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Macroeconomic and macro-financial factors as leading indicators of non-performing loans

Evidence from the EU countries

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Abstract

Purpose – Large or increasing stocks of non-performing loans in the banking sector constitute threats to financial stability. This paper considers to which extent various macroeconomic and macro-financial factors may serve as leading indicators for the dynamics of the ratio of non-performing loans to total loans.
Design/methodology/approach – The paper estimates panel data models for all EU countries and two groups of EU countries using quarterly data over approximately 20 years.
Findings – The estimations show that many macroeconomic and macro-financial variables are leading indicators for non-performing loans in the EU countries, even years ahead. Higher GDP growth, lower inflation and lower debt are robust leading indicators of a lower ratio of non-performing loans in the future. The current account balance and real house prices are important indicators for the Western European group but not for the Central and Eastern European group.
Research limitations/implications – The estimations are carried out for panels of EU countries and the effects may hence be seen as averages for the countries in the particular panel and may not apply for individual countries.
Practical implications – National and international authorities have brought in systems to detect and address imbalances and emerging problems in the financial sectors. Many of the measures operate with long lags, and so it is important to assess whether various macroeconomic and macro-financial variables may serve as leading indicators for future developments of non-performing loans.
Originality/value – The main contribution of the paper is that it estimates models meant expressly for predicting non-performing loans several years ahead. The results are thus of practical use for national and international authorities which typically have access to measures that operate with a long delay. The analysis also includes more macroeconomic and macro-financial variables as leading indicators than have typically been used in earlier studies.

Keywords Macroeconomic factors, Leading indicators, Financial stability, Non-performing loans
Paper type Research paper

1. Introduction

High or increasing ratios of non-performing loans in the banking sector threaten financial stability, impede the intermediation of funds from savers to borrowers, and may reduce investment and long-term growth. The potentially severe consequences of an accumulation of

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non-performing loans for the whole economy raise the question of how well future developments can be accounted for, and in particular whether macroeconomic and macro-financial variables can be used as leading indicators of future developments in non-performing loans. This question is clearly of importance both in academic terms and for policy-making.

To guard against problems in the banking sector, national and international authorities monitor developments in the stock of non-performing loans, but they must also development an understanding of the factors that help predict or warn of future developments in non-performing loans. This paper estimates panel data models to assess to which extent various macroeconomic and macro-financial factors may function as leading indicators for the future dynamics of the ratio of non-performing loans. We use a large set of macroeconomic and macro-financial variables, including variables that reflect developments in the real economy, credit, the housing market and the external balance. We consider possible differences between the EU countries from Western Europe and those from Central and Eastern Europe. The length of the prediction horizon is of key importance for policy making and therefore considered in some detail.

Banking distress and financial instability have been at the forefront of economic analysis and policymaking since the global financial crisis and the ensuing recession. National and international authorities have brought in systems to monitor developments and detect signs of imbalances and emerging difficulties in the economy. They have in their toolboxes various regulatory measures which they may use to strengthen the resilience of the financial sector. However, many of these measures, however, operate with long lags, so leading indicators providing an early warning about future imbalances is of the essence[1].

A large number of studies analyse distress and crises in the banking sector; see the survey in Demirgüç-Kunt and Detragiache (2005). The literature typically focuses on explaining the dynamics of non-performing loans, not on whether the variables serve as leading indicators, where one of the main differences lies in the different lag structures used in the models. We will briefly discuss some studies that are particularly relevant for this paper as they consider the importance of macroeconomic variables for the dynamics of non-performing loans.

One branch of the literature comprises papers that use aggregate data, typically country level data. Rinaldi and Sanchis-Arellano (2006) estimate panel VECM models on a sample of seven euro area members. They conclude that lower indebtedness and higher house prices are associated with a lower ratio of non-performing loans. Nkusu (2011) uses annual data for a small panel of advanced countries in a VAR model with only a few variables and finds that higher GDP growth, lower unemployment and higher house prices are followed by a lower ratio of non-performing loans in the short term. Skarica (2014) uses a very short panel of quarterly data from 2007–2012 for numerous Central and Eastern European countries and reach the conclusion that GDP growth, unemployment and inflation are important for non-performing loans in the short term.

Beck *et al.* (2015) use a comprehensive dataset with annual data for 75 countries over the decade 2000–2010, with the aim of uncovering some key determinants of non-performing loans. The paper considers contemporaneous and one-year lagged effects and finds that GDP, share prices, the nominal effective exchange rate and the lending interest rate have explanatory power.

Klein (2013) estimates the dynamics of non-performing loans in a panel of Central, Eastern and Southern European countries and finds that banking-sector factors are much less important than overall macroeconomic conditions, when these are included contemporaneously and with a lead time of up to two years. Marki *et al.* (2014) consider the aggregate ratio of non-performing loans in a panel of 14 EU countries during the pre-crisis years 2000–2008. The number of observations is very small, but even so they find that bank-specific variables are important alongside macroeconomic variables, either contemporaneously or lagged by one year.

Another branch of the literature comprises papers that use bank-level data. One example is Anastasiou *et al.* (2019), who use bank data for the EU countries and a limited set of macroeconomic variables not including house prices. They estimate VECM models and consider generalised impulse responses for up to 10 quarters after-shocks in the macroeconomic variables. They find that higher economic growth and higher credit growth are associated with lower levels of non-performing loans in the short term. It is notable however that none of the variables used in the analysis have any relationship with the ratio of non-performing loans in the longer term, as the effects die out within one and a half years. There appear to be some differences between the dynamics of banks in the core of the euro area and those of banks in the periphery.

