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Macroeconomic and bank-specific determinants of non-performing loans in Greece: A comparative study of mortgage, business and consumer loan portfolios

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This paper uses dynamic panel data methods to examine the determinants of non-performing loans (NPLs) in the Greek banking sector, separately for each loan category (consumer loans, business loans and mortgages). The study is motivated by the hypothesis that both macroeconomic and bank-specific variables have an effect on loan quality and that these effects vary between different loan categories. The results show that, for all loan categories, NPLs in the Greek banking system can be explained mainly by macroeconomic variables (GDP, unemployment, interest rates, public debt) and management quality. Differences in the quantitative impact of macroeconomic factors among loan categories are evident, with non-performing mortgages being the least responsive to changes in the macroeconomic conditions.

1. Introduction

Exploring the determinants of ex post credit risk is an issue of substantial importance for regulatory authorities concerned with financial stability and for banks' management. The ex post credit risk takes the form of Non-Performing Loans (NPLs). Reinhart and Rogoff (2010) point out that NPLs can be used to mark the onset of a banking crisis.

In the majority of studies that investigate the determinants of NPLs, the aggregate level of NPLs is considered and either macroeconomic or bank-specific determinants (but not both) are used as explanatory variables. Exceptions include Salas and Saurina (2002) who combine macroeconomic and microeconomic variables to explain aggregate NPLs of Spanish Commercial and Savings Banks for the period 1985–1997. They focus on the NPLs determinants for commercial and savings banks and find that bank-specific determinants can serve as early warning indicators for future changes in NPLs. Other similar studies include Clair (1992) and González-Hermosillo et al. (1997).

Most empirical studies examine the influence of the macroeconomic environment on NPLs. Rinaldi and Sanchis-Arellano (2006) analyze household NPLs for a panel of European countries and provide empirical evidence that disposable income, unemployment and monetary conditions have a strong impact on NPLs. Berge and Boye (2007) find that problem loans are highly sensitive to the real interest rates and unemployment for the Nordic banking system over the period 1993–2005. Boss et al. (2009) examine the coupling of credit risk of the main Austrian corporate sectors with the business cycle. Other studies focusing on the macroeconomic determinants of NPLs include Cifter et al. (2009), Nkusu (2011) and Segoviano et al. (2006).

Another strand of the literature emphasizes the effect of bank-specific characteristics on problem loans. Berger and DeYoung (1997) draw attention to the links between bank-specific characteristics and focus on efficiency indicators and problem loans. Specifically, Berger and Young formulate possible mechanisms, namely 'bad luck', 'bad management', 'skimping' and 'moral hazard', relating efficiency and capital adequacy. They test the derived hypotheses for a sample of US commercial banks spanning the period from 1985 to 1994 and conclude that, generally, decreases in measured cost efficiency lead to increased future problem loans. Podpiera and Weill (2008) continue along this line of research and examine the relationship between efficiency and bad loans

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in the Czech banking industry from 1994 to 2005. They also provide empirical evidence in favor of a negative relationship between decreased cost efficiency and future NPLs. Both papers focus solely on bank-specific determinants. Li et al. (2007) finds that incentive contracts have a positive effect on managerial efforts to reduce NPLs in the Chinese banking system. Finally, Breuer (2006) examines the influence of a very wide range of institutional variables on NPLs.

The present study aims to contribute to the NPLs literature in three ways. First, we examine the determinants of NPLs across different loan categories, rather than the aggregate level of NPLs. The majority of previous studies focuses on aggregate NPLs. This approach may obscure significant channels through which credit risk fluctuates.[1] In particular, macroeconomic and bank-specific variables may impact each type of NPLs in a different way. This can be attributed to institutional settings creating different incentive structures for each loan type with regard to the costs of bankruptcy.[2,3] Moreover, differences in the sensitivity of various NPLs categories to macroeconomic developments may be related to differential effects of the business cycle, especially economic downturns, on agents' cash flows and collateralized assets' values. Therefore, we distinguish between consumer, business and mortgage loans and investigate separately their corresponding determinants.

Second, the paper focuses on the Greek banking system, which due to the recent economic developments in Greece, may serve as a benchmark for the study of the public debt and banking crisis nexus. Reinhart and Rogoff (2009), for instance, concentrate on the temporal direction from a banking crisis to a debt crisis, motivated by the financial turmoil in the US. The case of Greece, however, provides an example of a fragile public finance condition leading to a deterioration of the NPLs. In this paper we investigate the effect of the sovereign debt on the banking system through the NPLs.

Finally, the paper considers two distinct types of determinants, namely macroeconomic (systematic) and bank-specific (idiosyncratic). Our aim is to identify the most significant bank-specific determinants, after controlling for the macroeconomic environment. The methodology is to estimate a baseline model, which includes only general macroeconomic indicators and then examine if the addition of bank-specific variables contributes to the explanatory power of the model. The choice of the bank-specific variables is based on hypotheses which have been put forward in the literature. Under the assumption that the macroeconomic situation and the business cycle constitute fundamental determinants of NPLs for all types of loans, this approach enables us to isolate the bank-specific features, which have an impact on NPLs per type of loan.

There is no standardized approach to analyze the factors influencing NPLs in the literature. Data availability represents a major limitation, constraining to a large extent the methodological options available. This paper utilizes a panel data set comprising nine Greek commercial banks spanning from the first quarter of 2003 to the third quarter of 2009 and a loan portfolio broken down into mortgage, business and consumer loans. Our results are intuitively expected but have not been documented before. For example, empirical evidence is provided that macroeconomic and bank-specific variables should be combined when modeling the NPLs evolution and we show that there exist both qualitative and quantitative differences among the effects of these variables on the various NPL categories.

[1] Sinkey and Greenawalt (1991) analyze the determinants of loan loss rates, separately for various loan classes.

[2] For an international comparison of bankruptcy laws see Kolecek (2008).

[3] The regulatory framework e.g. the time period within which banks are obliged to write off NPLs is another factor that affects the observed value of NPLs.

The rest of the paper is organized as follows. Section 2 briefly presents the evolution of NPLs in the Greek banking system. Section 3 provides an overview of the theoretical and empirical literature on the determinants of problem loans and formulates the hypotheses relating bank-specific variables to NPLs. Section 4 describes the econometric methodology, while Section 5 presents the results of the empirical analysis. Finally, Section 6 summarizes our findings.

2. Evolution of non-performing loans in the Greek banking system

Before the liberalization of the Greek financial sector, which started in the early 1990s, the regulatory restrictions determined to a large extent the risk attitude of the banking institutions. According to (Tsakalotos, 1991, quoted in Gibson and Tsakalotos, 1992) decisions on extending bank credit were frequently made on the basis of non-banking criteria such as "personal contacts and social pressure" which lead to inefficiency as regards risk management and to problems with NPLs.

On the contrary, the changing economic environment within which the banks operated, and which was clarified around the late-1990s,[4] changed the mode of operation of Greek banks with regard to the way they handled risk. In order to achieve satisfactory levels of profitability and survive in the face of intensified competition, as a result of financial liberalization, the banks were forced to improve their risk management efficiency and adopt sophisticated technology.

Taking into account the evolution of the banking sector in Greece it is logical to assume that the determinants of NPLs must have changed over time. In the place of determinants related to public policy directions, market forces are expected to have taken over as the major drivers of NPLs. Our investigation is thus restricted to the post-liberalization time period.

Since the 2000s the Greek banking system can certainly be characterized as a relatively mature financial sector, where market forces govern its functioning. This period encompasses a part of the booming period (which started since the mid-1990s) and the current financial crisis. Therefore, all phases of the business cycle are included in our empirical analysis.

In addition to the concerns raised by the current financial crisis for a further NPL ratio deterioration, the steep credit expansion, which occurred during this decade (see Fig. 1), also poses the question whether the quality of loans granted during this euphoric period was accurately evaluated by the banking system. Generally, the high rates of credit growth during the 2000s can be attributed to rightward shifts in both the demand and the supply curves. On the supply side, the liberalization of the financial system, which took place in the 1990s and the ensuing competition between banks for market share, fueled credit growth. On the demand side, the increase in debt ceilings, brought about by bank competition, induced households to attempt to smooth their consumption through borrowing.[5] Furthermore, high rates of growth that prevailed in Greece since the mid-1990s,[6] motivated firms to undertake

[4] Eichengreen and Gibson (2001) provide a comprehensive review of the Greek banking sector's development during the 1990s.

[5] In a theoretical contribution, Antzoulatos (1994) argues (using a stochastic optimization framework) that increases in the debt ceiling may lead to increases in optimal consumption. Debt ceiling is assumed to be exogenous in his model, so that one can interpret it as a choice variable for bank policy. Antzoulatos links this theoretical result with the observed decrease in savings, presumably related to improved consumer access to credit (caused by financial deregulation), across a diverse set of countries. Furthermore, the proposed model implies that improved access to credit primarily affects middle-income groups.

[6] For a periodization of the growth phases for the Greek economy see Bosworth and Kollintzas (2001).

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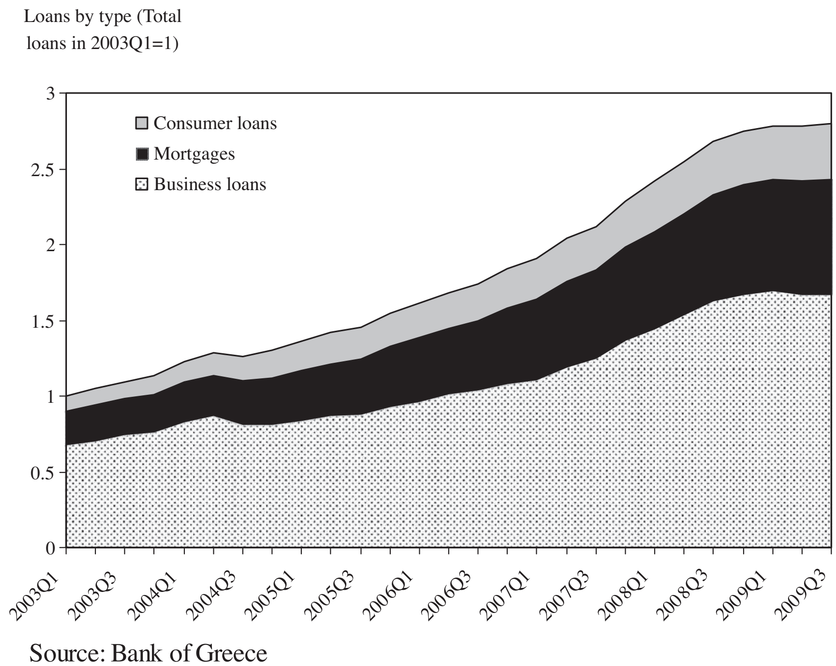

Fig. 1. Credit expansion per type of loan.

investments, leading to increased debt obligations for the business sector as well.

