policies aiming to alleviate the amplifying macroeconomic effects of bank lending practices along the business cycle. From the standpoint of bank stakeholders, it is important for banks to behave in a more forward-looking way by providing for bad years during good years.

Numerous empirical studies have examined the behavior of banks' provisioning policies based on bank-specific or aggregate (industry-wide) data for one or more countries; see e.g. Bikker and Hu (2001); Cavallo and Majnoni (2001); Lobo and Yang (2001); Leaven and Majnoni (2003); Bikker and Metzemakers (2005); Forseca and Gonzalez (2005); Anandarajan (2005); Bouvatier and Lepetit (2006); Perez et al. (2006); and Dewenter and Hess (2006). Some of the issues and testable hypotheses examined in these contributions include: procyclicality of provisioning policies, the role of provisioning in the broader context of capital regulation and the use of provisions for managing earnings.

Bank' provisioning practices may differ considerably across countries and institutional arrangements and be greatly influenced by existing accounting and taxation rules (Dinamona, 2008). Broadly speaking, it is common to distinguish between two types of provisioning: general provisions and specific provisions. The former are generally taken against expected losses on non-impaired loans and are based on a probabilistic (and judgmental) assessment of the future evolution of the quality of the credit portfolio. The latter are made only when losses are known to occur and are somewhat akin to write-offs.

The aforementioned definitions suggest that general provisioning may be subject to a discretionary assessment on the part of bank managers. This, in turn, increases the risk of accounts manipulation and explains why regulatory authorities have set up rules for this particular class of provisions. On the other hand, specific provisions are generally taken against loan losses that are known to materialize. This reduces the risk of accounts manipulation, but potentially contributes to the amplification of the business cycle (Borio and Lowe, 2001; Bouvatier and Lepetit, 2006).

The literature cites several reasons for the potential use of provisioning for purposes not directly related to the need to adjust the value of loans to more realistic levels. One such use relates to earnings management. In more detail, provisions may be increased in good times for use in lean years, so as for banks to be able to report a more stable income stream. That is, on the basis that the latter is usually a good indication of performance from the perspective of stock price stability, credit ratings, cost of funds and management rewards (Greenawalt and Sinkey, 1998; Fudenberg and Tirole, 1995).

Separately, though not unrelated to the above argument, general provisioning may also be used to manage the capital ratio, particularly if general provisions account as regulatory capital (Kim and Kross, 1998; Ahmed et al., 1999; Cortavarria et al., 2000). A relevant hypothesis that has been tested in the literature conjectures a negative correlation between a bank's capitalization ratio and the level of general loan loss provisions.

Lobo and Yang (2001) show that banks which have a small capital ratio can increase their loan loss provisions with the intention to reduce the regulatory costs imposed by capital requirements. However, in recessionary periods capital becomes expensive and loan loss provisions are high. Banks often respond by reducing their loans. Consequently, it is difficult for banks to manage their capital by the way of loan loss provisions in periods of recession. On their part, Hasan and Wall (2003) argue that the effect on earnings is so important that banks' stock analysts routinely discuss whether a bank has managed its loss accounting so as to help smooth earnings or hit the current period's earnings target.

Finally, another reason may have to do with existing taxation rules. For countries in which general provisions are tax deductible, there may be a strong incentive for banks to increase general provisions (Cartavarria et al., 2000). On the other hand, a very restrictive tax policy may discourage banks from adequately provisioning against future loan losses (Cavallo and Majnoni, 2001). To complicate things further, taxation rules may interfere with broader state financing objectives, especially in countries facing severe fiscal pressure. Overall, the disincentives built in different layers of regulation (accounting, fiscal and prudential) may jointly explain why loan loss provisions do not often reach the required level suggested by expected loan impairments.

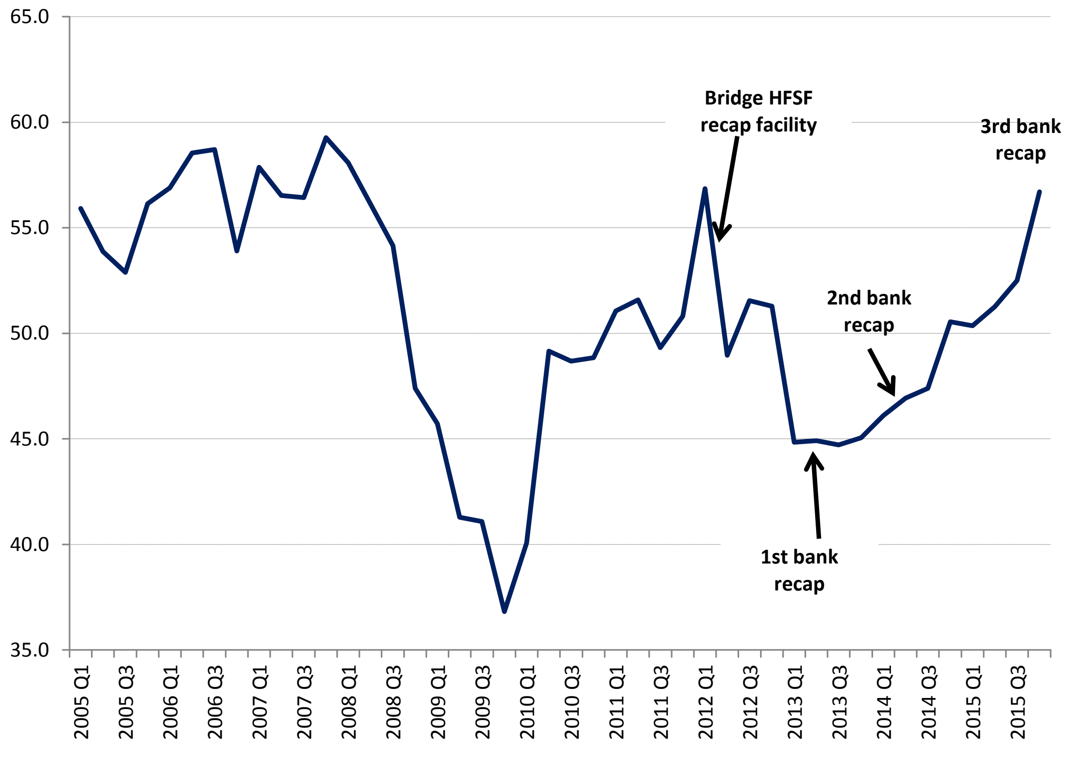
There is a general agreement that unexpected loan losses should be covered by bank capital, whereas expected losses by loan loss provisions. As a result, cyclical capital shortages may not only be due to inadequate risk based capital regulation but most prominently to the lack of risk based regulation of banks' provisioning policies. Given this close relation between provisions and capital, a number of studies have argued that a sound provisioning policy should be part of any regulations on capital requirements (Cavallo and Majnoni, 2001). For instance, these authors argue that the lack of a coherent and internationally accepted regulation of provisions, as is the case in many emerging markets, reduces the usefulness of minimum capital regulation. Furthermore, the lack of a well-defined and internationally agreed code of conduct may give rise to a multiplicity of institutional solutions. In several cases, for instance, the protection of outsider claims to banks' incomes may be too rigid or too expensive, providing a disincentive to adequately provision for loan losses, with negative implications for banking system stability.

3. The evolution of NPLs and LLRs in the Greek banking system

In Greece, a country that has experienced one of the most severe and prolonged recessions in recent economic history, cumulative real GDP losses between Q1 2008 and Q4 2015 amounted to around 26 percent, while the ratio of non-performing loans to total loans increased by 30.9ppts (and by 38.4ppts if restructured loans are also accounted for), hitting 35.6 percent (and 43.5 percent, respectively) at the end of that period. This followed double-digit growth of domestic bank lending in the post euro-entry years that led to the 2007/2008 global financial crisis. However, it is important to note that the global crisis found Greece's private sector not particularly over-levered relative to other euro area economies. In terms of nominal amounts, the total outstanding stock of NPLs (including restructured loans) in Greek commercial banks' balance sheets stood at €98.4bn at the end of 2015, with corporate bad loans accounting for 57.1 percent of the total stock. The overwhelming portion of the latter share consists of bad debts owed by very small, small and medium-sized firms. The corresponding percentages for mortgage and consumer problem loans were 27.6 and 15.2 at the end of 2015. In terms of provisioning, the coverage of NPLs (excluding restructured loans) by loan loss reserves ranged between 50 and 60 percent during the initial part of our sample (Q1 2005-Q4 2008).