Messai and Jouini (2013) study the determinants of non-performing loans in 85 banks in Italy, Spain and Greece. They find that GDP growth, unemployment and the real interest rate are important factors, but so are bank-specific variables such as the profitability of banks and their loan loss reserves. Kjosevski and Petkovski (2016) study non-performing loans in a panel of Baltic banks and find that macroeconomic variables such as GDP growth, inflation and the private credit stock are important, but so are a number of bank-specific variables.

The studies cited until this stage typically rely on models where the macroeconomic variables are included contemporaneously or with very short lags. This limits the applicability of the models for early warning of potential imbalances many periods into the future. The need for timely indication of future instability has led to a large literature on early warning models and in which it is examined which variables that serve as leading indicators for proxies of banking distress[2]. It is notable that this literature typically does not include non-performing loans into the composite measures of financial distress; see for example Hollo *et al.* (2012) or Vermeulen *et al.* (2015)[3].

This paper contributes to the literature on prediction of future banking sector distress. It estimates panel data models in order to assess whether various macroeconomic and macro-financial factors may serve as leading indicators for the accumulation of non-performing loans several years in the future. Our modelling strategy follows the literature on leading indicators in early warning models although with some differences due to our focus on non-performing loans in the banking sector[4]. Data are at the country level data so the data on non-performing loans are for the entire country, not of individual banks.

The models include macroeconomic and macro-financial variables but do not include variables that capture the exposure of the banking sector. We have made this choice because the inclusion of banking sector variables would lead to the loss of very many observations but also because the literature often finds that banking sector variables have very little prediction power in models using aggregate data for entire economies (Klein, 2013; Ghosh, 2015). Moreover, the models always include country fixed effects which will absorb time-invariant effects due to different banking sector characteristics across the countries. The models also include appropriately defined long lags of the non-performing loan variable, and this variable may absorb some of the time-varying effects due to different banking sectors in the countries.

The focus on the EU is pertinent because the banking sector is the key intermediate of funds between borrowers and savers in the EU countries. Besides the estimations for a sample consisting of all the EU countries, we also run estimations to assess possible differences in the factors driving the future dynamics of non-performing loans in Western Europe and in Central and Eastern Europe; in this way the paper also contributes to the discussion of possible heterogeneities in the European Union.

The results of the baseline estimations are for a prediction horizon of eight quarters, implying that the lagged dependent variable and the co-variates are all lagged by eight quarters (or alternatively that the dependent variable is leaded by eight quarters). The long horizon is chosen to take account of the time needed by the policy-makers and regulatory authorities to react to changes in the macroeconomic environment and implement

counteracting measures. The results with prediction horizons from one to 12 quarters are also considered as ascertain the importance of the prediction horizon.

The paper contributes to the literature in several ways. First of all, it is to the best of our knowledge the first to estimate models meant expressly to ascertain whether macroeconomic variables serve as leading indicators for non-performing loans several years ahead. Second, we use a large number of macroeconomic and macro-financial variables in the analysis, including the current account balance, which is seldom used in studies of financial stability and non-performing loans. Third, we consider the results for the full panel of EU members, but we also investigate how far Western Europe and Central and Eastern Europe are different. Finally, we investigate in detail the importance of the prediction horizon, a feature which may matter when supervisory and regulatory measures are devised.

The rest of the paper is structured as follows. Section 2 discusses the methodology and data used. Section 3 presents the results of the baseline estimations. Section 4 considers the importance of different prediction horizons for the results. Section 5 presents some robustness checks. Finally, Section 6 concludes.

2. Methodology and data

2.1 Model specification

This paper estimates panel data models for the EU countries on quarterly data in order to identify macroeconomic factors that function as leading indicators of non-performing loans.

The starting point for our baseline specification is the logit models with macroeconomic variables typically used to identify leading indicators for financial crises (Bussiere and Fratzscher, 2006; Betz *et al.*, 2014; Lainà *et al.*, 2015; Vermeulen *et al.*, 2015). The dependent variable in these models is a binary variable indicating whether or not a financial crisis is present while the explanatory variables are lagged a substantial number of periods in order to ensure that warnings of crises are called well in advance. In models with quarterly data the individual indicators typically appear with a lag of either 8 or 12 quarters[5].

We deviate from the standard logit specification of leading indicator models by treating the explanatory variable, the ratio of non-performing loans to total loans, as a continuous variable. It is not straightforward to map a continuous variable into a binary crisis variable and this is particularly the case for non-performing loans; a given level of non-performing loans may be benign in some situations but signal serious distress in the banking sector in other situations. Moreover, turning the explanatory variable into a binary variable entails a substantial loss of information.

The baseline specification is given in eq. (1), where i indicates the country, t is the quarter and h is the horizon of the leading indicators:

$$\mathrm{NPL}_{i,t} = \alpha \mathrm{NPL}_{i,t-h} + \beta X_{i,t-h} + \mu_i + \varepsilon_t \tag{1}$$

The ratio of non-performing loans, $\mathrm{NPL}_{i,t}$, is regressed on its value lagged h periods, $\mathrm{NPL}_{i,t-h}$, on the macroeconomic and macro-financial variables lagged h periods, $X_{i,t-h}$, and on the country fixed effects, μ_i. The coefficient α and the coefficients in the vector β are to be estimated. Finally, ε_t is the error term.

If an estimated coefficient is precisely estimated and economically significant, then the variable is a *leading variable* which may or may not have a causal effect (Blanchard, 1990). In the literature on early warning models, leading variables are typically termed *leading indicators* and we use the same term here (Bussiere and Fratzscher, 2006; Betz *et al.*, 2014; Lainà *et al.*, 2015; Vermeulen *et al.*, 2015).

The long lags of the leading variables (or equivalently, the long lead of the dependent variable) mitigate possible problems of reverse causality as the dynamics of NPL eight or 12

quarters ahead are unlikely to affect the contemporaneous values of macroeconomic and macro-financial variables[6].