3. Determinant factors of NPLs

3.1. (Systematic) macroeconomic factors

Several papers in the banking literature examine the relationship between macroeconomic environment and loan quality. In this line of research, it has been hypothesized that an expansionary phase of the economy features relatively low NPLs, as both consumers and firms face a sufficient stream of income and revenues to service their debts. As the booming period continues, however, credit is extended to lower-quality debtors and subsequently, when recession sets in, NPLs increase.[7,8] Indeed, Carey (1998) argues that "the state of the economy is the single most important systematic factor influencing diversified debt portfolio loss rates" (Carey, 1998, p. 1382).

Other empirical studies also tend to confirm the aforementioned link between the phase of the cycle and credit defaults. Quagliarello (2007) finds that the business cycle affects NPLs for a large panel of Italian banks over the period 1985–2002. Furthermore, Cifter et al. (2009) provides empirical evidence for a lagged impact of industrial production on the number of NPLs in the Turkish financial system over the period 2001–2007. Salas and Saurina (2002) estimate a significant negative contemporaneous effect of GDP growth on NPLs and infer the quick transmission of macroeconomic developments to the ability of economic agents to service their loans (see further Bangia et al., 2002; Carey, 2002).

The primary macroeconomic determinants of NPLs may be selected from the theoretical literature of life-cycle consumption models. Lawrence (1995) examines such a model and introduces explicitly the probability of default. This model implies that borrowers with low incomes have higher rates of default due to increased risk of facing unemployment and being unable to settle their obligation. Additionally, in equilibrium, banks charge higher interest rates to riskier clients. Rinaldi and Sanchis-Arellano (2006) extend Lawrence's model by assuming that agents borrow in order to invest in real or financial assets. They argue that the probability of default depends on current income and the unemployment rate, which is linked to the uncertainty regarding future income and the lending rates.[9]

Based on the aforementioned literature, we use the GDP growth, the unemployment rate and the lending rates as the primary macroeconomic determinants of NPLs and estimate a baseline model using this set of variables as regressors. In the Sections 3.2 and 3.3, we undertake a review of the literature in order to select additional NPLs' explanatory variables, which may have an effect on NPLs.

3.2. Debt

The interlinkages between sovereign debt crises and banking crises have been recognized after the recent financial crisis and the consequent sovereign debt events. Reinhart and Rogoff (2010) present ample empirical evidence that banking crises most often either precede or coincide with sovereign debt crises.[10] Nonetheless, they also note that "A causal chain from sovereign debt crisis to banking crisis [...] cannot be dismissed lightly" (Reinhart and Rogoff, 2010 p. 26). In fact, the latter temporal sequence has taken place in Greece, but also in other countries that entered the financial crisis, while in a fragile fiscal situation (see for example BIS Annual Report, 2010). [11]

[7] For a model explaining the countercyclical variation of credit standards see Ruckes (2004).

[8] The inability of lower-quality debtors (either households or firms) to service their loans during a recession is also caused by the decrease in asset values which serve as collateral and the subsequent contraction of credit as banks become more risk-averse (see e.g. Geanakoplos, 2009).

[9] The probability of default, in this model, also depends on the amount of loan taken, the volume of investment and the time preference rate.

[10] The mechanisms at work include either the taking over of massive debt on the part of the government which undermines its solvency or the collapse of the currency which inflates foreign currency debt.

[11] For the temporal sequence of credit crises see also Reinhart and Rogoff (2009).

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Two channels of transmission of a sovereign debt crisis to the banking system have been identified. First, deterioration of public finances places a 'ceiling' on the market evaluation of credibility for the national banks and consequently banks become hard-pressed for liquidity (Reinhart and Rogoff, 2010). In this context, banks have to cut lending and thus debtors cannot refinance their debts. Moreover, a rise in public debt may lead to fiscal measures, especially cuts in social expenditure and the wage component of government consumption (Perotti, 1996). This may render unserviceable a number of outstanding loans, as households' income will experience a negative shock, while second-order effects in corporate loans may take place due to decreasing demand. Thus, the following hypothesis may be formulated:

(1) '*Sovereign debt hypothesis*': Rising sovereign debt leads to an increase in NPLs.

3.3. Bank specific factors

The determinants of NPLs should not be sought exclusively among macroeconomic variables, which are exogenous to the banking industry. The distinctive features of the banking sector and the policy choices of each bank, particularly with respect to their efforts to improve efficiency and the risk management, are expected to influence the evolution of NPLs. A strand in the literature examines the relationship between bank-specific factors and NPLs.

In their seminal paper, Berger and DeYoung (1997) investigate the existence of causality among loan quality, cost efficiency and bank capital. This study formulates and tests the following three hypotheses concerning the flow of causality between these variables:

(2) '*Bad management' hypothesis*: low cost efficiency is positively associated with increases in future NPLs. The proposed justification links 'bad' management with poor skills in credit scoring, appraisal of pledged collaterals and monitoring borrowers.
(3) '*Skimping*' *hypothesis*: high measured efficiency causes increasing number of NPLs. According to this view, there exists a trade-off between allocating resources for underwriting and monitoring loans and measured cost efficiency. In other words, banks which devote less effort to ensure higher loan quality will be more cost-efficient, however, there will be a burgeoning number of NPLs in the long-run.
(4) '*Moral hazard' hypothesis*: low-capitalization of banks leads to an increase in NPLs. The justification lies on in the moral hazard incentives on the part of banks' managers, who increase the riskiness of their loan portfolio when their banks are thinly capitalized.[12]

Berger and DeYoung find evidence supporting the 'bad management' hypothesis, implying causation from cost efficiency to NPLs (negative association), and of the moral hazard hypothesis. Podpiera and Weill (2008) also provide strong evidence in favor of the bad management hypothesis. Salas and Saurina (2002) estimate a statistically insignificant effect of lagged efficiency on problem loans (probably as a consequence of the counteraction of the 'bad management' and 'skimping' effects) and a statistically significant negative effect of the lagged solvency ratio on NPLs, which is consistent with the moral hazard hypothesis.

Banks' diversification opportunities may also be related with loan quality. We expect a negative relation between diversification and NPLs, since diversification lowers credit risk. Some authors use bank size as a proxy for diversification opportunities. In this line of research, Salas and Saurina (2002) find a negative relation between bank size and NPLs and argue that bigger size allows for more diversification opportunities. Hu et al. (2004) and Rajan and Dhal (2003) report similar empirical evidence.[13] Nonetheless, diversification opportunities can be also proxied using the non-interest income as a share of total income, on the grounds that this ratio reflects banks' reliance on other types of income, except for loan making, and therefore on diversified sources of income.[14] Stiroh (2004a) does not find evidence of benefits from diversification in the form of reduced risk, for the US banking system, since non-interest income growth was highly correlated with net interest income during the 1990s.

Thus, the following hypothesis may also be formulated:

(5) '*Diversification' hypothesis*: The bank size and the proportion of non-interest income as a share of total income are negatively related to NPLs.

The moral hazard of too-big-to-fail (henceforth TBTF) banks represents another channel relating bank-specific features with NPLs. A policy concern is that TBTF banks may resort to excessive risk taking since market discipline is not imposed by its creditors who expect government protection in case of a bank's failure (Stern and Feldman, 2004). Consequently, large banks may increase their leverage too much and extend loans to lower quality borrowers.

Empirical studies do not provide clear-cut evidence for a differential performance and risk attitude of TBTF banks. For example, Boyd and Gertler (1994) argue that in the 1980s the tendency of US large banks towards riskier portfolios was encouraged by the US government's TBTF policy. On the other hand, Ennis and Malek (2005) examine US banks' performance across size classes over the period 1983–2003 and conclude that the evidence for the TBTF distortions is in no way definite.

Thus, the following hypothesis may be formulated:

(6) '*Too big to fail' hypothesis*: Large banks take excessive risks by increasing their leverage under the TBTF presumption and therefore have more NPLs. We expect a positive effect of leverage on NPLs conditional on size.

The link between lagged measures of performance and problem loans is ambiguous in its direction. One hypothesis is that worse performance may proxy for lower quality of skills with respect to lending activities (similarly to the 'bad management' hypothesis). This implies a negative relationship between past earnings and problem loans.

(7) *'Bad management II' hypothesis* : performance is negatively associated with increases in future NPLs. This may be justified in a way analogous to the 'bad management' hypothesis by regarding past performance as a proxy for the quality of management.

[12] See Berger and DeYoung (1997, pp. 852–854) for a more detailed formulation of these hypotheses.

[13] Another channel through which size may affect NPLs is increasing returns to scale in information processing. For example, Hu et al. (2004) argue that large-sized banks possess enhanced capabilities for loan evaluation and processing due to their ability to devote more resources.

[14] We would like to thank an anonymous reviewer for pointing out that alternative proxies for diversification, apart from size, have also been suggested.

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Table 1
Definition of variables used to test the various hypotheses.

Variable	Definition	Hypothesis tested
Debt	$Debt_t = \frac{\text{Central Government Debt}_t}{\text{Nominal GDP}_t}$	"Sovereign Debt" (+)
Return on equity	$ROE_{it} = \frac{\text{Profits}_{it}}{\text{Total Equity}_{it}}$	"Bad management II" (−) "Procyclical credit policy" (+)
Solvency ratio	$SOLR_{it} = \frac{\text{Owned Capital}_{it}}{\text{Total Assets}_{it}}$	"Moral hazard" (−)
Inefficiency	$INEF_{it} = \frac{\text{Operating Expenses}_{it}}{\text{Operating Income}_{it}}$	"Bad Management"(+) "Skimping" (−)
Size	$SIZE_{it} = \frac{\text{Total Assets}_{it}}{\sum_{i=1}^{9}\text{Total Assets}_{it}}$	"Diversification" (−)
Non-interest income	$NII_{it} = \frac{\text{NonInterest Income}}{\text{Total Income}}$	"Diversification" (−)
Leverage ratio and size	$LR_{it} = \frac{\text{Total Liabilities}}{\text{Total Assets}}, SIZE_{it}$	"Too-big-to-fail" (+) LR_{it} conditional on $SIZE_{it}$
Ownership concentration	Three dummy variables, equal to 1 if the maximum percentage of ownership is greater than 10%, 25% and 50% respectively	"Tight control" (−)

Notes: All ratios are expressed in percentage points. The expected coefficient signs are shown in parenthesis.