The said coverage fell precipitously in the following few quarters (reached a low of 36.8 percent in Q4 2009), before increasing gradually thereafter and hitting a post-crisis high of 56.7 at the end of 2015 (figure A). Finally, the flow (measured as e.g. the quarterly change of the level) of NPLs including restructured loans embarked on an upward path after the outbreak of the global crisis, hitting a record peak of €13.8bn in Q1 2013. This compares with an average quarterly flow of c. €3.5bn in the prior three years and can be mainly attributed to the absorption of the balance sheets of the Cypriot subsidiaries in Greece by one of the domestic systemic banks. The pace of increase of the said flow measure declined significantly in 2014 (it even recorded a negative reading of c. -€2.4bn in Q4 2014), it hit a two-year high in Q1 2015 (€2.35bn) and ended that year with a small increase of €0.2bn.

Figure A: coverage of NPLs (excluding restructured loans) by Loan Loss Reserves.



Source: BoG, Eurobank Economic Research

3.1 A brief history of domestic banking-system recapitalizations following the outbreak of the Greek sovereign debt crisis

Greece's four largest (systemic) banks were first recapitalized in May 2012 via a bridge HFSF facility of €18bn, which aimed to bring their capital adequacy ratio to 8% (minimum required threshold under Basel II). The implementation of the aforementioned followed the publication of domestic banks' results for FY-2011, which revealed that the restructuring of privately-held Greek sovereign debt (PSI) had completely wiped out their capital base. Then, a full-scale recapitalization of domestic credit institutions was conducted between May and June 2013, following an exercise carried out by the Bank of Greece (BoG), which estimated the capital needs of the four systemic banks at €27.5bn for the period 2012-2014. Under a minister cabinet act, agreed in consultation with the European Commission, the ECB and the IMF, Greek banks had to meet a Core Tier 1 capital ratio of at least 6% exclusively through the issuance of common shares. Private shareholders were required to cover at least 10% of new common equity capital so as to keep credit institutions privately run. The remaining 90% would have to be covered through the issue of common shares to the Hellenic Stability Fund (HFSF) with restrictive voting rights. The remaining capital requirement i.e., above the 6% core tier 1 ratio- that was necessary to meet the BoG's core Tier 1 target (estimated at 9%) would be covered through the issue of contingent convertible bonds (CoCos) taken up by the HFSF- upon approval of the general meeting of shareholders of each credit institution. However, private sector participation was enough to cover at least 10% of total capital needs, allowing the coverage of the full required amount solely through common equity. The total share capital increase for the four systemic banks amounted to €28.6bnm, above the capital needs estimated by the BoG, as the HFSF approved and provided Piraeus Bank with a further capital contribution of €1.1 in order to meet the additional capital requirements arising from the purchase of: (i) the “healthy” part of publicly owned Agriculture Bank of Greece (ATEbank) that was resolved in July 2012 (€570mn); and (ii) balance sheet items of the Greek branches of 3 Cypriot banks (€524mn). Out of the total share capital increase, HFSF contribution (in the form of EFSF bonds) stood at €25bn. The remaining €3.6bn was covered by private investors who were granted warrants as an incentive enabling them to purchase the remaining common shares from the HFSF at a future time.

The second bank recapitalization (March-May 2014) was based on the results of an independent diagnostic study conducted by Blackrock under the supervision of the Bank of Greece. The exercise aimed to ensure that the financial system was “well prepared to face the impact of expected losses from the high-level of non-performing loans” and was conducted under an amended recapitalization framework. Incentives provided by the HFSF to the private sector in the first recapitalization exercise, such as the issuance of warrants, were no longer foreseen and any injection of capital (via the HFSF) into viable banks would be done through subscription of ordinary shares carrying full voting rights, on the condition that at least 50% of the total share capital increase would be covered by the private sector. BlackRock Solutions estimated that the total capital needs of the domestic banks over the period June 2013-December 2016 would amount to €6.4bn under the baseline scenario. All four systemic banks opted for a share capital increase via private placements and public offerings. Solely with the participation of the private sector, the share capital increase amounted to €8.3bn, covering fully the capital needs of these banks and allowing for the repayment of the preference shares of Alpha Bank (€950mn) and Piraeus Bank (€750mn) held by the state. As a result, the HFSF's shareholding in all four systemic banks was reduced significantly; in Alpha Bank, it dropped from 81.7% to 69.9%, in Eurobank, from 95.2% to 35.4%, in National Bank of Greece from 84.4% to 57.2% and in Piraeus Bank from 67.3% to 66.9%.

In line with the conditionality underling Greece's 3rd adjustment programme that was agreed with official creditors in August 2015, Greece's four system banks underwent another recapitalization that was successfully completed in December 2015. A comprehensive assessment carried out by the ECB estimated total capital needs of €4.4bn under a baseline scenario and €14.4bn under an adverse scenario. Banks had to exhaust all private means to cover at least the capital needs identified under the baseline scenario. Any remaining shortfall (under the adverse scenario) would be covered through a combination of common equity capital and CoCos while any common shares acquired by the HFSF would have full voting rights. Two banks, Eurobank and Alpha Bank, managed to raise the required capital exclusively through internal capital raising means (LME) and private sector injections while the capital shortfalls of the other two were partially covered by the HFSF via ordinary shares and (CoCos). As a result, total financing from official sources (i.e., the ESM through the Hellenic Financial Stability Fund) was limited to just €5.43bn. This was below the amount committed (up to €25bn) in the context of Greece's new bailout programme for bank recapitalization and resolution purposes. The HFSF's shareholding in all four core banks was reduced further; in Alpha Bank, it dropped from 69.9% to 11.0%, in Eurobank, from 35.4% to 2.4%, in National Bank of Greece, from 57.2% to 40.4% and in Piraeus Bank, from 66.9% to 26.4%.

4. Data and methodology

4.1 Data

For the purpose of our empirical analysis, we utilize a novel data set of macroeconomic and bank-specific variables (quarterly observations) spanning the period between Q1 2005 and Q4 2015. Our data sources include Bank of Greece, Greece's statistics agency (EL.STAT.) and EUROSTAT.

4.2 Personal circumstances

Loan loss reserves: aggregate (system-wide) loan loss reserves to total loans ratio (acronym: LLR). This variable constitutes the primary focus of our empirical study. The data are taken from the consolidated balance sheet of the domestic banking system, which is regularly reported by the Bank of Greece. Loan loss reserves constitute a stock variable, while loan loss provisions (not examined in this study) a flow variable[4]. The following relationship links loan loss reserves and loan loss provisions:

$$\boldsymbol{LLR_t = LLR_{t-1} + LLP_t - WO_t} \qquad (1)$$

Where, *LLR* denotes loan loss reserves, *LLP* loan loss provisions, *WO* write offs, and t is the time subscript (here it measures quarters). As can

[4] Data for loan loss provisions can be found in banks' income statements.

be inferred by the above equation, the change (*Δ*) of the stock of loan loss reserves between quarter *t-1* and quarter t equals the flow of provisions taken in quarter *t* minus the loans that are written off banks' balance sheets in that quarter. As noted in Bikker and Metzemakers (2005), loan loss reserves and provisions are different in character. LLPs reflect discrete managerial decisions at a point in time, which may be more cycle-dependent. On the other hand, LLRs reflect the respective accumulation of provisions (net of write offs) that, on average, ought to better reflect actual expected loan losses. Analysts, regulators and bank managers regularly view the latter variable as an important metric for the credit quality of a loan portfolio.

4.3 Explanatory variables

4.3.1 Realized credit risk variables

Non-performing loans: Greek banks' loans overdue for more than ninety (90) days. For the purposes of our analysis, we utilize supervisory data for the aggregate (industry-wide) stock of bad loans including restructured loans. The relevant variable examined in the study is the ratio of bad loans to the total outstanding stock of loans (acronym: ***TNPL***). As noted in Quagliariello (2007), this variable can be viewed as a reliable proxy for the overall quality of a bank's portfolio, implying a positive association between non-performing loans and loan loss reserves.

Default rate: The stock of bad debts is considered by some authors to be only a rough measure of bank credit quality as some of these debts are simply written off as time elapses. For this reason, our study also examines the behavior of a proxy for the loans classified as non-performing for the first time in the reference period. The relevant explanatory variable we use is the ratio of the flow of loans classified as bad debt in the reference period to the total stock of performing loans of the prior period. The respective acronym is ***DR***. The expected sign of this variable is positive on the basis that banks that are not able to screen potential debtors are more likely to incur loan losses in the future (Quagliarello, 2007).