Although the model specification is derived from the leading indicators literature, it also relates to studies that estimate panel models with short lags and cross-sectional fixed effects as discussed in the introduction. The main difference is the lag structure where models of leading indicators typically use much longer lags than models seeking to explain the dynamics of non-performing loans. We only include one lag of a variable at the time. This follows the early warning literature and reduces potential problems with multi-collinearity that may otherwise arise.

Our use of country-level data for the non-performing loans stands in contrast to the use of NPL data for individual banks. Aggregating the loan portfolios before calculating the ratio means we consider the average effect of macroeconomic factors on non-performing loans in the countries, not the average effect on individual banks.

We consider as potential leading indicators a number of macroeconomic and macro-financial variables found to be of importance in the literature; see Subsection 2.2. The macroeconomic variables comprise GDP growth, the unemployment rate and inflation. The macro-financial variables are total private loans, the current account balance and real house prices. In some estimations, we replace total private loans with private housing loans or household loans to examine to which extent the specification of the debt measure matters.

The quarterly data run from 1997Q4–2017Q1, but the panel is unbalanced as some observations are missing at the beginning or the end of the sample. The baseline models assume a horizon of eight quarters, so the lagged dependent variable and all the macroeconomic and macro-financial variables are lagged by eight quarters or, equivalently, the dependent variable is leaded by eight quarters. Besides the baseline specification with quarter $h = 8$, we also carry out analyses with quarters $h = 1,\ldots,12$ to assess how important the prediction horizon is for the results.

We estimate the model in eq. (1) using ordinary least squares with country fixed effects as is customary in the literature (Betz *et al.*, 2014; Lainà *et al.*, 2015; Vermeulen *et al.*, 2015). Estimations of dynamic panels are typically subject to the Nickell bias which affects the coefficient of the lagged dependent variable as well as other explanatory variables (Nickell, 1981). In this case, however, the dependent variable is typically included with a long lag so that the Nickell bias will not be present.

The panel consists of all the EU countries except Luxembourg and the United Kingdom, in total 26 countries[7]. Analyses are carried out on the full EU sample and also on two different groupings of EU countries. The group labelled WEST consists of 15 EU members from Western Europe, including Cyprus and Malta (but excluding Luxembourg and the United Kingdom). The group labelled CEE comprises the 11 countries from Central and Eastern Europe which joined the EU in 2004, 2007 or 2013[8]. We believe that it is of interest to consider not only the whole EU but also the two groups separately as they have somewhat different economic institutions, different financial sectors and different business cycle features (Epstein and Jacoby, 2014). A key issue is whether these differences cause the leading indicators to differ across the country groups.

2.2 Data

The data come from various data sources; Table AI in Appendix A lists the variables and the data sources. The variable NPL is computed as the percentage of non-performing loans to total loans. The quarterly data from the ECB start in 2003Q1 for many countries and later for some. We augment the quarterly data from the ECB with annual data on non-performing loans from the World Bank. Observations are available from 1997 and we interpolate the missing quarters with cubic splines. As the baseline models are for eight quarters ahead, the interpolated data are used for a relatively short period in most cases.

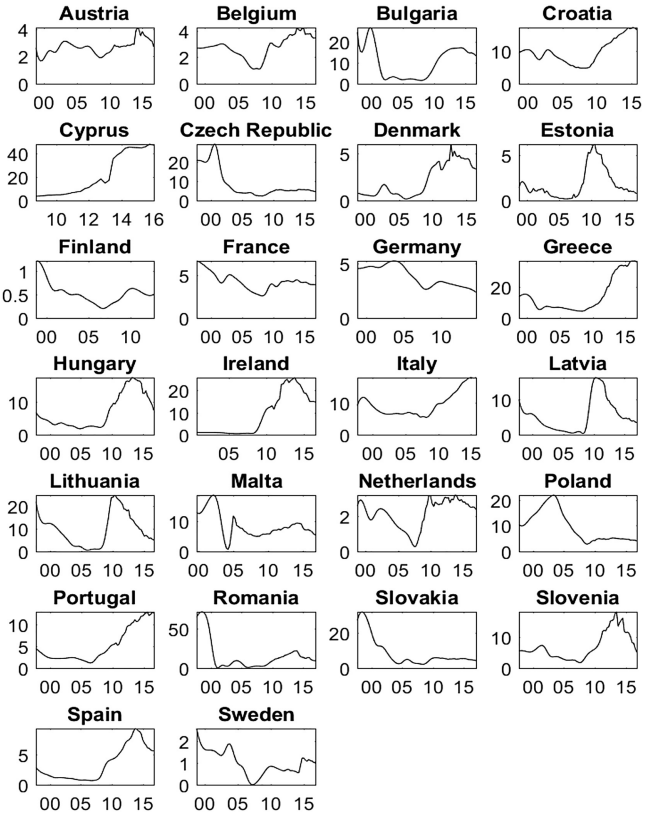

Figure 1.
Non-performing loans in per cent of total loans

The data on non-performing loans in per cent of total loans, NPL, are shown in Figure 1. It is notable that NPL and its dynamics vary substantially across countries. NPL is generally higher and its variability larger for the CEE countries than for the Western European countries, but there are exceptions such as the very rapid increases in NPL in Greece, Cyprus or Ireland after the outbreak of the global financial crisis.

The rate of GDP growth depicts the dynamics of household and corporate income that may be used to service debt obligations. Strong growth generates income and lowers the loan to income ratio for the economy conditional on the dynamics of loans and real estate. There could potentially also be a negative relationship if strong GDP growth acts as a signal of an unsustainable boom that will be followed by banking distress in the future[9]. Unemployment is another measure of the cyclical stance of the economy. Unemployment leads to lower incomes and more uncertainty at the household level and especially those directly affected[10]. The final macroeconomic variable is the inflation rate, the year-on-year change in the consumer price index[11]. Higher inflation can measure potential booms in consumption and investment that could cause NPL to rise in future, though it also reduces the real value of debt already accumulated, making debt repayments cheaper.