The reverse direction of this effect is also possible, as in the model of Rajan (1994) who aims to explain the correlation between changes in credit policy and demand side conditions. In this model, credit policy is not determined solely by the maximization of banks' earnings but also by the short-term reputation concerns of rational banks' management. Consequently, management may attempt to manipulate current earnings resorting to a liberal credit policy, defined as a 'negative NPV extension of credit'. In this manner, a bank may attempt to convince the market for its profitability by inflating current earnings at the expense of future problem loans. A bank may also use loan loss provisions in order to boost its current earnings.[15] Consequently, past earnings may be positively linked to future NPLs:

(8) '*Procyclical credit policy' hypothesis*: performance is positively related with future increases in NPLs, as it reflects liberal credit policy on the part of the bank (i.e. 'negative NPV extension of credit').

Moreover, we also consider ownership dispersion as a determinant of NPLs. In a seminal study, Berle and Means (1933) argue that dispersed ownership of corporate equity may lead to a poorer performance of the firm as the incentive of shareholders to monitor the management weakens. An opposing view is that an efficient capital market imposes discipline on firm's management and therefore dispersed ownership should not have an effect on firm's performance (Fama, 1980).

A strand in the empirical literature tests these contrasting views using loan quality as an indicator of riskiness but evidence is inconclusive. For example, Iannotta et al. (2007) find a link between higher ownership concentrations and loan quality using a sample of 181 large banks over the period 1999–2004, thus lending support to the Berle and Means view. On the other hand, Laeven and Levine (2009) employ data on 279 banks and find a positive association between greater cash flow rights of a large owner and risk taking. Furthermore, Shehzad et al. (2010) present empirical evidence, from a data set comprising 500 banks from 2005 to 2007, that ownership proxied by three levels of shareholding (10%, 20% and 50%) has a positive impact on the NPL ratio when the level of ownership concentration is defined at 10% but a negative impact when the level of level of ownership concentration is defined at 50%. Therefore they suggest that sharing of control may have adverse effects on the quality of loans extended up to a level, but in cases of a strong controlling owner, bank's management becomes more efficient leading to lower NPLs.[16] Finally, Azofra and Santamaria (2011) find that high levels of ownership concentration benefit both the bank's profitability and efficiency for a sample of Spanish commercial banks.

(9) '*Tight control' hypothesis*: Higher ownership concentration tends to promote prudent risk taking through tighter control of the bank's management. Therefore, ownership concentration is negatively related with NPLs.

Table 1 presents the bank specific variables used in the econometric analysis and their correspondence to the specific hypothesis.

4. Econometric methodology

4.1. Dynamic panel data estimator

Following the recent literature in panel data studies (e.g. see Salas and Saurina, 2002; Merkl and Stolz, 2009), we adopt a dynamic approach in order to account for the time persistence in the NPL structure.[17] A dynamic panel data specification is generally given by:

$$y_{it} = \alpha y_{it-1} + \beta(L)X_{it} + \eta_i + \varepsilon_{it}, \ |\alpha| < 1, \ i = 1, \dots, N, \ t = 1, \dots, T, \tag{1}$$

where the subscripts i and t denote the cross sectional and time dimension of the panel sample respectively, y_{it} is the change in the NPLs, $\beta(L)$ is the $1 \times k$ lag polynomial vector, X_{it} is the $k \times 1$ vector of explanatory variables other than y_{it-1}, η_i are the unobserved individual (bank specific) effects and ε_{it} is the error term.

We consistently estimate Eq. (1) using the Generalized Method of Moments (GMM) as proposed by Arellano and Bond (1991) and generalized by Arellano and Bover (1995) and Blundell and Bond (1998). The GMM estimation of Arellano and Bond is based on the first difference transformation of Eq. (1) and the subsequent elimination of bank specific effects:

$$\Delta y_{it} = \alpha \Delta y_{it-1} + \beta(L)\Delta X_{it} + \Delta\varepsilon_{it}, \tag{2}$$

where Δ is the first difference operator. In Eq. (2) the lagged depended variable, Δy_{it-1} is by construction correlated with the error term, $\Delta\varepsilon_{it}$, imposing a bias in the estimation of the model. Nonetheless, y_{it-2}, which is expected to be correlated with Δy_{it-1} and not correlated with $\Delta\varepsilon_{it}$ for $t = 3, \dots, T$, can be used as an instrument in the estimation of Eq. (2), given that ε_{it} are not serially

[15] Ahmed et al. (1999), however, do not find evidence of earnings management via loan loss provisions for a sample of US banks over the period 1986–1995.

[16] Shehzad et al. (2010) condition their results on supervisory power. We do not include a supervisory power index in our empirical analysis as the specific index has remained constant in Greece for the period under examination.

[17] We use the ratio of non-performing loans to total loans. Nonperforming loans are defined as the loans overdue by more than ninety (90) days.

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correlated. This suggests that lags of order two, and more, of the dependent variable satisfy the following moment conditions:

$$E[y_{it-s}\Delta\varepsilon_{it}] = 0 \text{ for } t = 3,\ldots,T \quad \text{and } s \geqslant 2. \tag{3}$$

A second source of bias stems from the possible endogeneity of the explanatory variables and the resulting correlation with the error term. In the case of *strictly exogenous* variables, all past and future values of the explanatory variable are uncorrelated with the error term, implying the following moment conditions:

$$E[X_{it-s}\Delta\varepsilon_{it}] = 0 \; t = 3,\ldots,T \quad \text{and for all } s. \tag{4}$$

The assumption of strict exogeneity is restrictive and invalid in the presence of reverse causality i.e. when $E[X_{is}\varepsilon_{it}] \neq 0$ for $t < s$. For a set of *weakly exogenous* or *predetermined* explanatory variables, only current and lagged values of X_{it} are valid instruments and the following moment conditions can be used:

$$E[X_{it-s}\Delta\varepsilon_{it}] = 0 \; t = 3,\ldots,T \quad \text{and for } s \geqslant 2. \tag{5}$$

The orthogonality restrictions described in Eqs. (3)–(5) provide the underpinnings of the one-step GMM estimation, which produces, under the assumption of independent and homoscedastic residuals (both cross sectional and over time), consistent parameter estimates. The two-step GMM estimator (Arellano and Bond, 1991), which utilizes the estimated residuals in order to construct a consistent variance–covariance matrix of the moment conditions,[18] may impose a downward (upward) bias in standard errors (t-statistics) due to its dependence on the estimated residuals. This may lead to unreliable asymptotic statistical inference (Bond, 2002; Bond and Windmeijer, 2002; Windmeijer, 2005), especially in data samples with relatively small cross section dimension (see Arellano and Bond, 1991; Blundell and Bond, 1998).

We test the overall validity of the instruments by implementing the Sargan specification test, which, under the null hypothesis of valid moment conditions, is asymptotically distributed as chi-square (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). Furthermore, we assess the fundamental assumption of serially uncorrelated errors, ε_{it}, by testing the hypothesis that $\Delta\varepsilon_{it}$ are not second order autocorrelated. Rejection of the null hypothesis of no second order autocorrelation of the differenced errors implies serial correlation for the level error term and thus inconsistency of the GMM estimates.

4.2. Econometric specification

Eq. (1) takes the following form in the baseline model:

$$\Delta NPL_{it}^{h} = a\Delta NPL_{it-1}^{h} + \sum_{j=1}^{2}\beta_{1j}^{h}\Delta GDP_{t-j} + \sum_{j=1}^{2}\beta_{2j}^{h}\Delta UN_{t-j} + \sum_{j=1}^{2}\beta_{3j}^{h}\Delta RLR_{it-j}^{h} + \eta_i^h + \varepsilon_{it}^{h}, \tag{6}$$

with $|a| < 1$, $i = 1,\ldots,9$ and $t = 1,\ldots,27$.

In Eq. (6) the superscript h denotes the type of NPLs, ΔNPL_{it}^{h} is the first difference of the non-performing loans ratio, ΔGDP_t is the real GDP growth rate, ΔUN_t is the change in the unemployment rate and ΔRLR_{it}^{h} is the change in the real lending rates. We estimate the baseline model in Eq. (6) separately for each NPLs categories.

We test the 'sovereign debt hypothesis' by formulating Eq. (6) as follows:

$$\Delta NPL_{it}^{h} = a\Delta NPL_{it-1}^{h} + \sum_{j=1}^{2}\beta_{1j}^{h}\Delta GDP_{t-j} + \sum_{j=1}^{2}\beta_{2j}^{h}\Delta UN_{t-j} + \sum_{j=1}^{2}\beta_{3j}^{h}\Delta RLR_{it-j}^{h} + \beta_4\Delta Debt_{t-4} + \eta_i^h + \varepsilon_{it}^{h}. \tag{7}$$

We choose the lag order of the *Debt* variable after a 'general to specific' exercise, which resulted in retaining only the fourth lag in all three types of NPLs.

Next, we add each of the bank-specific indicators of Table 1 to the baseline model of Eq. (6) in order to examine its additive explanatory power.[19] The number of cross sectional units poses limitations on the number of instruments that can be used in the estimation and subsequently the number of exogenous variables that can be added to Eq. (6).[20] Consequently, we implement a "restricted" GMM procedure (Judson and Owen, 1999),[21] i.e. we use only a limited number of lagged regressors as instruments and moreover, as it has already mentioned, we add just one bank-specific variable at a time reducing the need of additional instruments. The number of instruments is determined so as their total number does not exceed the number of cross sections. Thus, we extend the baseline model in Eq. (6) in order to account for the additional microeconomic variable:

$$\Delta NPL_{it}^{h} = a\Delta NPL_{it-1}^{h} + \sum_{j=1}^{2}\beta_{1j}^{h}\Delta GDP_{t-j} + \sum_{j=1}^{2}\beta_{2j}^{h}\Delta UN_{t-j} + \sum_{j=1}^{2}\beta_{3j}^{h}\Delta RLR_{it-j}^{h} + \sum_{j=1}^{4}\beta_{4j}^{h}X_{it-j}^{h} + \eta_i^h + \varepsilon_{it}^{h}, \tag{8}$$

where X_{it}^{h} denotes the bank-specific variables of Table 1. Following Berger and DeYoung (1997), we use four lags for the bank-specific regressors in order to capture the dynamics of explanatory variables over the previous year.[22] Here, we assume that the current level of the bank specific variables does not affect the current level of NPL ratios. This can be explained by the nature of accounting data and the time delay between changes in management's decisions (e.g. devoting more resources in monitoring loans) and changes in banks' balance-sheet data.