4.3.2 Macroeconomic variables

*Real GDP growth (**RGDP**)*: an aggregate indicator of the state of the macro economy and the phase of the business cycle. If the procyclicality hypothesis holds (i.e., credit risks increase in a downturn and vice versa) then there is a negative association between LLRs and real GDP growth. For instance, in their empirical study involving 8,000 bank-year observations from 29 OECD countries between 1991 and 2001, Bikker and Metzemakers (2005) find a negative and significant coefficient of GDP growth, with the respective short- and long-run elasticities of the effects on the LLR ratio being -0.77 and -4.95[5]. These authors state that their findings imply procyclicality and, probably, a lack of forward looking risk assessment over the business cycle. A negative (but mostly insignificant) association between the loans loss reserves ratio and GDP growth is also found in Makri (2015), a recent study utilizing both aggregate and bank-specific data for the Greek banking system. An alternative view to the procyclicality argument has been proposed by Borio et al. (2001) and Lowe (2002), who claim that risks are actually

[5] In their study, Bikker and Metzemakers (2005) measure loan loss reserves as a ratio to total banking-system assets. In the study presented in this paper, we express LLRs as ratio to total outstanding bank loans.

built up during economic booms, when loan growth accelerates. If the latter hypothesis holds, then we should expect a positive association between LLRs and real GDP growth.

Labour market conditions: unemployment rate as a percentage of the total labor force (***UNPL***). In line with the procyclicality argument, a positive association holds between the LLR ratio and the unemployment rate.

Collateral values: index of prices of dwellings, deflated by the harmonized inflation rate for Greece (***RHP***)[6]. One should expect a negative relationship between collateral values and loan loss reserves. That is, provided that the procyclical hypothesis for bank provisions holds and housing prices constitute a good coincident indicator for the phase of the business cycle. In line with Quagliarello (2007), the impact of collateral values on the overall riskiness of a bank's loan portfolio may also be given an alternative interpretation; namely, in periods of increased collateral valuations, banks may be tempted to reduce their screening activity making their portfolios riskier. This behavior would then lead to higher NPLs (and thus, the need for higher provisioning), implying a positive association between LLR and RHP[7].

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[6] Bank of Greece publishes a newer index based on apartment prices. However, our study uses the historical series of the index of prices of dwellings due to the greater time span of the latter series.

[7] As noted in Borio (2012), combining credit and property prices appears to be the most parsimonious way to capture the core features of the link between the financial cycle, the business cycle and financial crises. Analytically, this is the smallest set of variables needed to replicate adequately the mutually reinforcing interaction between financial constraints (credit) and perceptions of value and risks (property prices). Empirically, there is a growing literature documenting the information content of credit, as reviewed by Dell'Arricia et al (2012), and property prices (eg IMF, 2003) taken individually for business fluctuations and systemic crises with serious macro dislocations. But it is the interaction between these two sets of variables that has the highest information content.

Debt service cost: real interest rate on bank loans calculated using as weights the outstanding volumes of domestic monetary financial institutions' loans vis-à-vis euro area private-sector residents (***L_RIR***). Many empirical studies document a positive link between lending interest rates and non-performing loans, particularly in the case of floating rate loans (see e.g. Louzis et al., 2012, Beck et al., 2013; and Klein 2013). This should also imply a positive association between real loan rates and the LLR ratio. In our analysis, the aforementioned variables enter in first-differences (quarterly change in the respective real loan interest rate), alleviating concerns related to the fact that interest rates are usually higher in expansionary phases, when NPLs tend to be low (negative association).[8]

Inflation (INFL): herein proxied by the quarterly change in the harmonized consumer price index for Greece. The impact of inflation on future bad debts (and, by implication, on banks' provisioning policies) may be ambiguous (see e.g. Nkusu, 2011). On the one hand, higher inflation erodes the real value of outstanding debt, thus making debt servicing easier. On the other hand, it may reduce real incomes (when prices are sticky) and/or instigate an interest rate tightening by the monetary authority.

4.3.3 Bank-specific variables

The pro-cyclical behavior of bank provisioning practices implied by a negative association between loan loss reserves and GDP growth may be

[8] A casual look at the evolution of the aforementioned variables in levels (data available on request) shows that, with the exception of a significant decline experienced in 2010, real loan rates in Greece have been on a upward path in more recent years due to strengthening disinflation and excessively tight conditions in the domestic lending market. At the end of 2015 (latest part of our data sample), real rending rates were higher relative to their levels in the pre-crisis period under examination.

mitigated by the potential impact of bank earnings (income smoothing hypothesis). That is, provided that banks provision considerably more when earnings are high (and vice versa). Such a behavior contributes to banks' financial soundness (by reducing procyclicality) and implies a positive association between loan loss provisions and earnings. Since our study lacks income statement data, we cannot directly test the income smoothing hypothesis. However, the data at hand do allow us to test the existence of other effects that could somewhat mitigate the procyclicality of banks' provisioning policies. As analyzed below, this can be done by looking at e.g. the growth of total loans and its impact on loan loss reserves.

Bank solvency and capitalization: industry-wide solvency ratio, measured as total common shareholders equity to total bank assets (***ETA***). Based on a number of earlier empirical studies, a negative association between the capital to assets ratio and provisions provides support to the capital management hypothesis, which postulates that banks with low regulatory capital are inclined to take more general loan loss provisions in order to keep their capital ratios adequate. That is, especially if general provisions are tax deductible. On the other hand, expected gains to boosting capital may be very small once a bank attains a sufficiently high capital adequacy ratio (Hasan and Wall, 2003; Bikker and Metzemakers, 2005). An alternative phenomenon causing a negative relationship between provisions and capital may relate to the fact that some banks may simply hold a greater share of risky loans (and thus, incur more losses and provision more) and, at the same time, have a lower capital ratio (Bikker and Metzemakers, 2005).

*Loans growth rate (**LG_R**)*: an indicator of loan portfolio riskiness. In line with the procyclical credit hypothesis, there must be a negative association between the said variable and banks' loan loss provisions. That is, especially if loans growth in good economic times is associated with reduced monitoring efforts. An alternative hypothesis is that loan portfolio risk is actually building up during economic booms, which implies a positive coefficient on loans growth (Borio et al., 2001; and Lowe, 2002).[9]

*Loans to assets (**LtA**)*: ratio of banking-system wide loans to total assets. This is another indicator of the overall riskiness of banks' portfolios. In the context of our study, it would be of interest to estimate model specifications that include both *LG* and *LtA* as potential explanatory variables of loan loss reserves. For instance, the finding of a negative coefficient on the growth of loans in conjunction with a positive coefficient on the loans to assets ratio could be interpreted as evidence supporting the view that provisions increase as a share of total assets when the increase of new lending tends to reinforce the risk exposure of bank portfolios (Bikker and Metzemakers, 2005).

*Loans-to-deposits interest rate spread (**LD_IRS**)*: the interest rate spread between loans and deposits could be viewed as an indicator of the relative competitiveness conditions in the domestic loans and deposits

[9] An interesting interpretation of the growth of performing loans as a potential determinant of Italian banks' provisioning policies is provided in Quagliariello (2007). Using a large dataset of Italian intermediaries over the period 1985-2002, the study estimates both static and dynamic models to investigate whether loan loss provisions and non-performing loans show a cyclical pattern. The author notes that the growth of performing loans may signal a positive phase of the business cycle if it is led by demand factors (suggesting a negative sign) or an aggregate supply policy of banks, which in turn involves lower credit standards, the exposure to excessive risks and higher future provisions (positive sign). In line with this reasoning, the growth of performing loans may show a negative sign when current values are considered and a positive sign when lagged (see also Salas and Saurina, 2002).

markets or the degree of risk taking on the part of domestic credit institutions, implying a positive association with non-performing loans and hence provisions. Table A provides a summary of the sign(s) of the theoretical relationship between the LLR ratio and the set of explanatory variables examined in this study.

Table A: Potential drivers of Loan loss reserves.

	variable	acronym	sign of theoretical relationship
Realized credit risk	Non-performing loans to total loans	NPL	(+)
	Default rate	DR	(+)
Macroeconomic variables	Real GDP growth	RGDP	(-)
	Unemployment rate	UNPL	(+)
	Real growth of the index of prices of dwellings	RHP	(-)
	Harmonized consumer price index	INLF	(-) / (+)
	Real interest rate on bank loans	L_RIR	(+)
Bank-sector variables	Common equity to total assets	ETA	(-) / (+)
	Loans growth	LG	(-) / (+)
	Loans to deposits	LtD	(+)
	Loans to total assets	LtA	(+)
	Loans-to-deposits interest rate spread	LD_IRS	(+)

4.4 Methodology

Since our time series are relatively short, we avoid complicated methods that could potentially require a larger data sample. Instead, we employ an unrestricted vector autoregession (VAR) in differences as well as single equations estimated in different samples, with the aim to examine the robustness of our empirical results and identify potential regime-switching behaviors.