The macro-financial variable includes total private loans in per cent of GDP. The variable has a wide coverage in the sample countries, but we also include total private loans and mortgages in some estimations[12]. House prices may be leading indicators of future NPL dynamics. A higher rate of growth in house prices might reflect a bubble and signal future

problems, while low house prices may or may not incentivise households to service their debt obligations[13]. The current account balance is a measure or proxy of international financial flows. A current account deficit means that a country receives capital inflows, while a surplus shows it is a source of outflows. The capital flows may be associated with changes in lending from the domestic banking sector (Cuestas and Staehr, 2017). We have not uncovered any other studies using the current account balance in empirical models of non-performing loans with the partial exception of Betz *et al.* (2014) who use the international investment position to GDP as a possible leading indicator.

3. Baseline results

This section presents the results of the baseline estimations of the model in eq. (1) with a horizon of eight quarters for three different country samples, i.e. the full EU, the WEST and the CEE. The models contain the lagged dependent variable, macroeconomic and macro-financial variables, and country fixed effects. Following the literature, we consider a variable for a leading indicator if the coefficient of the variable is precisely estimated and of a size so that it is of economic importance (Bussiere and Fratzscher, 2006; Betz *et al.*, 2014; Lainà *et al.*, 2015; Vermeulen *et al.*, 2015). Table I shows the estimation results of the baseline models for the three country groups, in the case where the debt stock is taken to be total private loans in per cent of GDP.

It follows from column (1.1) for all EU countries that the coefficient of the eight quarters lagged dependent variable is positive and a bit below 0.7. The substantial persistence is unsurprising given that it is typically time consuming to resolve delinquent loans. In spite of the substantial persistence, many of the independent variables also serve as leading indicators of importance for the ratio of non-performing loans eight quarters ahead.

Among the macroeconomic variables, an increase in annual GDP growth of 1 percentage point is followed by NPL being 0.3 percentage point lower eight quarters ahead. This result is broadly in line with the short-term relationships found in other studies[14]. An increase in unemployment of 1 percentage point is followed by NPL being 0.3 percentage point higher eight quarters ahead. The sign is as expected and the magnitude of the coefficient is reasonable[15]. The coefficient of the inflation rate is positive and precisely estimated. An increase of 1 percentage point in the rate of inflation is associated with an increase of 0.6 percentage point in non-performing loans eight quarters ahead, which is a non-negligible effect broadly in line with the literature[16].

The results for the macro-financial variables are also noteworthy. Total private debt-to-GDP being 1 percentage point higher is followed by NPL being 0.1 percentage point higher eight

	(1.1) EU	(1.2) WEST	(1.3) CEE
NPL (−8)	0.670*** (0.031)	0.734*** (0.036)	0.485*** (0.051)
GDP growth (−8)	−0.297*** (0.026)	−0.259*** (0.039)	−0.211*** (0.035)
Unemployment (−8)	0.252*** (0.045)	0.417*** (0.055)	−0.381*** (0.073)
Inflation (−8)	0.585*** (0.054)	0.534*** (0.082)	0.539*** (0.072)
Total private loans (−8)	0.050*** (0.004)	0.037*** (0.004)	0.140*** (0.014)
Real house prices (−8)	−0.752 (0.701)	−3.413*** (0.886)	−1.210 (1.011)
Current account (−8)	−0.175*** (0.033)	−0.245*** (0.044)	0.010 (0.051)
R^2	0.655	0.757	0.663
Countries	26	15	11
Observations	1,287	848	439

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table I.
Estimation of the baseline model of leading indicators

quarters ahead[17]. The debt-to-GDP ratio is a leading indicator as high debt levels are followed by debt servicing problems in the future. The coefficient of the lagged house prices is negative, but the coefficient is imprecisely estimated[18]. Finally, an improvement of 1 percentage point in the current account balance is followed by a decrease in NPL of 0.2 percentage point eight quarters ahead. One explanation may be that capital outflows lead to stricter financing conditions for the banks so that they tighten lending requirements. The current account balance seems to be an important leading indicator of NPL for the full EU sample.

It is informative to compare the results for the Western European group of countries and those for the CEE group. The results for WEST in column (1.2) are very similar to those for the full EU sample with the exception of real house prices, which appear to serve as a leading indicator in the WEST. For the CEE countries the differences to the full EU sample are larger, as shown in column (1.3). Surprisingly, the sign of the coefficient of the unemployment rate is negative for the CEE, which may reflect different features of the business cycles in Western Europe and in Central and Eastern Europe. The estimated coefficient of private loans is somewhat larger for the CEE than for the full EU sample and the WEST sample. Finally, the coefficients of real house prices and the current account balance may not serve as leading indicators for this group of countries.

The baseline models in Table I showed that a number of variables were leading developments in the non-performing loans. It is customary in the early warning literature on financial crises to assess how precise the early warnings are in warning about crises by comparing the correct predictions with the false positives and false negatives (Bussiere and Fratzscher, 2006; Betz *et al.*, 2014; Lainà *et al.*, 2015; Vermeulen *et al.*, 2015). This comparison is often computed using in-sample data although some studies use post-sample data. We adopt the same idea but make the changes necessitated by the fact that our left-hand variable is a continuous variable.

We compute the in-sample root mean square error (RMSE) of the predictions of the share of non-performing loans eight quarters ahead using the baseline models in Table I. For comparison we compute the RMSE of a naïve prediction model where the predicted share of non-performing loans eight quarters ahead is simply the current share. This naïve model implies a static prediction where no additional macroeconomic and macro-financial variables are used. The computations restrict the samples of the naïve model so that the model-based and the naïve predictions always refer to the same sample. Table II shows the results.