Moreover, since we are interested in the cumulative impact of each explanatory variable on the current NPL ratio, we also calculate the respective long-run coefficients, defined as:

$$\beta_4^{LR} = \sum_{j=1}^{4}\beta_{4j} \Big/ (1-a). \tag{9}$$

As in Stuart and Ord (1998, p. 351), we calculate the variance of the long-run coefficients as follows[23]:

[18] Although the two-step estimator is asymptotically more efficient than the one-step estimator and relaxes the assumption of homoscedasticity, the efficiency gains are not that important even in the case of heteroscedastic errors (e.g. see Arellano and Bond (1991), Blundell and Bond (1998) and Blundell et al. (2000)). This result is further supported by the empirical findings of Judson and Owen (1999), who perform Monte Carlo experiments for a variety of cross sectional and time series dimensions and show that the one-step estimator outperforms the two-step estimator.

[19] For the TBTF hypothesis see the econometric specification in Eq. (11).

[20] Specifically, when the number of instruments is greater or equal to the number of cross sectional units, then both the standard errors and the Sargan test are downwards biased and as a consequence the asymptotic inference may be misleading.

[21] Judson and Owen (1999) show that the use of the restricted procedure does not essentially worsen the performance of the GMM estimation.

[22] In the case of "size" we utilize only its contemporaneous value. We also examine the inclusion of additional lags; however, the results show that adding lags has no explanatory power. This may be attributed to the fact that size is a more permanent feature of the Greek banking system compared with the other bank specific variables used in this study (see also Salas and Saurina, 2002).

[23] The superscript h is dropped to ease notation.

$$Var(\beta_4^{LR}) = \frac{\left(\sum_{j=1}^4 \beta_{4j}\right)^2}{(1-a)^2}\left[\frac{Var\left(\sum_{j=1}^4 \beta_{4j}\right)}{\left(\sum_{j=1}^4 \beta_{4j}\right)^2} - 2\frac{Cov\left(\left(\sum_{j=1}^4 \beta_{4j}\right), (1-a)\right)}{\left(\sum_{j=1}^4 \beta_{4j}\right)(1-a)} + \frac{Var(a)}{(1-a)^2}\right], \quad (10)$$

where $Var\left(\sum_{j=1}^4 \beta_{4j}\right) = \sum_{j=1}^4 Var(\beta_{4j}) + 2\sum_{j\neq l} Cov(\beta_{4j}, \beta_{4l})$.

It should be noted that the estimation of the long-run coefficient variance in Eq. (9) accounts for the covariance between the estimated parameters, β_{4j}, providing accurate and robust statistical inference for the total effect of the lagged variables. It is also evident that any multicollinearity between the lags of the regressors, resulting in misleading statistical (in)significance of the individual lags, is taken into account when we consider the long-run standard errors (see also Berger and DeYoung, 1997, p. 856). Therefore, we test the hypotheses of Section 3.3 on the basis of the long-run coefficients, i.e.:

- $H_0: \ \beta_4^{LR} = 0$,
- $H_1: \ \beta_4^{LR} > or < 0$, depending on the hypothesis tested.

In the TBTF hypothesis, the size effect conditions the impact of leverage on NPLs, implying that we have to utilize interaction terms between the size and the leverage. Therefore, the corresponding econometric specification is given by:

$$\Delta NPL_{it}^h = a\Delta NPL_{it-1}^h + \sum_{j=1}^2 \beta_{1j}^h \Delta GDP_{t-j} + \sum_{j=1}^2 \beta_{2j}^h \Delta UN_{t-j} + \sum_{j=1}^2 \beta_{3j}^h \Delta RLR_{it-j}^h + \beta_4^h SIZE_{it} + \sum_{j=1}^4 \beta_{5j}^h LR_{it-j}^h + \sum_{j=1}^4 \beta_{6j}^h SIZE_{it} \times LR_{it-j}^h + \eta_i^h + \varepsilon_{it}^h. \quad (11)$$

Taking the derivative with respect to the leverage ratio (LR) in Eq. (11), we assess its effect given a range of different values of banks' relative size. Accordingly, we compute the long-run marginal effect of leverage on NPLs conditional on the banks' size as follows:

$$\beta_5^{LR} + \beta_6^{LR} SIZE = \sum_{j=1}^n \beta_{5j} \Big/ (1-a) + \left[\sum_{j=1}^n \beta_{6j} \Big/ (1-a)\right] \times SIZE. \quad (12)$$

The corresponding variance is based on Eq. (10) and is given in the Appendix. Brambor et al. (2006) and Shehzad et al. (2010) point out that the statistical inference of the multiplicative terms should not be based on simple parameters t-statistics. Hence, we test the TBTF hypothesis based on the statistical significance of the long-run marginal effect of the leverage ratio on NPLs i.e.:

- $H_0: \ \beta_5^{LR} + \beta_6^{LR} SIZE = 0$.
- $H_1: \ \beta_5^{LR} + \beta_6^{LR} SIZE > 0$.

In order to determine whether the null hypothesis is rejected, we construct confidence intervals using the standard errors derived from Eq. (A1) in the Appendix (Shehzad et al., 2010; Aiken and West, 1991).

In all four specifications (i.e. Eqs. (6)–(8), (and) (11)) we assume that macroeconomic variables are strictly exogenous. On the other hand, for the bank specific variables, the assumption of strict exogeneity is too strong. Instead, bank specific variables can be considered as forward-looking. This implies that banks' management takes into account the expected future level of NPLs, when taking decisions. However, they do not take into account future random shocks to NPLs (as they are unpredictable). Therefore, we assume a weak form of exogeneity for bank specific variables. This means that there is an endogeneity (correlation) issue concerning the current and past realizations of the error term,[24] but there is no correlation with future shocks in NPLs (Bobba and Coviello, 2007). Accordingly, we use as instruments for the macroeconomic and microeconomic variables those described in conditions (4) and (5) respectively.

Table 2
Descriptive statistics for the NPL ratios (%) per type of loan.

	Mortgages	Business	Consumer
Mean	5.291	8.011	8.381
Median	4.880	8.467	8.159
Maximum	9.246	10.075	14.576
Minimum	4.092	5.321	6.316
St. dev	1.346	1.537	1.876
Skewness	1.653	−0.470	1.849
Kurtosis	4.992	1.846	6.538
JB test	16.756	2.495	29.463
p-Values	[0.000]	[0.287]	[0.000]

Notes: *JB* denotes the Jarque–Bera normality test. The *p*-values of the *JB* test are shown in brackets.

5. Empirical analysis

5.1. The data set

The data set is a balanced panel consisting of supervisory data for the nine (9) largest Greek banks[25] spanning from 2003Q1 until 2009Q3. We conduct the analysis in a disaggregated manner by classifying the banks' total loan portfolio into three main categories i.e. mortgages, business and consumer loans. The composition of the total loan portfolio during the full sample period is relatively unchanged with the proportion of the business loans fluctuating between 58% and 68%, mortgages between 21% and 28% and consumer loans between 10% and 15%. Given these differences in the composition of the banks' loan portfolios, an aggregate approach (i.e. summing all types of NPLs) may be misleading. Thus, we examine separately each problem loan category so as to identify possible (dis)similarities in the determinants of each type of loan portfolio.[26]

Table 2 presents the descriptive statistics for each category of NPLs for all nine banks.[27] Mortgages loans have on average the lowest NPLs, while consumer loans have the highest with the average business NPLs being very close to the latter one. Consumer NPLs are the most volatile exhibiting the highest positive skewness and excess kurtosis as well. The distribution of the mortgage NPLs is also skewed to the right and it is more fat-tailed than the Gaussian distribution. The sample statistics and the Jarque–Berra test (see Table 2) indicate that for both categories of NPLs the normality assumption is rejected. However, the guassianity assumption cannot be rejected for the business NPLs.[28] These findings suggest that consumer and mortgage NPLs are more likely to attain higher positive values than

[24] In other words, the NPLs can reversely cause the microeconomic factors used in Eq. (8) (e.g. bank profitability) thus allowing for feedback effects from NPLs to microeconomic factors.

[25] At the end of September of 2009 the nine largest banks accounted for the 87.68% of the Greek banking system (quoted and non-quoted commercial banks). During the full sample period (2003–2009) the average value of this share was 90.86% (source: Bank of Greece).

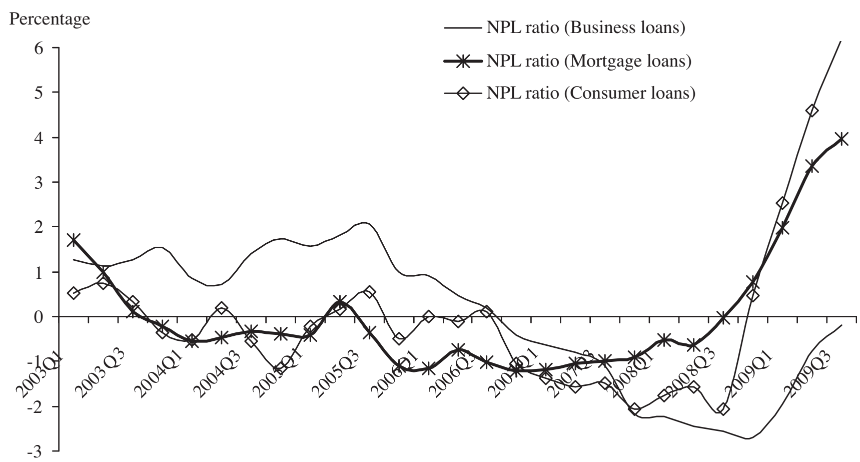
[26] The NPL dataset is proprietary and it comes from the supervisory database of the Bank of Greece.