The standard VAR model with p lags, when the variables are expressed in differences, is written as:

$$\Delta y_{q,t} = \nu + \sum_{t=1}^{p} A_i \Delta y_{q,t-i} + \mathrm{B} X_t + u_t \tag{1}$$

$y_{q,t}$ is a $(K \times 1)$ column vector, $\nu = (\nu_1, ..., \nu_k)'$, $\mathrm{B} = (B_1, ..., B_k)'$ are $(K \times 1)$ column vectors of intercept terms , A_i are $(K \times K)$ coefficient matrices, u_t is $i.i.d\ N(0, \Sigma)$ and X_t is an exogenous variable, herein the crisis dummy C10 as explained in the next section. The subscripts in the vector of our variables are used to identify the different models and variable combinations as follows:

$$y_{q,t} = [LLR_t, \begin{Bmatrix} TNPL_t, UNPL_t, INFL_t, RGDP_t^*, RHP_t^*, DR_t^*, L\_RIR_t, \\ ETA_t, LtD_t, LtA_t, LD\_IR_t, LG\_R_t^*, PERFO\_RG_t^* \end{Bmatrix}_q]', \quad for\ q = 1, ..., 35$$

The optimal lag length is chosen by fitting the VAR representation sequentially with lag orders $p = 0, 1, ..., p_{\max}$ and selecting the value that minimizes standard information criteria, with the following (generic) form:

$$IC(p) = \ln \left| \tilde{\Sigma}_u(p) \right| + h(p, n) \tag{5}$$

where h(p,n) stands for the penalty function $\tilde{\Sigma}_u(p) = T^{-1} \sum_{t=1}^{T} \hat{\varepsilon}_t \hat{\varepsilon}_t'$ of the respective VAR(p) model. Depending on the penalty function, the information criteria used include the Akaike Information criterion (AIC), the Schwarz criterion (SC) and the Hannan-Quinn criterion (HQ). We mostly rely on the latter for selecting the lag length.

Finally, we briefly illustrate below the causality testing, partitioning the vector of interest in m-dimensional and (K−m)-dimensional sub-vectors $y_{a,t}$ and $y_{\beta,t}$:

$$y_t = \begin{bmatrix} y_{a,t} \\ y_{\beta,t} \end{bmatrix} \text{ and } A_i = \begin{bmatrix} A_{11,i} & A_{12,i} \\ A_{21,i} & A_{22,i} \end{bmatrix} \quad i = 1 \ldots p \tag{6}$$

where A_i are partitioned in accordance with the partitioning of y_t, $y_{a,t}$ *does not* Granger-cause $y_{\beta,t}$ if and only if the following hypothesis *cannot* be rejected:

$$H_o: \quad A_{12,i} = 0 \quad for \quad i = 1 \ldots p \tag{7}$$

Thus, the null hypothesis is formulated as zero restrictions on the coefficients of the lags of a subset of the variables. This is in the form of a standard Wald-type test and therefore inference is asymptotically normal. After estimating each of the VAR models, a set of standard residual and misspecification tests is applied. Detailed results on these tests are available on request.

Selecting the variables presenting the highest stability in terms of significance, sign and magnitude, we construct univarite time series models and estimate them using both the full time length, from 2005Q1 to 2015Q4 and the subsample from 2010Q1 onwards. These models have the following general representation:

$$y_t = a + B' X_t + \gamma t + \in_t$$

Where B is either a scalar when we estimate bivariate models or a column vector in the case of multivariate analysis. We also include a time component to capture any trend like characteristics. Splitting the time length into two different samples allows us to examine whether any structural break has been created following the outbreak of Greece’s sovereign debt crisis in late 2009/early 2010. Besides using different estimation periods, we also conduct a range of stability diagnostic tests in order to verify the significance of any structural change in the variables under examination.

We perform two stability diagnostics; namely, the Quandt-Andrews test and the Bai-Perron test. We first apply the Quandt-Andrews breakpoint test for one or more unknown structural breakpoints in the sample and test whether there has been a structural change in a subset of the parameters. The Quandt-Likelhood Ratio (QLR) statistic, also called the "sup-Wald statistic" is the maximum of all the chow F-statistics over a range of τ, $\tau_o \le \tau \le \tau_1$, in which a conventional choice for $\tau_o \,\&\, \tau_1$ is such so as to produce the inner 70 percent of the sample (after trimming the first and the last 15 percent of observations). Thus, QLR has the following form:

$$QLR = \max[F(\tau_o), F(\tau_o + 1), ..., F(\tau_1 - 1), F(\tau_1)] \quad (8)$$

Secondly, we apply the Bai-Perron approach for m potential breaks, producing m+1 regimes within the sample. Hence, for the observations $T_{j,} T_{j+1,} ..., T_{j+1} - 1$ in regime j we estimate the following regression model:

$$y_t = X_t^{'} \beta + Z_t^{'} \delta_j + \in_t$$

for $j = 0, ..., m$; where X variables are those whose parameters do not vary across regimes, while Z variables have coefficients that are regime specific. The procedure begins with the full sample and performs a test of parameter constancy with unknown break. If the test rejects the null hypothesis of constancy, break date is determined and the sample is divided into two samples where single unknown breakpoint tests are performed in each subsample. Each of these tests may be viewed as a test of an alternative to the null hypothesis of breaks. The procedure is repeated until all of the subsamples do not reject the null hypothesis, or, alternatively, until the maximum number of breakpoints allowed or the maximum subsample intervals to test is reached.

5. Empirical analysis and discussion of policy implications

5.1 VARs with macro- and bank-specific variables

This section discusses the estimates of our vector autoregression (VAR) models that analyze the dynamic impact of random disturbances on systems incorporating different combinations of the variables under study. Compared to the data panel estimation techniques that have been extensively used in the literature to analyze non-performing loans and bank provisioning policies, the VAR methodology has the advantage of addressing the issue of potential endogeneity (by treating all variables as endogenous) and of fully capturing the dynamic interactions between the different types of potential determinants. The variables utilized in the analysis include:

Δ(LLR): quarterly change in the aggregate (system-wide) loan loss reserves to total loans ratio;

Δ(TNPL): quarterly change in the aggregate (system-wide) ratio of non-performing loans (including restructured loans) to total loans;

DR: ratio of the flow of loans classified as bad debt in the reference period to the total stock of performing loans of the prior period;

RGDP: quarterly growth of Greece's real GDP;

Δ(UNPL): quarterly change in Greece's unemployment rate (all domestic industries);

RHP: real quarterly growth of the residential house prices index;

Δ(L_RIR): quarterly change of the real interest rate on bank loans (calculated using as weights the outstanding volumes of domestic monetary financial institutions' loans vis-à-vis euro area private-sector residents);

Δ(INFL): quarterly change in the harmonized consumer price index for Greece;

Δ(ETA): quarterly change in the aggregate (banking-sector wide) solvency ratio, measured as total common shareholders equity to total bank assets;

LG_R: real quarterly growth of bank loans;

LG_PERFO: real quarterly growth of bank performing loans;

Δ(LtD): quarterly change of the aggregate (banking sector-wide) loans to deposits ratio;

Δ(LtA): quarterly change of the aggregate (banking sector-wide) loans to total assets ratio;

Δ(LD_IRS): quarterly change of the interest rate spread between loans and deposits; and

C10: crisis dummy taking the value of 1 from Q1 2010 onwards; and zero otherwise.

The estimates of our VAR model specifications for the ratio of loan loss reserves to total loans are shown in Tables (1) to (4). The tables also report the results of a series of relevant causality tests, which confirm the efficacy of the selected model specifications. In most cases, the estimated coefficients have the correct theoretical sign and are statistically significant. Furthermore, all estimated VAR models presented in this sector pass the usual diagnostic tests as regards model specification and stability, selected lag length as well as residual autocorrelation, heteroscedasticity and normality (all results are available on request).

Table 1: Estimated models M1-M9 for loans loss provisions.