It follows that the RMSE is much lower for the in-sample predictions of the model in Table I than for the predictions of the naïve model, and this applies for all three country groups considered. The improvement in prediction accuracy is noticeable for the total sample of EU countries and the group of Western European countries, but particularly large for the CEE countries. The improvement in the prediction accuracy is somewhat larger when the model is estimated for the two groups WEST and CEE separately than when it is estimated for all EU countries together.

The conclusion of the baseline estimations in this section is that a range of macroeconomic and macro-financial variables appear to be important leading indicators for the ratio of

	(2.1) EU	(2.2) WEST	(2.3) CEE
Naïve prediction	4.490	4.157	5.071
Model prediction	2.970	2.594	2.716
Countries	26	15	11
Observations	1,287	848	439

Note(s): RMSE indicates the in-sample root mean square error of the predictions from the naïve model and the model in Table I

Table II.
RMSE of in-sample prediction of non-performing loans

non-performing loans. For the full sample of in the EU countries higher GDP growth, lower inflation and lower debt are robust leading indicators of a lower ratio of non-performing loans in the future. The current account balance and real house prices are important indicators for the Western European group but less important for the Central and Eastern European group. Moreover, the predictions of future non-performing loans generated by the early warning model in Table I are more precise the predictions from a naïve prediction assuming an unchanged share of non-performing loans.

4. Prediction horizon

The results so far have considered a prediction horizon of eight quarters. This follows the literature and is mainly predicated on the need for early warning of imbalances when the models are used in policy making. We also consider the results when eq. (1) is estimated for other horizons as this may useful for policy making and also give some indications of the robustness of the baseline results.

Figure 2 presents the results for the prediction horizons from one to 12 quarters for the full EU sample[19]. The prediction horizon is on the horizontal axis, and the coefficient estimates with the confidence intervals computed as plus/minus two standard deviations are on the vertical axis.

Unsurprisingly, the coefficient of the lagged dependent variable decreases in the prediction horizon; it is close to one when the horizon is one-quarter and 0.4 when it is 12 quarters.

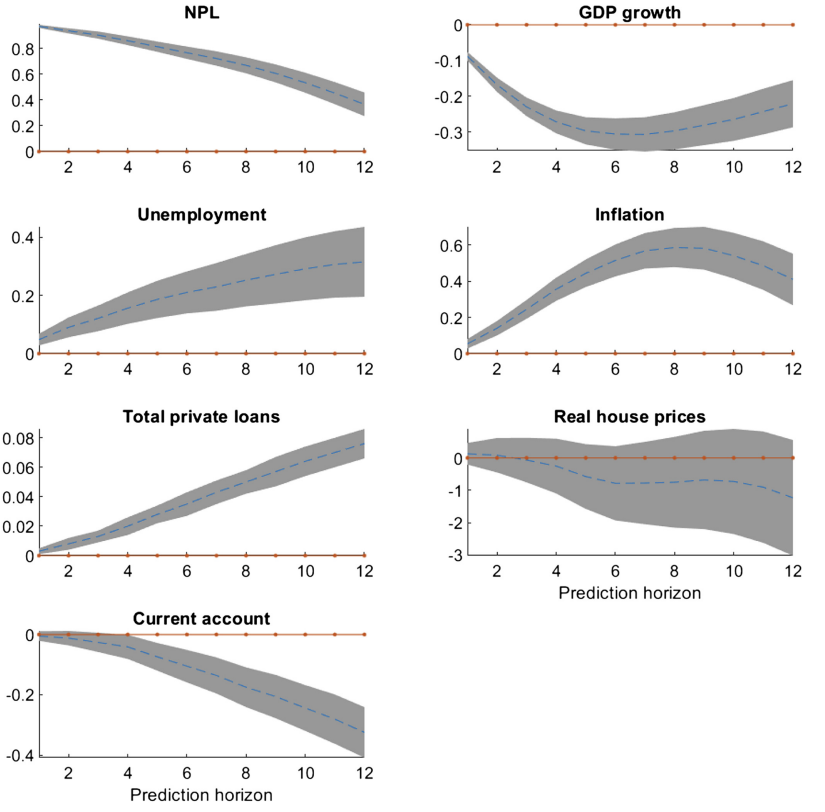

Figure 2.
Estimated coefficients at different prediction horizons, full EU sample

The estimated coefficients of the macroeconomic variables, i.e. GDP growth, unemployment and inflation, vary over the prediction period. Unsurprisingly the coefficients are numerically small at short horizons when the lagged non-performing loans variable is very important. At longer horizons, all three variables serve as important leading indicator. It is notable that the numerical size of the coefficients is relatively irrespective for prediction horizons longer than four-quarters.

Among the macro-financial variables, total private loans and the current account balance become increasing important as the prediction horizon increases, suggesting that these variables are particularly useful for longer-term predictions. The coefficient of the housing price variable does not attain statistical significance irrespective of the prediction horizon.

Figure 2 provides important insights since that macroeconomic and macro-financial variables may be used for monitoring and prediction of non-performing loans at different future time horizons. For short horizons, the current share of non-performing loans is an important leading indicator of non-performing loans while the information content in the macroeconomic and macro-financial variables is limited. For longer horizons, the existing non-performing loans are less important while most macroeconomic and macro-financial are useful leading indicators. It is notable however that the real house price index appears to have no predictive potential for the future dynamics of non-performing loans at any horizon.