[27] We compute the descriptive statistics using the aggregate NPL ratios per type of loan. This means that for each time period, we compute the NPL ratio by summing the NPLs and the loans of the nine banks of the sample. Then we calculate the descriptive statistics using the twenty-seven (27) time series points (2003Q1–2009Q3).

[28] Evidence in favor of the normality assumption for the business NPL ratio is also given by the Lilliefors and Anderson–Darling normality tests at a 5% significance level.

the business NPLs, underlying once again the differences among the three NPL categories and the importance of adopting a disaggregated approach in our analysis.

Fig. 2 depicts NPL ratios for all loan types. A common feature for all three NPL categories is that they exhibit a downward trend from 2003 onwards, which is abruptly reversed after the outbreak of the financial crisis (the trend reversal is evident in the last two quarters of 2008). Moreover, business NPLs are noticeably lower compared to the consumer and mortgage NPLs during the crisis period, while this does not hold for the pre-crisis period.



Source: Bank of Greece

Fig. 2. Total NPL ratio of loan portfolios (demeaned series).

Table 3
GMM estimation results for the models with macroeconomic variables.

	Baseline model			Model 1		
	Mortgages	Business	Consumer	Mortgages	Business	Consumer
Panel A: Individual lag coefficients estimation						
Constant	0.031**	−0.037**	0.034***	0.037***	−0.032	0.045***
	(2.342)	(−1.983)	(3.232)	(3.030)	(−1.520)	(−3.260)
ΔNPL^h_{it-1}	−0.003	−0.102**	−0.175***	−0.006	−0.090*	−0.162***
	(−0.068)	(−2.081)	(−3.103)	(−0.132)	(−1.790)	(−3.180)
ΔGDP_{t-1}	−0.238**	−0.280***	−0.15	−0.187**	−0.217***	−0.041
	(−2.48)	(−4.562)	(−1.433)	(−2.160)	(−2.840)	(−0.321)
ΔGDP_{t-2}	−0.041	−0.436***	−0.398***	−0.009	−0.393**	−0.325***
	(−0.670)	(−2.685)	(−3.204)	(−0.145)	(−2.560)	(−3.280)
ΔUN_{t-1}	0.135*	0.156**	0.160**	0.128*	0.155*	0.146
	(1.723)	(2.036)	(1.893)	(1.690)	(2.000)	(1.080)
ΔUN_{t-2}	−0.000	0.107	0.053	0.025	0.135	0.112
	(−0.006)	1.084	(0.525)	(0.432)	1.410	(1.020)
ΔRLR^h_{it-1}	0.096	0.175*	0.438***	0.087	0.154*	0.393***
	(1.582)	(1.803)	(4.438)	(1.370)	(1.689)	(3.950)
ΔRLR^h_{it-2}	0.070	0.043	0.081	0.087	0.044	0.112
	(0.918)	0.505	(1.081)	(1.190)	0.524	(1.510)
$\Delta DEPT^h_{it-4}$				4.122**	5.137**	9.870**
				(2.120)	(1.980)	(1.930)
Panel B: Long-run coefficients estimation						
ΔGDP	−0.278**	−0.650***	−0.466***	−0.195**	−0.559***	−0.315**
	(−2.501)	(−3.534)	(−2.850)	(−1.973)	(−3.153)	(−2.138)
ΔUN	0.134***	0.239**	0.181*	0.152***	0.265***	0.221*
	(3.065)	(2.208)	(1.893)	(3.737)	(2.400)	(1.662)
ΔRLR^h	0.166**	0.199**	0.442**	0.172**	0.181*	0.435***
	(2.031)	(1.972)	(6.331)	(2.112)	(1.710)	(5.787)
Sargan test	119	181.7	137.1	119.8	181.1	141.0
	[0.820]	[0.388]	[0.363]	[0.981]	[0.785]	[0.728]
m_2	−1.795	−0.462	−1.027	−1.844	−0.697	−1.099
	[0.073]	[0.644]	[0.304]	[0.065]	[0.486]	[0.0272]

Notes: *t*-statistics are reported in parenthesis. The *p*-values for the Sargan and the m_2 test are reported in brackets.
*** Denote significance at 1% respectively.
** Denote significance at 5% respectively.
* Denote significance at 10% respectively.

Table 4
GMM estimation results for mortgage loans NPLs (models with bank specific variables).

	Model 2		Model 3		Model 4		Model 5
Panel A: Individual lag coefficients estimation							
Constant	0.036^{**}		0.032^{**}		0.031^{**}		0.032^{**}
	(2.301)		(2.387)		(2.281)		(2.345)
ΔNPL^h_{it-1}	−0.011		−0.019		−0.013		0.013
	(−0.220)		(−0.392)		(−0.277)		(0.225)
ΔGDP_{t-1}	-0.193^{*}		-0.219^{**}		-0.230^{**}		-0.217^{**}
	(−1.760)		(−2.060)		(−2.412)		(−2.120)
ΔGDP_{t-2}	−0.014		−0.027		−0.054		−0.052
	(−0.199)		(−0.346)		(−0.874)		(−0.766)
ΔUN_{t-1}	0.127		0.124		0.131^{*}		0.073
	(1.457)		(1.545)		(1.753)		(1.065)
ΔUN_{t-2}	−0.031		0.011		0.004		−0.01
	(−0.444)		(0.175)		(0.0737)		(−0.170)
ΔRLR^h_{it-1}	0.074		0.069		0.106		0.064
	(1.178)		(1.08)		(1.507)		(1.015)
ΔRLR^h_{it-2}	0.086		0.05		0.074		0.058
	(1.276)		(0.596)		(0.988)		(1.174)
$INEF_{it-1}$	0.000	$SOLR_{it-1}$	-0.109^{**}	$SIZE_{it}$	0.005	NII_{it-1}	0.031
	(0.036)		(−2.04)		(0.056)		(1.135)
$INEF_{it-2}$	0.002	$SOLR_{it-2}$	−0.025			NII_{it-2}	−0.021
	(0.436)		(−0.397)				(−1.231)
$INEF_{it-3}$	0.001	$SOLR_{it-3}$	0.071			NII_{it-3}	-0.028^{***}
	(1.064)		(−1.60)				(−2.898)
$INEF_{it-4}$	0.005^{**}	$SOLR_{it-4}$	−0.029			NII_{it-4}	0.003
	(2.211)		(−0.557)				0.166
Panel B: Long-run coefficients estimation							
ΔGDP	−0.205		-0.242^{**}		-0.280^{**}		-0.273^{**}
	(−1.496)		(−1.968)		(−2.560)		(−2.360)
ΔUN	0.095^{*}		0.133^{**}		0.133^{***}		0.063
	(1.940)		(−2.421)		−3.304		(1.377)
ΔRLR^h	0.158^{*}		0.118		0.177^{**}		0.123^{*}
	(1.902)		1.313		(2.238)		(1.783)
INEF	0.009^{***}	*SOLR*	−0.092	*SIZE*	0.006	*NII*	−0.016
	(3.061)		(−0.994)		(0.057)		(−0.463)
Sargan test	134.5		128.4		132		132.8
	[0.829]		[0.909]		[0.900]		[0.855]
m_2	−2.006		−2.122		−1.976		−1.535
	[0.045]		[0.034]		[0.048]		[0.125]

	Model 6		Model 7		Model 8 [b]		Model 9 [b]		Model 10 [b]
Panel A: Individual lag coefficients estimation									
Constant	0.025^{*}		0.033^{**}		0.034^{**}		0.040^{*}		0.037^{*}
	(1.917)		(2.485)		(2.565)		(1.878)		(1.919)
ΔNPL^h_{it-1}	0.033		0		−0.039		−0.033		−0.008
	(0.804)		(0.006)		(−0.676)		(−0.644)		(−0.166)
ΔGDP_{t-1}	-0.222^{**}		-0.198^{*}		-0.247^{**}		-0.238^{**}		-0.224^{**}
	(−2.032)		(−1.748)		(−2.238)		(−2.372)		(−2.185)
ΔGDP_{t-2}	−0.024		−0.03		−0.056		−0.054		−0.063
	(−0.318)		(−0.452)		(−1.140)		(−1.006)		(−1.042)
ΔUN_{t-1}	0.147^{*}		0.135		0.156^{*}		0.141		0.133
	(1.903)		(1.618		(1.704)		(1.432)		(1.365)
ΔUN_{t-2}	0.006		−0.036		−0.055		−0.06		−0.059
	(0.088)		(−0.522)		(−0.876)		(−0.959)		(−0.899)
ΔRLR^h_{it-1}	0.064		0.086		0.078		0.087		0.087
	(0.987)		(1.412)		(1.37)		(1.438)		(1.422)
ΔRLR^h_{it-2}	0.024		0.092		0.059		0.071		0.084
	(0.307)		(1.201)		(0.824)		(0.945)		(1.091)
$SIZE_{it}$	0.627^{**}	ROE_{it-1}	0.005	OC^1_{it}	−0.136	OC^2_{it}	−0.74	OC^3_{it}	−0.596
	(2.395)		(1.282)		(−0.303)		(−0.893)		(−0.895)
LR_{it-1}	$0.181^{***} - 0.004SIZE_{it}$	ROE_{it-2}	-0.009^{**}						
	(2.917) (−1.150)		(−2.103)						
LR_{it-2}	$0.016 - 0.003SIZE_{it}$	ROE_{it-3}	0						
	(0.183) (−0.640)		(−0.024)						
LR_{it-3}	$-0.118^{**} + 0.005^{*}SIZE_{it}$	ROE_{it-4}	-0.008^{**}						
	(−2.384) (1.796)		(−2.281)						
LR_{it-1}	$0.111^{*} - 0.006^{**}SIZE_{it}$								
	(1.795) (−2.150)								
Panel B: Long-run coefficients estimation									
ΔGDP	-0.255^{**}		-0.228^{*}		-0.293^{**}		-0.283^{**}		-0.285^{**}
	(−2.204)		(−1.640)		(−2.573)		(−2.655)		(−2.578)

(*continued on next page*)

Table 4 (*continued*)

	Model 6		Model 7		Model 8 [b]		Model 9 [b]		Model 10 [b]
ΔUN	0.159***		0.099**		0.097		0.078		0.073
	2.71		(2.496)		(1.523)		(1.092)		(0.949)
ΔRLR^h	0.091		0.178**		0.133*		0.154**		0.170**
	(1.086)		(2.049)		(1.872)		(2.073)		(2.204)
SIZE	0.648**	*ROE*	−0.012**	OC^1	−0.131	OC^2	−0.717	OC^3	−0.591
LR	(2.437)		(−2.491)		(−0.312)		(−0.906)		−0.909
	−0.197 + 0.007*SIZE* [a]								
Sargan test	165.7		135.8		109.1		111.8		119
	[1.000]		[0.807]		[0.908]		[0.874]		[0.746]
m_2	−2.012		−1.881		−2.011		−2.052		−2.064
	[0.044]		[0.060]		[0.044]		[0.040]		[0.039]

Notes: *t*-statistics are reported in parenthesis. The *p*-values for the Sargan and the m_2 test are reported in brackets.
[a] The 95% confidence interval of the leverage marginal effect is shown in Fig. 3.
[b] The ownership concentration data are available from 2005 q1 and onwards.
*** Denote significance at 1% respectively.
** Denote significance at 5% respectively.
* Denote significance at 10% respectively.