	M1	M2	M3	M4	M5	M6	M7	M8	M9
D(LLR(-1))	-0.29	-0.19	-0.28	-0.30	-0.19	0.16	-0.22	-0.25	-0.23
t-statistic	*-1.71*	*-1.24*	*-1.58*	*-1.74*	*-1.19*	*0.95*	*-1.40*	*-1.63*	*-1.44*
RGDP(-1)	-0.13					-0.12	-0.12	-0.06	-0.06
t-statistic	*-0.77*					*-2.17*	*-2.73*	*-1.15*	*-1.14*
D(LLR(-2))	-0.11								
t-statistic	*-2.56*								
RGDP(-2)	-0.07								
t-statistic	*-1.41*								
D(UNPL(-1))		0.26		0.21	0.24			0.22	0.16
t-statistic		*2.78*		*2.01*	*2.44*			*1.84*	*1.27*
RHP(-1)			-0.10	-0.07					
t-statistic			*-2.35*	*-1.43*					
INFL(-1)					0.13	-0.07			
t-statistic					*1.20*	*-0.58*			
D(L_RIR(-1))							-0.13	-0.16	-0.01
t-statistic							*-1.45*	*-1.80*	*-0.29*
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
t-statistic	*0.62*	*0.25*	*0.42*	*0.24*	*-0.62*	*2.53*	*0.27*	*0.00*	*0.41*
					Exogenous-Variables				
C10	0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.01
t-statistic	*3.96*	*4.27*	*4.05*	*4.13*	*4.34*		*4.79*	*4.80*	*3.45*

					Statistics				
R^2	0.50	0.49	0.46	0.51	0.51	0.20	0.50	0.55	0.51
Akaike Criterion	-7.88	-7.96	-7.91	-7.97	-7.95	-7.52	-7.95	-7.99	-7.91
					Causality Wald-Test (P-Values)				
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**
RGDP	0.01					0.03	0.01	0.25	0.25
D(UNPL)		0.00		0.04	0.02			0.07	0.20
RHP			0.02	0.15					
INFL					0.23	0.56			
D(L_RIR)							0.15	0.07	0.77*
All	0.01	0.00	0.02	0.00	0.01	0.08	0.01	0.00	0.03

Notes:
1. All variables are expressed in growth rates or first differences with the exception of L_RIR in model M9 which is measured in levels.
2. The first panel of the table presents the estimates and associated t-statistics for the dynamic equation; the second panel presents the estimates and associated t-statistics for the exogenous (dummy) variable; the third panel presents the standard statistics for goodness of fit (R^2) and the Akaike Information Criterion (AIC); and the fourth panel presents the p-values for standard causality tests, with the null hypothesis being that the respective explanatory variable does not cause LLR.
3. C10 is a dummy variable that takes the value 1 from Q1 2010 onwards and the value zero (0) otherwise.

Table 2: Estimated models M10-M18 for loans loss provisions.

	M10	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**
D(LLR(-1))	0.33	0.36	0.31	0.22	-0.15	0.22	0.20	0.18	-0.02
t-statistic	*2.07*	*2.23*	*1.88*	*1.28*	*-0.75*	*1.28*	*1.13*	*1.04*	*-0.12*
RGDP(-1)		-0.09	-0.04				-0.08	-0.05	
t-statistic		*-1.71*	*-0.66*				*-1.66*	*-0.89*	
D(ETA(-1))	0.17	0.18	0.16	0.14	0.04	0.14	0.14	0.14	0.07
t-statistic	*2.54*	*2.74*	*2.47*	*2.17*	*0.55*	*2.17*	*2.20*	*2.08*	*1.01*
LG_R(-1)				-0.04	-0.03	-0.04	-0.05	-0.04	-0.04
t-statistic				*-1.77*	*-1.24*	*-1.77*	*-2.16*	*-1.85*	*-1.81*
D(UNPL(-1))	0.23		0.18	0.18	0.21	0.18		0.11	
t-statistic	*2.06*		*1.29*	*1.59*	*2.08*	*1.59*		*0.77*	
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
t-statistic	*1.55*	*1.78*	*1.60*	*2.31*	*0.94*	*2.31*	*2.74*	*2.42*	*1.44*
					Exogenous-Variables				
C10					0.01				0.01
t-statistic					*2.88*				*2.54*
					Statistics				
R^2	0.35	0.33	0.36	0.40	0.51	0.40	0.40	0.41	0.45
Akaike Criterion	7.72	-7.69	-7.69	-7.76	-7.92	-7.76	-7.77	-7.73	-7.85
					Causality Wald-Test (P-Values)				
	M10	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**

D(UNPL)	0.04		0.20	0.11	0.04	0.11	0.10	0.44	
D(ETA)	0.01	0.01	0.01	0.03	0.58	0.03	0.03	0.04	0.31
RGDP		0.09	0.51					0.37	
LG_R				0.08	0.22	0.08	0.03	0.06	0.07
All	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.09

Notes:

1. All variables are expressed in growth rates or first differences.
2. The first panel of the table presents the estimates and associated t-statistics for the dynamic equation; the second panel presents the estimates and associated t-statistics for the exogenous (dummy) variable; the third panel presents the standard statistics for goodness of fit (R2) and the Akaike Information Criterion (AIC); and the fourth panel presents the p-values for standard causality tests, with the null hypothesis being that the respective explanatory variable does not cause LLR.
3. C10 is a dummy variable that takes the value 1 from Q1 2010 onwards and the value zero (0) otherwise.

Table 3: Estimated models M19-M27 for loans loss provisions.

	M19	**M20**	**M21**	**M22**	**M23**	**M24**	**M25**	**M26**	**M27**
D(LLR(-1))	-0.07	-0.13	-0.12	0.07	-0.02	-0.05	-0.05	0.27	-0.01
t-statistic	*-0.40*	*-0.72*	*-0.66*	*0.36*	*-0.10*	*-0.31*	*-0.31*	*1.73*	*-0.07*
RGDP(-1)		-0.08	0.04			-0.07	-0.06		
t-statistic		*-1.59*	*0.23*			*-1.55*	*-1.01*		
D(ETA(-1))			-0.07						
t-statistic			*-1.15*						
LG_R(-1)	-0.05	-0.06	0.15		-0.07	-0.07	-0.07		-0.06
t-statistic	*-2.27*	*-2.61*	*1.49*		*-2.76*	*-3.26*	*-2.83*		*-2.28*
D(UNPL(-1))	0.14		-0.06		0.15		0.06		0.17
t-statistic	*1.08*		*-2.39*		*1.24*		*0.44*		*1.33*
D(TNPL(-1))	0.14	0.16		0.22					
t-statistic	*1.39*	*1.79*		*2.31*					
D(LD_IRS(-1))									0.23
t-statistic									*0.52*
DR(-1)					0.10	0.11	0.10	0.09	0.10
t-statistic					*1.92*	*2.12*	*1.90*	*1.56*	*1.71*
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
t-statistic	*2.68*	*2.92*	*2.80*	*1.61*	*2.79*	*3.15*	*2.90*	*1.70*	*2.70*
					Statistics				
R^2	0.36	0.38	0.38	0.21	0.38	0.40	0.40	0.15	0.39
Akaike Criterion	-7.69	-7.73	-7.68	-7.58	-7.74	-7.76	-7.72	-7.51	-7.69
					Causality Wald-Test (P-Values)				
	M19	**M20**	**M21**	**M22**	**M23**	**M24**	**M25**	**M26**	**M27**
D(UNPL)	0.28		0.82		0.22	0.12	0.66		0.18
D(ETA)							0.31		

RGDP	0.02	0.11	0.25						
LG_R		0.01	0.02		0.01	0.00	0.00		0.02
D(TNPL)	0.16	0.07	0.14	0.02					
DR					0.05	0.03	0.06	0.12	0.09
D(LD_IRS)									0.60
All	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.12	0.00

Notes:

1. All variables are expressed in growth rates or first differences.
2. The first panel of the table presents the estimates and associated t-statistics for the dynamic equation; the second panel presents the estimates and associated t-statistics for the exogenous (dummy) variable; the third panel presents the standard statistics for goodness of fit (R2) and the Akaike Information Criterion (AIC); and the fourth panel presents the p-values for standard causality tests, with the null hypothesis being that the respective explanatory variable does not cause LLR.
3. C10 is a dummy variable that takes the value 1 from Q1 2010 onwards and the value zero (0) otherwise.

Table 4: Estimated models M28-M35 for loans loss provisions.