Figure 3 presents the estimated coefficients for different prediction horizons for the sample of EU countries from Western Europe. The results follow closely those for the full EU

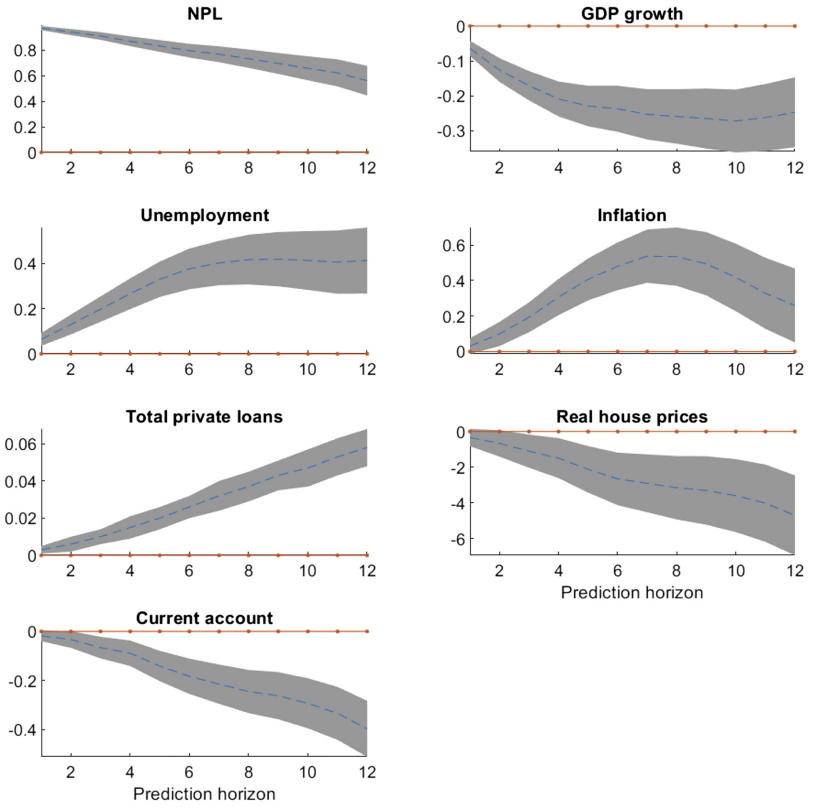

Figure 3.
Estimated coefficients at different prediction horizons, Western European sample

sample except in two cases. First, the stock of non-performing loans appears to be a more important leading indicator for the WEST group than for the full EU group for longer prediction horizons. Second, the coefficient of the house price variable is now statistically significant for longer horizons, and the leading indicator arguably becomes more important as the prediction horizon is lengthened.

Figure 4 presents the results for the sample of CEE countries. The autoregressive coefficient declines in the prediction horizon and becomes very small at longer horizons. In the CEE countries the NPL has very little information content for longer-term predictions. GDP growth appears to become relatively unimportant as a leading indicator of NPL for long prediction horizons, while the unemployment rate become more important as the prediction horizon is extended. Among the macro-financial variables, the coefficient of total loans increases as the prediction horizon is lengthened, while the coefficients of total loans and real house prices imprecisely estimated at any prediction horizon.

This section considered the importance of the prediction horizon for the information contents of the various leading indicators. The share of non-performing loans becomes a less important leading indicator as the prediction horizon gets longer while the macroeconomic and macro-financial variables become more important. The results in Figures 2 and 3 showed that the overall picture is the same for the groups of countries from Western Europe and from

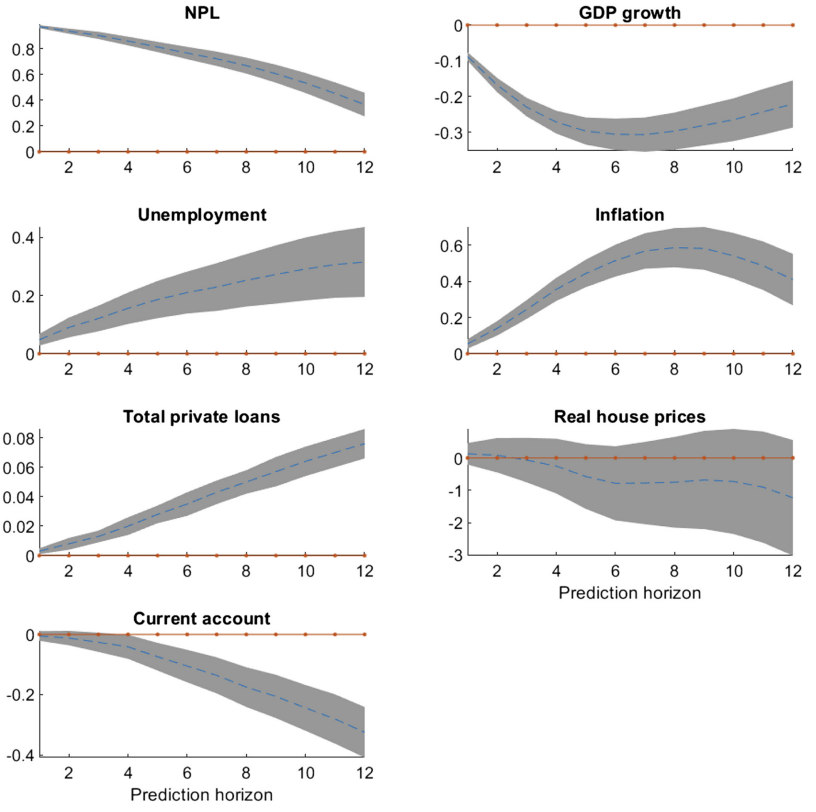

Figure 4.
Estimated coefficients at different prediction horizons, Central and Eastern European sample

Central and Eastern Europe, although there are also differences between the groups, likely reflecting the different economic structures and dynamics in the two regions.