5.2. Dynamic panel data estimations

5.2.1. Models with macroeconomic variables

Panel A of Table 3 presents the individual lag one-step GMM coefficients estimations for the baseline models with macroeconomic variables and for all NPL categories, while Panel B presents the corresponding long-run coefficients estimations.[29,30] For each model, we also report the Sargan and the m_2 test results at the bottom of the table.

The coefficient of the lagged dependent variable (see Panel A, Table 3) is negative and statistically significant in the case of business and consumer NPLs. The implication is that NPLs are likely to decrease when they have increased in the previous quarter, due to the write-offs.[31] On the other hand, this coefficient is statistically insignificant for mortgages. Particularly for mortgages, macrofundamentals are the main drivers of the NPLs. In the rest of the paper, we concentrate on the long run coefficients in order to assess in a more transparent manner the differential impact of all explanatory variables (see also Section 4.2).

For all macroeconomic variables, the estimated long-run coefficients are statistically significant and have the expected sign, compatible with the theoretical arguments surveyed in Section 3. The NPL ratio is negatively affected by a slowdown in economic growth for all loan types. The overall effect of GDP growth rate is found to be stronger for business NPLs. This result points to a strong dependence of the business sector's ability to repay its loans on the phase of the cycle. Moreover, the small average size of Greek firms (Voulgaris et al., 2004) is probably another contributing factor to this effect, as they tend to be less diversified and thus more vulnerable to adverse macroeconomic shocks. Consumer and mortgage NPLs are also negatively related to the GDP growth rate. Nevertheless, the quantitative impact of GDP growth rate on mortgage NPLs is attenuated compared to the NPLs of the other two loan types.

Unemployment has a significant impact on all NPL categories with business NPLs being the most sensitive. Therefore, it seems that firms cut their labor cost before they face debt servicing problems. Additionally, unemployment is a leading indicator of consumer NPLs implying that a rise in unemployment affects households' ability to service their debts. Mortgages are again the least sensitive NPL type. This can be explained by the fact that in Greece mortgage loans are mostly extended to civil servants and high-skilled workers of the private sector, who are less likely to get unemployed (Mitrakos et al., 2005; Mitrakos and Simigiannis, 2009).

The coefficients for the real lending rates are positive as expected. Consumer NPLs are the most sensitive to changes in lending rates. It should be noted that the vast majority of both consumer and business loans are floating rate loans. On the contrary, there is a significant part of fixed rate mortgage loans which explains to an extent the relative insensitivity of mortgage NPLs. Moreover, consumer loans are not easily refinanced, as banks tend to resort to tighter credit policies with regard to consumer loans during recessions. In contrast, firms facing difficulties in servicing their debt are able to renegotiate a debt restructuring.

Overall, the most striking implication of the estimation results is that there are significant quantitative differences between the different NPL types as regards macroeconomic variables. Focusing on specific macrofundamentals, the real GDP growth has the strongest effect on business NPLs, as does unemployment. On the other hand, lending rates have a noticeable impact on consumer NPLs. Finally, the mortgage NPLs are the least responsive to the macroeconomic conditions.[32]

We also find strong evidence in favor of the 'sovereign debt hypothesis'. Specifically, the coefficients of the *Debt* variable are positive and statistically significant for all NPL types. The impact of public debt is more pronounced on consumer NPLs. We have also tested the 'sovereign debt hypothesis' using the sovereign bond spread as an additional explanatory variable and the results are qualitatively the same.[33]

5.2.2. Baseline model with bank specific variables

Tables 4–6 present the GMM estimation results for all NPL categories when bank-specific variables are included. Specifically,

[29] The Blundell–Bond system GMM estimator (Blundell and Bond 1998) has also been proposed in the literature. However, using the Sargan – difference test we reject its underlying assumptions.

[30] For all three baseline models, we check for the existence of multicollinearity. We find that all the variables in all models have VIF value (Greene, 2003, p. 57) less than 6, while most of them have VIF value of 2 or less. These results indicate that there is no multicollinearity (e.g. see Kutner et al., 2004, p. 409). The results of the VIF test are available upon request.

[31] Sorge and Virolainen (2006) report a negative coefficient for the lagged dependent variable in their estimated equation of loan loss provisions for the Finnish banking system. The economic interpretation for the negative coefficient in both cases is similar.

[32] Another possible explanation for this empirical regularity is that home ownership is highly valued in Greece, a feature that may be considered as a social specificity.

[33] The sovereign bond spread is defined as the difference in yields between the Greek and the German 10 year bond. These results are available from the authors upon request.

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Table 5
GMM estimation results for business loans NPLs (models with bank specific variables).

	Model 2		Model 3		Model 4		Model 5
Panel A: Individual lag coefficients estimation							
Constant	−0.036*		−0.038*		−0.040*		−0.037*
	(−1.873)		(−1.768)		(−1.893)		(−1.798)
ΔNPL^{h}_{it-1}	−0.106*		−0.084		−0.109**		−0.068
	(−1.877)		(−1.604)		(−2.162)		(−1.524)
ΔGDP_{t-1}	−0.249***		−0.254***		−0.282***		−0.259***
	(−3.968)		(−5.543)		(−4.628)		(−4.932)
ΔGDP_{t-2}	−0.405***		−0.446***		−0.438***		−0.443***
	(−2.432)		(−2.373)		(−2.714)		(−3.001)
ΔUN_{t-1}	0.119*		0.137*		0.157**		0.101
	(1.668)		(1.784)		(2.151)		(1.334)
ΔUN_{t-2}	0.083		0.093		0.103		0.126
	(0.809)		(1.313)		(1.067)		(1.302)
ΔRLR^{h}_{it-1}	0.145		0.157*		0.175*		0.162*
	(1.598)		(1.684)		(1.914)		(1.901)
ΔRLR^{h}_{it-2}	0.023		0.066		0.043		0.027
	(0.280)		(0.887)		(0.522)		−0.307
$INEF_{it-1}$	0.006***	$SOLR_{it-1}$	−0.012	$SIZE_{it}$	0.096	NII_{it-1}	0.025
	(2.758)		(−0.156)		1.432		(1.485)
$INEF_{it-2}$	−0.0008	$SOLR_{it-2}$	−0.119			NII_{it-2}	−0.040*
	(−0.335)		(−0.902)				(−1.845)
$INEF_{it-3}$	0.003	$SOLR_{it-3}$	0.214***			NII_{it-3}	0.002
	(0.974)		(2.741)				(0.157)
$INEF_{it-4}$	0.002	$SOLR_{it-4}$	−0.033			NII_{it-4}	0.005
	(0.787)		(−0.680)				(0.465)
Panel B: Long-run coefficients estimation							
ΔGDP	−0.592***		−0.646***		−0.649***		−0.657***
	(−3.359)		−3.294		(−3.457)		(−3.936)
ΔUN	0.183*		0.212**		0.235**		0.213**
	(1.809)		(2.306)		(2.319)		(2.223)
ΔRLR^{h}	0.152		0.206***		0.197**		0.177*
	(1.597)		(2.626)		(2.320)		(1.717)
INEF	0.010**	*SOLR*	0.045	*SIZE*	0.086	*NII*	−0.006
	(2.323)		(1.418)		(1.534)		(−0.193)
Sargan test	185.1		182.8		187.9		184.1
	[0.664]		[0.707]		[0.667]		[0.683]
m_2	−0.215		−0.331		−0.562		−0.786
	[0.829]		[0.741]		[0.574]		[0.432]

	Model 6		Model 7		Model 8[b]		Model 9[b]		Model 10[b]
Panel A: Individual lag coefficients estimation									
Constant	−0.043*		−0.042**		−0.045		−0.046*		−0.046*
	(−1.717)		(−2.033)		(−1.625)		(−1.648)		(−1.648)
ΔNPL^{h}_{it-1}	−0.096		−0.091**		−0.107		−0.108		−0.108
	(−1.574)		(−2.074)		(−1.335)		(−1.360)		(−1.360)
ΔGDP_{t-1}	−0.243***		−0.256***		−0.234***		−0.238***		−0.238***
	(−3.909)		(−4.332)		(−3.235)		(−3.253)		(−3.253)
ΔGDP_{t-2}	−0.434**		−0.428***		−0.462***		−0.456***		−0.456***
	(−2.372)		(−2.513)		(−2.845)		(−2.852)		(−2.852)
ΔUN_{t-1}	0.194**		0.121*		0.232		0.236		0.236
	(2.171)		(1.645)		(1.398)		(1.398)		(1.398)
ΔUN_{t-2}	0.094		0.075		0.015		0.017		0.017
	(1.264)		(0.791)		(0.123)		(0.135)		(0.1350
ΔRLR^{h}_{it-1}	0.134*		0.156*		0.181*		0.181*		0.181*
	(1.694)		(1.734)		(1.738)		(1.735)		(1.735)
ΔRLR^{h}_{it-2}	−0.002		0.045		0.062		0.063		0.063
	(−0.028)		(0.589)		(0.580)		(0.593)		(0.593)
$SIZE_{it}$	0.844**	ROE_{it-1}	−0.009***	OC^{1}_{it}	0.417	OC^{2}_{it}	0.477**	OC^{3}_{it}	0.477**
	(1.282)		(−3.724)		(1.585)		(2.051)		(2.051)
LR_{it-1}	−0.012 + 0.009** $SIZE_{it}$	ROE_{it-2}	0.006*						
	(−0.142) (2.425)		(1.688)						
LR_{it-2}	0.315 − 0.026*** $SIZE_{it}$	ROE_{it-3}	−0.011						
	(1.615) (−2.581)		(−1.483)						
LR_{it-3}	−0.340*** + 0.019*** $SIZE_{it}$	ROE_{it-4}	0.007						
	(−4.558) (4.013)		(1.232)						
LR_{it-1}	0.073 − 0.010** $SIZE_{it}$								
	(1.114) (−2.454)								
Panel B: Long-run coefficients estimation									
ΔGDP	−0.618***		−0.627***		−0.630***		−0.627***		−0.627***
	(−2.767)		(−3.582)		(−3.062)		(−3.083)		(−3.083)