	M28	**M29**	**M30**	**M31**	**M32**	**M33**	**M34**	**M35**
D(LLR(-1))	-0.05	0.14	0.06	0.04	0.02	-0.30	0.32	0.36
t-statistic	*-0.29*	*0.89*	*0.32*	*0.20*	*0.13*	*-1.75*	*1.92*	*2.13*
RGDP(-1)	-0.08			-0.10	-0.06	-0.07		
t-statistic	*-1.59*			*-1.98*	*-1.01*	*-1.29*		
D(ETA(-1))							0.17	
t-statistic							*2.50*	
LG_R(-1)	-0.07		-0.05	-0.06	-0.05	-0.03		
t-statistic	*-2.93*		*-2.12*	*-2.61*	*-2.20*	*-1.44*		
D(UNPL(-1))		0.35	0.23		0.14	0.13	0.23	
t-statistic		*3.02*	*1.94*		*0.95*	*1.07*	*2.04*	
D(LD_IRS(-1))	0.18	0.67						
t-statistic	*0.43*	*1.61*						
DR(-1)	0.11							
t-statistic	*1.99*							
D(GLTA(-1))			0.00	-0.01	0.00	0.02	0.01	-0.02
t-statistic			*-0.04*	*-0.14*	*-0.09*	*0.58*	*0.33*	*-0.50*
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
t-statistic	*3.11*	*2.43*	*3.10*	*3.71*	*3.20*	*1.11*	*1.54*	*2.55*
				Exogenous-Variables				
C10						0.01		
t-statistic						*3.82*		
				Statistics				
R^2	0.40	0.29	0.32	0.33	0.34	0.54	0.35	0.11
Akaike Criterion	-7.71	-7.64	-7.64	-7.64	-7.62	-7.92	-7.68	-7.46

	Causality Wald-Test (P-Values)							
	M28	**M29**	**M30**	**M31**	**M32**	**M33**	**M34**	**M35**
D(UNPL)		0.00	0.05		0.34	0.29	0.04	
D(ETA)							0.01	
RGDP	0.00			0.05	0.31	0.20		
LG_R	0.11		0.03	0.01	0.03	0.15		
DR	0.05							
D(LD_IRS)	0.67	0.11						
D(GLTA)			0.97	0.89	0.92	0.56	0.74	0.62
All	0.00	0.01	0.01	0.01	0.01	0.02	0.00	0.62

Notes:

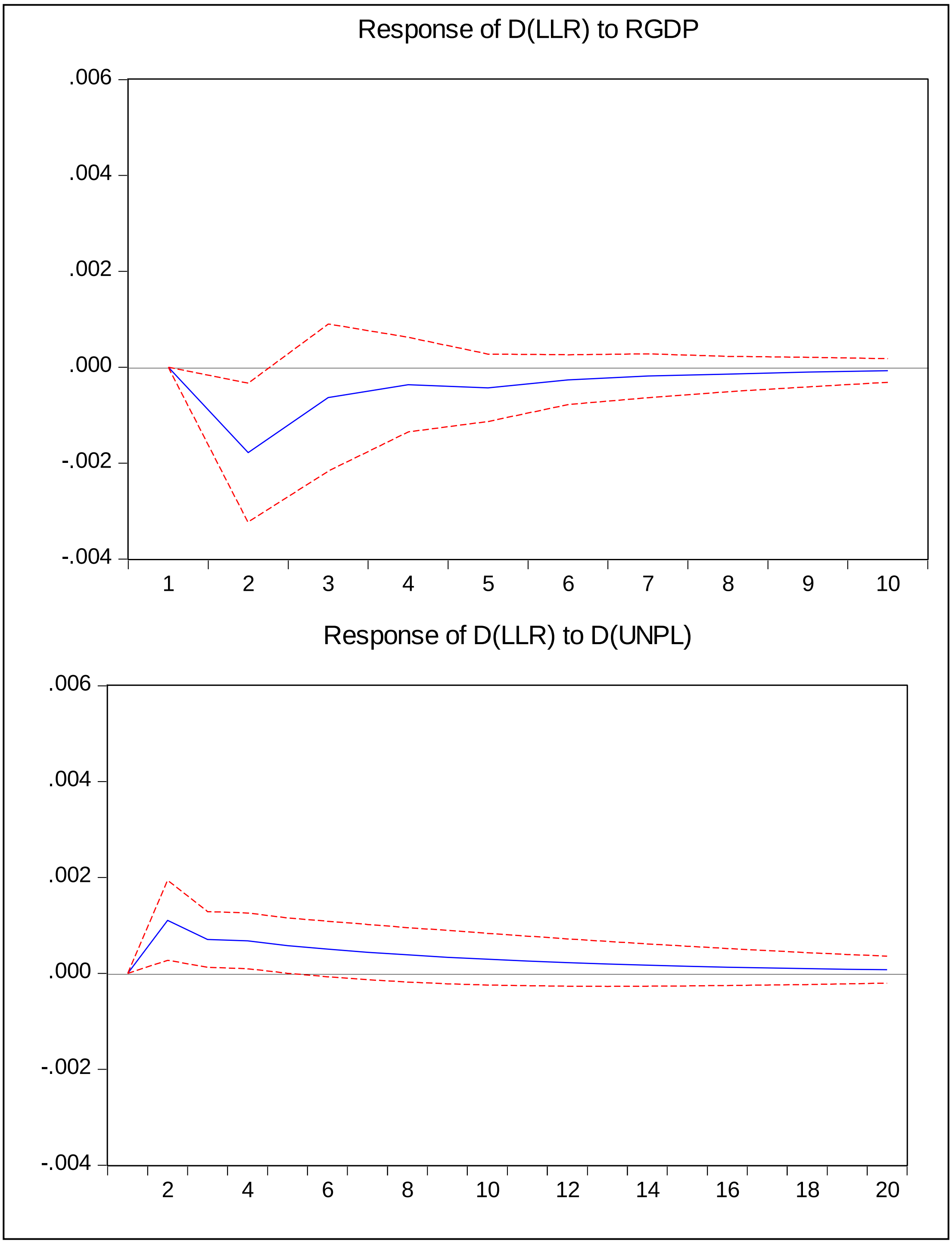
1. All variables are expressed in growth rates or first differences.
2. The first panel of the table presents the estimates and associated t-statistics for the dynamic equation; the second panel presents the estimates and associated t-statistics for the exogenous (dummy) variable; the third panel presents the standard statistics for goodness of fit (R2) and the Akaike Information Criterion (AIC); and the fourth panel presents the p-values for standard causality tests, with the null hypothesis being that the respective explanatory variable does not cause LLR.
3. C10 is a dummy variable that takes the value 1 from Q1 2010 onwards and the value zero (0) otherwise.

In the VAR equations that feature the quarterly change of the loan loss reserves ratio at the left-hand side, the coefficient of the first lag of that variable alters in sign across different model specifications and is not always significant (same result applies for models including more than one lags of Δ(LLR)). One possible explanation for this finding may relate to the fact that our loss reserves variable enters in first differences and thus, constitutes a flow variable. Recent empirical evidence on the sign (and the significance) of the lagged non-performing loans variable or that of the flow of loss provisions is somewhat ambiguous. For instance, in their earlier contributions for Italy by Salas and Saurina (2002) and Quagliariello (2007) find that the flow of provisions exhibits some positive persistence. These authors explain this finding on the basis that it usually takes some time for NPLs to be written off of banks' balance sheets. On the other hand, in their panel data study on Greek NPLs, Louzis et al. (2012) document a negative and significant coefficient on the lagged NPLs variable for the case of consumer and corporate loans, along with an insignificant coefficient for mortgage loans. They explain this finding on the basis that NPLs are likely to decrease when they have increased in the previous quarter, due to write-offs.

In all estimated models, the coefficients of the lagged real GDP growth and the quarterly change in the unemployment rate have the expected signs (negative and positive, respectively) and are statistically significant (models M1 & M2). Furthermore, the magnitude of these coefficients exhibits notable stability across model specifications. This result provides evidence in favor of the procyclicality hypothesis as regards the provisioning policies of Greek banks at an aggregate level and is in line with the findings of numerous earlier empirical studies on the behavior of loan loss reserves and provisions. On the other hand, it implies that the procyclicality argument advanced by Borio et al. (2001) and Lowe (2002) does not apply to the provisioning practices followed by the domestic credit institutions in recent years.

In more detail, our findings show that, at an aggregate level, Greek banks take higher provisions (and increase their loan loss reserves) when domestic macroeconomic conditions deteriorate and vice versa. Estimates of bi-variate VAR models that include real GDP growth or, alternatively, the change in the unemployment rate as the sole explanatory variable suggest that domestic banks respond relatively quickly to macroeconomic shocks, with the peak change in the LLR ratio being realized within two quarters. Yet, the effects of such shocks on the provisioning behavior of the domestic banking system shows significant persistence; in more detail, the impact of GDP shocks on loss reserves dies out in about 10 quarters, while the impact of shocks on the unemployment rate persists for a considerably longer period i.e., it takes about 20 quarters for these effects to die out (see impulse response graphs of Figure 1).

Figure 1. Impulse response of D(LLR) to Cholesky's one s.d. RGDP and D(UNPL) innovation for VAR



models M1 & M2 respectively.