5. Robustness

This section presents an array of robustness checks focusing on the definition of the loan measure, the country composition, the dynamics of the NPL variable and possible multi-collinearity.

5.1 The loan measure

The baseline estimation in Table I used a broad measure of debt, i.e. total loans in per cent of GDP. We found that this variable is an important leading indicator of NPL, but this raises the question of the prediction properties of other debt measures. We therefore include household loans and mortgage loans, although in separate specifications given the substantial correlation between the different debt measures.

Table III shows the results when household loans in per cent of GDP are used instead of total loans. The main change is that the coefficient of mortgage loans is approximately three times as large as that of total loans in Table I. This reflects the fact that household loans and total loans are correlated but household loans comprises only a share of total loans. Including household loans changes little in qualitative terms. The only other consequence of using household loans as the measure of debt is moderate changes in the estimated coefficients of the unemployment rate.

Table IV shows the results when mortgage loans in per cent of GDP are used instead of total loans. The results are qualitatively very close to those when the other debt measures are used. The coefficient of mortgage loans is positive, statistically significant and of broadly the same size for the three country groups considered. The coefficients of real house prices and the current account attain statistical significance in this specification, but only at the 10 per cent level and with a somewhat smaller sample than in the specifications with total debt and household debt.

5.2 Individual countries

The second robustness exercise seeks to establish whether individual countries with particularly volatile NPL dynamics affect the results unduly. The strategy is to repeat the baseline estimations from Table I but with the countries with the most volatile NPL dynamics left out from the samples. Table V shows the results with different countries excluded. Column (5.1) shows the results when four countries in Southern Europe are trimmed from the

	(3.1) EU	(3.2) WEST	(3.3) CEE
NPL (−8)	0.684*** (0.030)	0.743*** (0.035)	0.618*** (0.049)
GDP growth (−8)	−0.240*** (0.026)	−0.204*** (0.040)	−0.290*** (0.035)
Unemployment (−8)	0.156*** (0.046)	0.274*** (0.057)	−0.397*** (0.076)
Inflation (−8)	0.546*** (0.052)	0.493*** (0.080)	0.544*** (0.076)
Household loans (−8)	0.141*** (0.010)	0.118*** (0.011)	0.151*** (0.023)
Real house prices (−8)	−0.909 (0.682)	−3.866*** (0.882)	1.151 (0.023)
Current account (−8)	−0.188*** (0.032)	−0.216*** (0.044)	0.010 (0.054)
R^2	0.670	0.768	0.618
Countries	26	15	11
Observations	1,289	838	451

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table III. Estimation of model of leading indicators with household loans

EU sample. The qualitative results are unchanged, though the coefficient of the unemployment rate is lower for the trimmed panel than for the full sample of EU countries.

Column (5.2) shows the results when Cyprus and Greece are removed from the WEST sample. The coefficients of the macroeconomic variables change, though they retain their sign and statistical significance. This result is most likely to be a consequence of the very volatile macroeconomic environment in the two countries excluded. Interestingly, the coefficients of the macro-financial variables do not change much.

The results in column (5.3) reveal that little changes for the CEE sample when Bulgaria and Romania are excluded. The only notable change is that the coefficient of the current account balance is now negative and statistically significant in the trimmed sample. This bears some resemblance to the findings for the CEE sample, where the coefficient of the current account balance is statistically significant when the standardised NPL is used.

The conclusion from the exclusion of the countries with extreme NPL dynamics is that the baseline model is robust overall to the exclusion of countries with particularly volatile NPL dynamics. It is nevertheless clear that some countries have a substantial influence on the results, suggesting that studies of individual countries may be valuable.

	(4.1) EU	(4.2) WEST	(4.3) CEE
NPL (−8)	0.683*** (0.032)	0.757*** (0.036)	0.609*** (0.057)
GDP growth (−8)	−0.309*** (0.029)	−0.253*** (0.040)	−0.312*** (0.041)
Unemployment (−8)	0.217*** (0.049)	0.342*** (0.059)	−0.370*** (0.090)
Inflation (−8)	0.513*** (0.059)	0.513*** (0.083)	0.586*** (0.091)
Mortgage loans (−8)	0.130*** (0.013)	0.107*** (0.013)	0.172*** (0.043)
Real house prices (−8)	−0.187 (0.779)	−3.552*** (0.916)	2.419* (1.246)
Current account (−8)	−0.142*** (0.036)	−0.258*** (0.045)	0.106* (0.064)
R^2	0.643	0.755	0.546
Countries	26	15	11
Observations	1,235	838	397

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table IV.
Estimation of model of leading indicators with mortgage loans

	(5.1) EU[a]	(5.2) WEST[b]	(5.3) CEE[c]
NPL (−8)	0.596*** (0.029)	0.686*** (0.030)	0.486*** (0.053)
GDP growth (−8)	−0.241*** (0.022)	−0.106*** (0.028)	−0.195*** (0.035)
Unemployment (−8)	0.126*** (0.040)	0.207*** (0.038)	−0.289*** (0.079)
Inflation (−8)	0.529*** (0.046)	0.160*** (0.056)	0.571*** (0.080)
Total private loans (−8)	0.041*** (0.003)	0.032*** (0.003)	0.130*** (0.014)
Real house prices (−8)	−0.972* (0.580)	−2.748*** (0.610)	−1.970* (1.017)
Current account (−8)	−0.201*** (0.030)	−0.230*** (0.031)	−0.118** (0.058)
R^2	0.618	0.740	0.671
Countries	22	13	9
Observations	1,135	765	370

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

[a]EU excluding Bulgaria, Cyprus, Greece and Romania
[b]WEST excluding Cyprus and Greece
[c]EU excluding Bulgaria and Romania

Table V.
Estimation of model of leading indicators, countries excluded

5.3 Volatility differences

The volatility of non-performing loans varies a lot across the sample countries, as does the volatility of most other macroeconomic and macro-financial variables. To assess whether the regression results could be driven by particularly large volatility in some countries we standardise the data by first demeaning the data series and then dividing them by their standard deviation. This methodology is adopted from the early warning literature on financial crises which often uses an indicator for financial distress that is calculated from a set of standardised variables; see for example Vermeulen *et al.* (2015) and Hollo *et al.* (2012).