(*continued on next page*)

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Table 5 (*continued*)

	Model 6		Model 7	Model 8[b]		Model 9[b]		Model 10[b]
ΔUN	0.263**		0.180*	0.223*		0.228*		0.228*
	2.285		(1.751)	(1.890)		(1.925)		(1.925)
ΔRLR^h	0.120		0.185**	0.220**		0.220**		0.220**
	(1.456)		(2.112)	(2.528)		(2.532)		(2.532)
SIZE	0.769	*ROE*	−0.006	0.377*	OC^2	0.431**	OC^3	0.431**
	(1.347)		(−0.801)	(1.743)		(2.292)		(2.292)
LR	$0.032 - 0.006SIZE$[a]							
Sargan test	184.7		184.9	158.2		158.3		158.3
	[1.000]		[0.669]	[0.695]		[0.693]		[0.693]
	−0.7985		0.2336	0.089		0.1478		0.147
m_2	[0.425]		[0.815]	[0.929]		[0.882]		[0.882]

Notes: *t*-statistics are reported in parenthesis. The *p*-values for the Sargan and the m_2 test are reported in brackets.
[a] The 95% confidence interval of the leverage marginal effect is shown in Fig. 4.
[b] The ownership concentration data are available from 2005 q1 and onwards.
*** Denote significance at 1% respectively.
** Denote significance at 5% respectively.
* Denote significance at 10% respectively.

Table 6
GMM estimation results for consumer loans NPLs (models with bank specific variables).

	Model 2		Model 3		Model 4		Model 5
Panel A: Individual lag coefficients estimation							
Constant	0.037***		0.030***		0.033*		0.034***
	2.784		(2.948)		(2.043)		(3.085)
ΔNPL^h_{it-1}	−0.187***		−0.198***		−0.185***		−0.169***
	(−3.265)		(−3.489)		(−3.735)		(−3.701)
ΔGDP_{t-1}	−0.152**		−0.203**		−0.186**		−0.148**
	(−2.327)		(−2.224)		(−2.414)		(−2.478)
ΔGDP_{t-2}	−0.393***		−0.436***		−0.433***		−0.397***
	(−3.179)		(−3.835)		(−3.360)		(−3.334)
ΔUN_{t-1}	0.152		0.176		0.186		0.139
	(0.957)		(1.216)		(1.401)		(0.899)
ΔUN_{t-2}	−0.005		0.057		0.052		0.033
	(−0.062)		(0.580)		(0.563)		(0.304)
ΔRLR^h_{it-1}	0.376***		0.400***		0.395***		0.388***
	(3.724)		(5.114)		(4.764)		(5.346)
ΔRLR^h_{it-2}	0.019		0.019		0.042		0.077
	(0.406)		(0.226)		(0.556)		(0.939)
$INEF_{it-1}$	0.003	$SOLR_{it-1}$	−0.087	$SIZE_{it}$	−0.167	NII_{it-1}	−0.014
	0.827		(−1.150)		(−1.312)		(−0.776)
$INEF_{it-2}$	0.004	$SOLR_{it-2}$	−0.058			NII_{it-2}	−0.006
	(0.952)		(−0.949)				(−0.364)
$INEF_{it-3}$	0.0007	$SOLR_{it-3}$	0.157			NII_{it-3}	−0.048
	(0.155)		(1.264)				(−1.375)
$INEF_{it-4}$	0.006*	$SOLR_{it-4}$	−0.056			NII_{it-4}	0.002
	(1.844)		(−0.425)				(0.073)
Panel B: Long-run coefficients estimation							
ΔGDP	−0.460***		−0.533***		−0.523***		−0.466***
	(−3.778)		(−4.455)		(−3.551)		(−3.558)
ΔUN	0.123*		0.195*		0.202*		0.148*
	(1.735)		(1.713)		(1.675)		(1.885)
ΔRLR^h	0.333***		0.350***		0.369***		0.398***
	(4.444)		(5.675)		(6.056)		(6.473)
INEF	0.012*	*SOLR*	−0.037	*SIZE*	−0.141	*NII*	−0.057
	(1.770)		(−0.375)		(−1.571)		(−1.430)
Sargan test	156.0		156.5		159.1		147.8
	[0.330]		[0.321]		[0.330]		[0.512]
m_2	−0.860		−1.641		−1.255		−1.164
	[0.390]		[0.101]		[0.210]		[0.245]

	Model 6	Model 7	Model 8[b]	Model 9[b]	Model 10[b]
Panel A: Individual lag coefficients estimation					
Constant	0.020**	0.033***	0.030**	0.017	0.017
	(2.901)	(2.624)	(2.506)	(0.913)	(0.933)
ΔNPL^h_{it-1}	−0.143**	−0.185***	−0.219***	−0.210***	−0.202***
	(−2.458)	(−3.209)	(−4.904)	(−4.255)	(−4.275)
ΔGDP_{t-1}	−0.177**	−0.132*	−0.184**	−0.191**	−0.195**
	(−2.263)	(−1.905)	(−2.051)	(−2.036)	(−2.073)

Table 6 (*continued*)

	Model 6		Model 7		Model 8[b]		Model 9[b]		Model 10[b]
ΔGDP_{t-2}	−0.469		−0.365***		−0.399***		−0.389***		−0.403***
	(−4.225)		(−2.928)		(−3.766)		(−3.985)		(−4.157)
ΔUN_{t-1}	0.206		0.141		0.2		0.209*		0.217*
	(1.411)		(0.956)		(1.595)		(1.656)		(1.644)
ΔUN_{t-2}	0.035		−0.005		0.116		0.121		0.118
	(0.331)		(−0.066)		(0.965)		(0.959)		(0.947)
ΔRLR^h_{it-1}	0.385***		0.416***		0.428***		0.456***		0.435***
	(4.884)		(4.314)		(5.154)		(5.258)		(5.268)
ΔRLR^h_{it-2}	−0.029		0.072		0.066		0.052		0.034
	(−0.344)		−1.597		(0.863)		−0.604		−0.385
$SIZE_{it}$	0.936**	ROE_{it-1}	−0.002	OC^1	0.137	OC^2	1.547**	OC^3	1.352**
	(2.082)		(−0.439)		(0.228)		(2.025)		(2.579)
LR_{it-1}	$0.054 + 0.002SIZE_{it}$	ROE_{it-2}	−0.011						
	(0.625) (0.671)		(−1.615)						
LR_{it-2}	$0.197^{***} - 0.018^{***}SIZE_{it}$	ROE_{it-3}	0.001						
	(3.682) (−4.541)		(0.149)						
LR_{it-3}	$-0.350^{**} + 0.025^{***}SIZE_{it}$	ROE_{it-4}	−0.011						
	(−2.915) (2.571)		(−1.448)						
LR_{it-1}	$0.298^{**} - 0.019^{**}SIZE_{it}$								
	(2.364) (−2.404)								
Panel B: Long-run coefficients estimation									
ΔGDP	−0.566***		−0.419***		−0.479***		−0.480***		−0.498***
	(−4.496)		(−3.065)		(−3.805)		(−3.574)		(−3.761)
ΔUN	0.211*		0.114*		0.260*		0.273*		0.279*
	(1.727)		(1.729)		(1.952)		(1.921)		(1.819)
ΔRLR^h	0.311***		0.412***		0.405***		0.420***		0.390***
	(4.391)		(5.383)		(5.718)		(5.884)		(5.773)
$SIZE$	0.818**	ROE	−0.020***	OC^1	0.112	OC^2	1.278**	OC^3	1.124***
	(2.414)		(−3.759)		(0.280)		(2.592)		(3.227)
LR	$0.176 - 0.008SIZE$								
Sargan test	186.5		151.2		135.8		126.4		144.3
	[0.999]		[0.435]		[0.301]		[0.523]		[0.153]
	−0.515		−0.448		−0.135		−0.32		−0.216
m_2	[0.606]		[0.654]		[0.892]		[0.748]		[0.829]

Notes: *t*-statistics are reported in parenthesis. The *p*-values for the Sargan and the m_2 test are reported in brackets.
[a] The 95% confidence interval of the leverage marginal effect is shown in Fig. 5.
[b] The ownership concentration data are available from 2005 q1 and onwards.
*** Denote significance at 1% respectively.
** Denote significance at 5% respectively.
* Denote significance at 10% respectively.

Panels A and B of the aforementioned tables present the individual lag and the long-run coefficients estimates respectively. As in the baseline models, we concentrate on the long-run coefficients in order to determine which of the hypotheses presented in Section 3.3 find support in the Greek banking system. Therefore, the empirical evidence presented in Table 7, regarding the tested hypotheses, is based on the sign and the statistical significance of the long-run coefficients (Berger and DeYoung, 1997).

A general remark is that the incorporation of bank-specific variables in the baseline model does not affect the differential quantitative impact of the macrofundamentals on the different NPL categories. Specifically, for all NPL categories, the estimation results indicate that the coefficients of the macro-variables are fairly stable across different models with different bank-specific variables and very close to the estimations of the baseline model.

The coefficient of the inefficiency index is positive and statistically significant for all NPL categories, thus, lending support to the 'bad management' hypothesis. Moreover, its impact is quantitatively similar for all types of NPLs. It should be noted that our empirical evidence, providing support for the 'bad management' hypothesis, is consistent with the findings of Berger and DeYoung (1997) and Podpiera and Weill (2008).

On the other hand, banks' risk attitude, as proxied by the solvency ratio, does not have explanatory power for all NPL types. Thus, the 'moral hazard' hypothesis does not find support for the Greek banking system. A possible explanation is that the small sized market for bank managers in Greece creates disincentives for reckless risk-taking and short-termism for reputation reasons. In addition, due to the small number of banks, regulatory authorities tend to have an accurate on-site overview of the riskiness of each bank's loan portfolio and thus they can intervene accordingly. As a result, the potential of bank managers causing high levels of NPLs due to moral hazard incentives is minimized.