In terms of the respective quantitative impacts, our estimates show that a 1 percentage point (ppt) decline (increase) in real GDP growth leads to an increase (decline) of 0.11ppts in the quarterly change of the loss reserves ratio after a quarter, with the corresponding long-run effect being around 0.18ppts. This is actually comparable with the respective impacts documented in some earlier studies for other euro area economies. For instance, in a dynamic panel model estimated for a large number of Italian intermediaries over the period 1985-2002, Quagliariello (2007) finds that the long-run effect of a 1 percent GDP change on loan loss provisions is 0.13 (and 0.17 in the respective static model specification). As to the impact of labor market conditions, our estimates show that a 1 percent increase (decrease) in the unemployment rate leads to an increase (decrease) in the change of the LLR ratio by 0.26 percent after a quarter and by 0.27ppts in the long-run. These results are also in broad agreement with the estimates derived from the rest of the VAR specifications analyzed in this study as well as the single equation models presented in Table 5.

The coefficient of the lagged real growth of residential house prices is found to have the expected sign (negative), but not to be always significant. This especially applies to VAR model specifications that also include other macroeconomic indicators of the state of the macro economy e.g. GDP growth and unemployment rate (models M3 & M4). To the extent that our RHP variable constitutes a sound coincident indicator of the phase of the business cycle, the aforementioned result may be seen as providing some incremental support to the procyclicality hypothesis of banks' aggregate provisioning policies. On the other hand, our results do not support an alternative hypothesis postulating that in periods of increased collateral valuations banks may be tempted to reduce their screening activity making their portfolios riskier, which would in turn imply a positive association between LLRs and house prices.

The effect of inflation on the Greek banking system's loan loss reserves ratio is found to be ambiguous in sign and statistically insignificant in most estimated models (models M5 & M6). This is broadly in agreement with the findings of a number of recent empirical studies (see e.g. Nkusu, 2011). On the one hand, higher inflation erodes the real value of outstanding debt, thus making debt servicing easier. Other things being equal, the latter implies a lower volume of bank loans and thus, a lesser need for taking provisions (negative association). On the other hand, higher inflation may reduce real incomes (when prices are sticky) and thus, affect negatively the ability of borrowers to service their loans. This, in turn, would imply a positive association between inflation and the ratio of loan loss reserves. In our study, we find no conclusive evidence in favor of either of the aforementioned hypotheses.

The estimated coefficient of the real loan interest rate, *L_RIR*, is mostly negative in sign, regardless of whether it is measured in levels or quarterly changes (models M7-M9). Although this is not always found to be statistically significant, it seems a bit counterintuitive to us on the basis that an increase in loan servicing costs should normally hinder the debt servicing capacity of borrowers, leading to a higher number of bad loans in the future and thus, higher provisions to account for such loans. It also appears to be in disagreement with the findings of several earlier empirical studies. For example, in a recent analysis on the determinants of non-performing loans in the Greek banking system, Monokroussos et al. (2016a) document a positive and significant coefficient on the real loan interest rate, both at an aggregate level (all loans) and for the major categories (consumer, mortgage and corporate) of bank loans.

Separately, the coefficient of the loans-to-deposits interest rate spread, *Δ(LD_IRS)*, is insignificant in all cases and also with alternating sign (positive in the estimated VARs and negative in the single equation model specifications) (models M27-M29). As we have already noted, this variable can be viewed as a proxy for the degree of risk taking by domestic credit institutions. A positive association between the said variable and non-performing loans (and hence, loss provisions and reserves) could be interpreted as evidence favoring the view that Greek banks engage in riskier activities by selecting lower credit quality borrowers to whom they charge higher interest rates. The aforementioned analysis shows that our empirical results do not provide evidence in support of that hypothesis. This is despite the fact that in the latter part of our data sample there has mostly been a positive co-movement of LLRs and the loans-to-deposits interest rate spread due to the deep economic recession and the incipient tightening of domestic financial conditions. The latter saw major Greek banks becoming extremely cautious in extending new credit to domestic households and businesses, with loan interest rates lagging significantly behind the gradual declining trend in deposit interest rates witnessed after the first half of 2012.

The coefficient of our bank capitalization indicator, *Δ(ETA)*, is found to be positive and significant in the majority of model specifications under study (models M10-M14). This result argues against the so-called capital management hypothesis, which postulates that banks with low regulatory capital are inclined to take more general provisions in order to keep their capital ratios adequate (negative association between loan loss reserves and the equity to assets ratio). On the contrary, our analysis shows that in the Greek banking system strongly capitalized banks tend to take more provisions (and loan loss reserves) than weakly capitalized banks. However, an alternative explanation for the positive coefficient on the *ETA* variable is as follows: the sharp increase of non-performing loans and, by implication, of loss provisions and reserves has been one of the main reasons that necessitated the three major recapitalizations (in early 2013, mid 2014 and late 2015) of the domestic banking system in order to boost the capital base of Greek credit institutions to levels above the required regulatory minimum. This point mostly applies to the latter part (crisis period) of our data sample and relates especially to the latest two recapitalizations.[10] Note that a positive (though insignificant) coefficient on the ratio of bank capital to total assets is also reported in a dynamic panel analysis of the EU banking system presented in Bikker and Metzemakers (2015).

The coefficient of the real growth of both total and performing loans is negative and significant in all estimated models (M15-M18). This finding is in line with the classical procyclicality hypothesis of bank provisioning policies and it runs counter to an alternative hypothesis claiming that

[10] It can be argued that the 1st recapitalization of the domestic banking system (early 2012) was mainly caused by the debt restructuring of Greece's sovereign debt held by private-sector accounts (PSI), which completely wiped out the capital base of major Greek banks.

loan portfolio risks are actually building up during economic booms, which would instead imply a positive coefficient on loans growth (Borio et al., 2001; and Lowe, 2002).

As we noted in section 4.3 of this paper, the finding of a negative coefficient on the growth of loans in conjunction with a positive coefficient on the loans to assets ratio could be interpreted as supporting the view that provisions tend to increase as a share of total assets when the increase of new lending raises the risk exposure of banks portfolios (see e.g. Bikker and Metzemakers, 2005). In all VAR model specifications estimated in our study, the loans to assets ratio is found to be insignificant and with alternating sign both when estimated alone or in conjunction with the loans growth variable (models M30-M35). Therefore, based on this evidence alone, we cannot infer that the evolution of gross loans to assets ratio signifies an overly aggressive lending strategy by Greek credit institutions.

Finally, as expected, the estimated coefficients on the quarterly change in the non-performing loans to total loans ratio, *Δ(TNPL)* and the default rate, DR, are found to be positive and mostly significant (models M19-M22 and M23-M26).

5.2 Robustness & Stability Analysis: Single Equation Models

As a robustness check to the estimation procedure under study, we also run a series of single equation models that express loss reserves as a function of a range of macro- and bank-related variables that have mostly been found to be significant in the VAR equations (Table 5).

Table 5: Single bi- and multivariate models.

	Bivariate single models				
	Estimation period 2005Q1-2015Q4				
	S1	**S2**	**S3**	**S4**	**S5**
@TREND	0.02	0.03	0.01	0.03	0.03
RGDP(-1)	-0.09				
D(ETA)		-0.18			
LTD(-1)			0.02		
D(UNPL(-1))				0.29	
INFL(-1))					0.17[$]
	Estimation period 2010Q1-2015Q4				
	S1	**S2**	**S3**	**S4**	**S5**
@TREND	0.02	0.01	-0.01	0.03	0.01
RGDP(-1)	-0.21				
D(ETA)		-0.19			
LTD(-1)			0.01		
D(UNPL(-1))				0.34	
INFL(-1))					0.07[$]

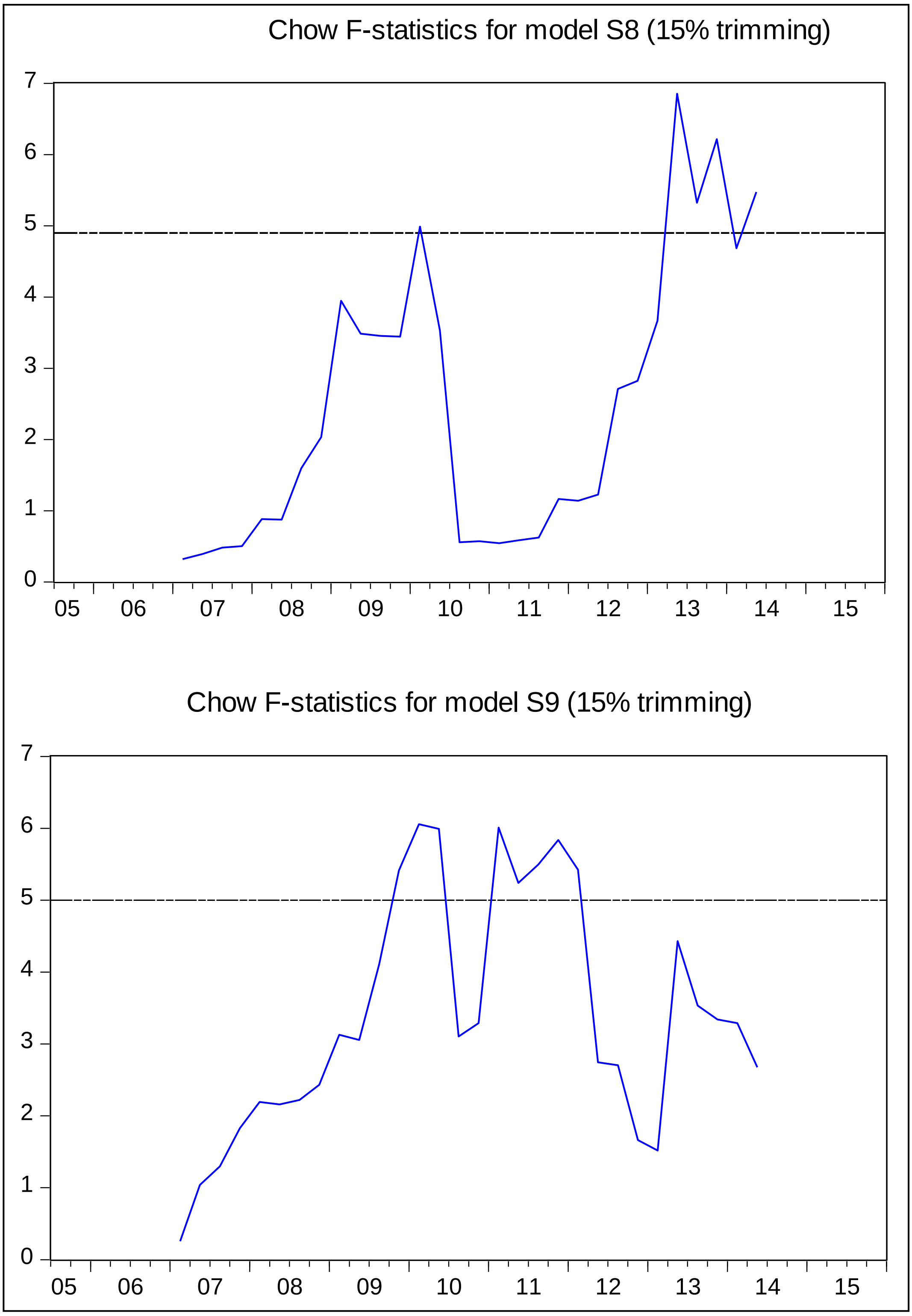
	Multivariate single models			
	Estimation period 2005Q1-2015Q4			
	S6	**S7**	**S8**	**S9**
@TREND	0.02	0.03	0.01	0.03
RGDP(-1)				-0.07
D(ETA)	-0.17	-0.17	-0.18	-0.17
LTD(-1)	0.01		0.02	
D(UNPL(-1))	0.15	0.26		
	Estimation period 2010Q1-2015Q4			
	S6	**S7**	**S8**	**S9**
@TREND	0.02	0.04	0.01	0.04
RGDP(-1)				-0.12
D(ETA)	-0.18	-0.18	-0.19	-0.18
LTD(-1)	0.01		0.02	
D(UNPL(-1))	0.17	0.30		

Notes:
1. All estimated coefficients are significant except those of the inflation variable (superscripted in $).
2. The first panel of the table presents coefficient estimates from single bivariate models estimated over the full data sample (2005Q1 to 2010Q1) and over the reduced (post crisis outbreak) sample 2010Q1-2015Q4. The second panel presents the respective estimates of the multivariate models.

A quite interesting result inferred by the estimates presented in Table 5 is that the impact of shocks in explanatory variables on the loan loss reserves ratio has become stronger (in terms of magnitude and statistical significance) in the period following the outbreak of the Greek crisis. For instance, in a bi-variate single equation model that is estimated from Q1 2010 onwards and includes GDP as the sole explanatory variable, a 1ppt decline in real GDP growth leads after a quarter to a 2.1ppts increase in the LLR ratio. This compares with an estimated impact of c. 0.9ppt when the full data set (Q1 2005-Q4 2015) is used in the estimation. The respective bi-variate model coefficients for the unemployment rate are 0.34 for the post crisis period and 0.29 for the full time horizon. From a macro policy perspective, these results indicate that a sustainable stabilization of macroeconomic conditions is a key precondition for safeguarding domestic financial stability. From a regulatory standpoint, the results suggest that the possibility of (macro) regime-related effects on banks' provisioning policies should be taken into account when supervisory authorities design and implement macro prudential stress tests of the banking system.

Towards this direction, our stability diagnostics results validate the post-crisis outbreak regime (from 2010Q1 onwards). As shown in Figure 2, the Quandt-Andrews breakpoint test indicates two structural breaks when LTDt-1 and D(ETA)t are jointly considered as breakpoint variables for model S8 and RGDPt-1 and D(ETA)t for model S9, respectively. In the case of S8, the Likelihood Ratio F-statistic rejects the null hypothesis of no breakpoints in Q1 2010 as well as in the period between Q3 2012 and Q3 2013. For model S9, the maximal individual chow F-statistic occurs also in Q1 2010.

Figure 2. Individual Likelihood Ratio F-statistics series of Quandt-Andrews breakpoint test for models 8 (up) and S9 (down).



Notes:

1. The QLR statistic for model S8 is 6.85 at Q2 2013 and for model S9 is 6.06 at Q1 2010.

Moreover, we find similar results for models S8 and S9 when multiple breakpoint tests are applied (see Table 6). F-statistics from Bai-Perron's sequentially determined breaks reject the null hypothesis in both models for Q1 2010 and Q2 2013. Hence, the increased estimated impact observed in most bi- and multivariate single equations can be justified on the basis of the post-crisis outbreak regime.

Table 6: Multiple breakpoint test for models S8 & S9.

Bai-Perron tests of L+1 vs. L sequentially determined breaks			
Multiple breakpoint tests for S8 model			
Break Test	**F-statistic**	**Scaled F-statistic**	**Critical Value**
0 vs. 1	6.85	13.70	9.81
1 vs. 2	10.34	20.69	11.40
Break dates	**Sequential**	**Repartition**	
1	2013Q2	2010Q1	
2	2010Q1	2013Q2	
Multiple breakpoint tests for S9 model			
Break Test	**F-statistic**	**Scaled F-statistic**	**Critical Value**
0 vs. 1	6.05	12.11	9.81
1 vs. 2	8.85	17.70	11.40
Break dates	**Sequential**	**Repartition**	
1	2013Q2	2010Q1	
2	2010Q1	2013Q2	

Notes:
1. Breakpoint variables are LTD_{t-1} and $D(ETA)_t$ for model S8 and $RGDP_{t-1}$ and $D(ETA)_t$ for model S9
2. Data are trimmed by 15% where we exclude the first and last 7.5% of the observations;
3. Significance level 0.10; Maximum breakpoints 2

6. Concluding remarks

This study utilizes a new set of macroeconomic and regulatory data to analyze the evolution of loan loss provisioning practices in the Greek banking system over the period 2005-2015. This is performed by examining the determinants of the aggregate (industry-wide) loan loss reserves to total loans ratio, which reflects the accumulation of provisions net of write-offs and constitutes an important metric of the credit quality of loan portfolios. Our empirical findings make several contributions to the literature, especially as the behavior of provisioning policies in the Greek banking system has not been thoroughly analyzed in the past. Among others, we empirically document that, at an aggregate level, Greek banks generally behave in line with the stylized facts of provisioning policy procyclicality, taking higher provisions (and increase their loan loss reserves) when domestic macroeconomic conditions deteriorate. On the other hand, our results do not provide evidence in support of the so-called capital management hypothesis, which postulates that banks with low regulatory capital are inclined to take more general provisions in order to keep their capital ratios adequate. On the contrary, our analysis shows that in the Greek banking system more strongly capitalized banks tend to take more provisions (and increase their loan loss reserves) than weakly capitalized banks. Separately, our estimates show that domestic banks respond relatively quickly to macroeconomic shocks, with the peak quarterly change in the loan loss reserves ratio (i.e., the flow of provisions net of write offs) being realized within two quarters. Yet, the effects of such shocks on the provisioning behavior of the domestic banking system show significant persistence. Another interesting finding of our analysis is that the impact of macroeconomic shocks on the loan loss reserves ratio has become stronger (both in terms of magnitude and statistical significance) following the outbreak Greek sovereign debt crisis. From a macro policy perspective, this result indicates that a sustainable stabilization of macroeconomic conditions is a key precondition for safeguarding domestic financial stability. For a regulatory standpoint, it suggests that the possibility of macroeconomic regime-related effects on banks' provisioning policies should be taken into account when macro prudential stress tests of the banking system are designed and implemented.

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