Furthermore, the diversification hypothesis is clearly rejected. When the size variable is used as a proxy for diversification, neither do the corresponding coefficients (for mortgages and business loans) have the expected sign, nor are they statistically significant (for all types of loans). It can be argued that size may not fully capture diversification (see also Section 3) or that there may be countertendencies to the degree of risk-taking from increasing size e.g. large banks may engage in activities that are inherently more risky compared to the activities of smaller banks. Nonetheless, our results do not change even when the non-interest income ratio is used as a proxy for diversification. Specifically, the sign of the non-interest income coefficient is negative for all three types of NPLs, as expected, however the coefficients are not statistically significant. These results can be attributed to the potential "dark sides" of diversification, as noted by Stiroh (2004b), namely that as managers enter a business where they are not experienced, or the bank does not have any comparative advantage, bank's risk increases.

Our empirical results are in favor of the TBTF effect on risk-taking. Specifically, within the actual range of size values, i.e. for a bank size up to ≈30% of the total banking system, leverage has a

Table 7
Empirical evidence for tested hypotheses.

Hypothesis tested	Mortgages	Business	Consumer
1. Sovereign debt	**Yes**	**Yes**	**Yes**
2. Bad management	**Yes**	**Yes**	**Yes**
3. Skimping	No	No	No
4. Moral hazard	No	No	No
5. Diversification	No	No	No
6. Too-big-to-fail	**Yes** (up to a size threshold)	**Yes** (up to a size threshold)	No
7. Bad management II	**Yes**	No	**Yes**
8. Procyclical credit policy	No	No	No
9. Tight control	No	No	No

Notes: The empirical evidence is based on the sign and the statistical significance of the long run coefficients. In the case of the too-big-to-fail hypothesis the empirical evidence is based on the long-run impact of leverage conditional on bank's size.

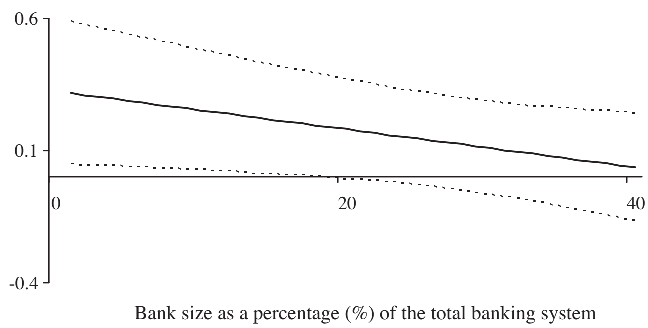

Fig. 3. Marginal effect of leverage on mortgages NPLs.

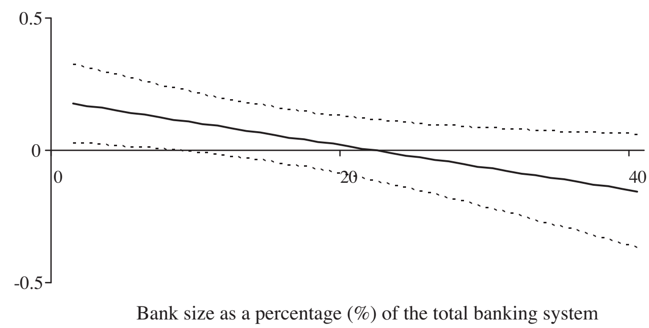

Fig. 5. Marginal effect of leverage on consumer NPLs.

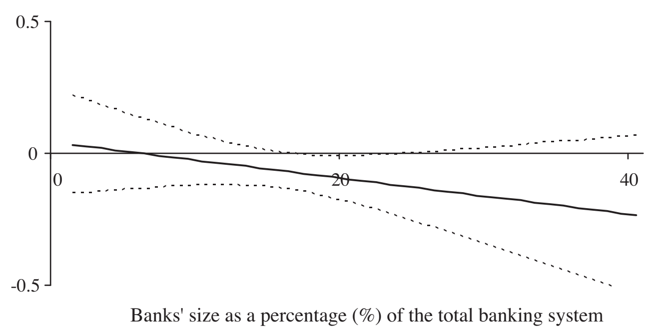

Fig. 4. Marginal effect of leverage on business NPLs.

positive and statistically significant effect on mortgage and business NPLs up to a certain size threshold (20% and 5% for the mortgages and consumer NPLs respectively, see Figs. 3 and 5 respectively). These results hint at a TBTF effect up to a size level indicating that leverage tends to increase NPLs, but this effect occurs only up to a certain size threshold. After that threshold, leverage conditional on size does not have any statistically significant effect on NPLs, implying that among the largest banks there is no differential TBTF effect on NPLs. On the other hand, for the business loans portfolio, a TBTF effect on the quality of loans cannot be inferred (see Fig. 4).

The ROE indicator is statistically significant and negatively related to the mortgages and consumer NPLs while it is insignificant for the business NPLs. The findings for mortgages and consumer NPLs provide evidence in favor of the 'bad management II' hypothesis. This may signify that the effect of management quality is mainly reflected on the efficiency of households' credit granting procedures, which are primarily based on the development of quantitative modeling techniques, while the quality of case-by-case assignment procedures, which characterize business loans granting, does not differ substantially among banks. Empirical support for the 'bad management II' hypothesis is also consistent with the aforementioned finding that lagged cost inefficiency is positively related to the problem loans through the 'bad management' hypothesis. Hence, both the performance and the inefficiency indicators may serve as proxies for the quality of management and both have explanatory power over the NPLs. Furthermore, the 'procyclical credit policy' hypothesis is rejected, as it implies a positive relation between past performance and current NPLs.

Finally, when the ownership concentration dummies are added as explanatory variables we obtain the surprising result that increasing concentration, i.e. greater than 25% and 50%, is positively associated with business and consumer NPLs. This is in contrast with the predictions of the 'tight control' hypothesis. The explanation for this result lies in the particularities of the Greek banking sector and specifically in two main factors. First, a number of previously state-controlled banks focusing on specific market segments, e.g. agriculture and commerce, had, historically, high levels of NPLs. Despite the fact that some of these banks are no longer state-owned, they are still characterized by highly concentrated ownership while also retaining relatively high levels of NPLs. Second, there are relatively recent entrants in the banking sector with a high degree of ownership concentration which had embarked in the past on aggressive lending as a strategic choice in order to gain market share.

6. Concluding remarks and discussion

In this study we use dynamic panel data methods to examine the determinants of NPLs in the Greek banking sector. We find that macroeconomic variables, specifically the real GDP growth rate, the unemployment rate, the lending rates and public debt have a strong effect on the level of NPLs. Moreover, bank-specific variables such as performance and efficiency possess additional explanatory power when added into the baseline model thus lending support to

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the ‘bad management’ hypothesis linking these indicators to the quality of management. Furthermore, evidence for the existence of a TBTF effect is found for mortgage and business loans up to a size level. In addition, the empirical results indicate that the quantitative effects of the various NPLs’ determinants depend on the category of loans. Particularly, consumer loans are the most sensitive to changes in the lending rates and business loans to the real GDP growth rate, while mortgages are the least affected by macroeconomic developments.

Our findings have several implications in terms of regulation and policy. Specifically, there is evidence that performance and inefficiency measures may serve as leading indicators for future problem loans. This suggests that regulatory authorities should focus on managerial performance in order to detect banks with potential NPLs increases. Moreover, regulators should place emphasis on risk management systems and procedures followed by banks in order to avert future financial instability.

In addition, the aforementioned relations can be used for forecasting and stress testing purposes for both regulators and banks (Melecky and Podpiera, 2010). In a macro-stress testing exercise, alternative scenarios for the evolution of the macro-variables can be used in order to evaluate the adequacy of loan loss provisions in the banking system. On the other hand, similar exercises could be performed on a bank specific level in order to assess future problems that may ensue in particular banks characterized by relatively low indices of performance and efficiency. Given that the analysis has been conducted in a disaggregated basis, stress testing exercises may focus on different types of loan portfolios enhancing the reliability of the results.

The study can be extended in various ways. In the first place, a “vintage” loan analysis may be used to pinpoint any differences in the quality of loans granted during the cycle. Such a type of analysis would be directly linked to the hypothesis of a change in the risk attitude of banks between the phases of the cycle. Moreover, further investigation of the crisis effects would be worthy of study. It may be conjectured that the financial crisis represents a structural break affecting the interrelations between non-performing loans and their determinant factors.

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Appendix A. Variance of the long-run marginal effect of leverage on NPLs

The corresponding variance of Eq. (12) is given by:

$$\begin{aligned} Var\left(\beta_5^{LR} + \beta_{6j}^{LR} SIZE\right) &= \frac{\left(\sum_{j=1}^n \beta_{5j} + \sum_{j=1}^n \beta_{6j} SIZE\right)^2}{(1-a)^2} \times \left[\frac{Var\left(\sum_{j=1}^n \beta_{5j} + \sum_{j=1}^n \beta_{6j} SIZE\right)}{\left(\sum_{j=1}^n \beta_{5j} + \sum_{j=1}^n \beta_{6j} SIZE\right)^2} \right. \\ &\left. -2 \frac{Cov\left(\left(\sum_{j=1}^n \beta_{5j} + \sum_{j=1}^n \beta_{6j} SIZE\right), (1-a)\right)}{\left(\sum_{j=1}^n \beta_{5j} + \sum_{j=1}^n \beta_{6j} SIZE\right)(1-a)} + \frac{Var(a)}{(1-a)^2} \right], \end{aligned} \tag{A1}$$

where $n = 4$ and

$$\begin{aligned} Var\left(\sum_{j=1}^n \beta_{5j} + \sum_{j=1}^n \beta_{6j} SIZE\right) &= \sum_{j=1}^n Var(\beta_{5j}) + SIZE^2 \sum_{j=1}^n Var(\beta_{6j}) \\ &+ 2 \sum_{j=1}^n \sum_{\substack{i=1 \\ i \neq j}}^n Cov(\beta_{5j}, \beta_{5i}) \\ &+ 2SIZE \sum_{j=1}^n \sum_{i=1}^n Cov(\beta_{5j}, \beta_{6j}) \\ &+ 2SIZE^2 \sum_{j=1}^n \sum_{\substack{i=1 \\ i \neq j}}^n Cov(\beta_{6j}, \beta_{6i}). \end{aligned}$$

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