Table VI shows the results when the non-performing loans variable is standardised but no other variables are. The most noticeable change is that the estimated coefficients of the macroeconomic and macro-financial variables are now very similar across all three country groups. This suggests that the very different variances of the NPL play some role in the results in Sections 3 and 4. The results for the EU and the WEST are largely unchanged in qualitative terms, as, unsurprisingly, the estimated coefficient of the lagged dependent variable declines somewhat. The changes are larger for the CEE countries, where the coefficient of the unemployment rate is still negative and statistically significant, while the coefficients of the real house prices variable and the current account balance now become statistically significant.

The conclusion is that standardising the non-performing loans does not change the results qualitatively, but it leads to more coefficients being statistically significant for the CEE sample.

5.4 Other robustness checks

The next robustness check is the exclusion of the macroeconomic and macro-financial variables one at a time. This exercise is pertinent since the variables may be correlated, which would cause multi-collinearity problems. Tables BI-BIII in Appendix B present the results for the EU, WEST and CEE. In each table the first column shows the baseline result from Table I and the next columns show the results with the variables removed sequentially.

The results are overall quite robust to the exclusion of individual variables with the exception of the removal of total private loans, which seems to have a noticeable impact on the estimated coefficients of real house prices and the current account balance. This is in all likelihood a reflection of the interconnectedness of financial markets and the three macro-financial variables included in the baseline prediction model.

The results are otherwise very robust for the Western European sample, while removing individual variables reveals some instability in the Central and Eastern European sample.

	(6.1) EU	(6.2) WEST	(6.3) CEE
Standardised NPL (−8)	0.501*** (0.026)	0.490*** (0.031)	0.467*** (0.051)
GDP growth (−8)	−0.059*** (0.005)	−0.048*** (0.009)	−0.047*** (0.006)
Unemployment (−8)	0.018** (0.008)	0.052*** (0.012)	−0.061*** (0.013)
Inflation (−8)	0.112*** (0.011)	0.116*** (0.019)	0.083*** (0.012)
Total private loans (−8)	0.013*** (0.001)	0.011*** (0.001)	0.028*** (0.002)
Real house prices (−8)	−0.442*** (0.141)	−0.635*** (0.227)	−0.641*** (0.161)
Current account (−8)	−0.029*** (0.007)	−0.037*** (0.000)	−0.031*** (0.008)
R^2	0.592	0.581	0.726
Countries	26	15	11
Observations	1,287	848	439

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table VI. Estimation of model of leading indicators, standardised NPL

This applies particularly to the real house price variable and the current account balance variable, a result which is not surprising given that the coefficients of these variables are statistically insignificant in the baseline specification.

The final robustness check is the inclusion of additional variables in the form of year-on-year differences for total private loans and real house prices (results available upon request). The estimated coefficients of the differenced variables are sensitive to the particular specification, but it is notable that the coefficients of the other variables remain largely unchanged, suggesting that the baseline results in Table I are reasonably robust.

6. Final comments

This paper estimates panel data models to assess whether various macroeconomic and macro-financial variables may function as leading indicators of the ratio of non-performing loans. This analysis provides key insights for the monitoring of imbalances in the banking sector and for policy-making seeking to reduce to the risk of banking sector distress in the future. The analyses consider the full sample of all EU countries, the group consisting of the Western European EU countries and the group consisting of the Central and Eastern European EU countries.

The prediction horizon of the baseline models is eight quarters, implying that the lagged dependent variable and the independent variables are included with lags of eight quarters. The estimations show that the current ratio of non-performing loans is an important leading indicator for the ratio many quarters ahead. More revealing, several macroeconomic and macro-financial variables also contain important information on the dynamics of the ratio of non-performing loans in the medium term. Higher GDP growth, lower inflation and lower debt are robust leading predictors of the future dynamics of non-performing loans. The current account balance and real house prices are important leading indicators for Western Europe but arguably less so for Central and Eastern Europe. The effect of the unemployment rate differs across the two country groups, possibly reflecting different properties of the business cycles in the two groups.

The importance of the horizon of the leading indicator is considered in some detail. The existing ratio of non-performing loans becomes less and less important as the prediction horizon gets longer. The horizon is generally of some importance for the macroeconomic variables, but of substantial importance for the macro-financial variables, especially total loans. There are some differences between the Western European countries and the Central and Eastern European countries, which in all likelihood reflect the different economic structures and dynamics in the two regions.

The results are robust to numerous changes in the specification and the sample. The analyses show that the specific choice of loan exposure may be of little importance. The results were qualitatively very similar in the models that use total private loans, household loans and mortgage loans. It is notable however that the removal of total private loans from the specification impacts the estimated coefficients of other macro-financial variables. This shows the key importance of the stock of total loans, or alternative measures of loan exposure, for the future dynamics of non-performing loans.

This paper is among the first to assess whether macroeconomic and macro-financial variables may serve as leading indicators for a continuous measure of non-performing loans. The analyses confirm the usefulness of key macroeconomic and macro-financial fundamentals in predicting non-performing loans in panels of EU countries. The findings may thus be useful for surveillance of the banking sector and for assessments of possible threats to financial stability. The analysis reveals however that the prediction models include more variables and are more robust for the group of Western European countries than they are for the group of Central and Eastern European countries.

Notes

1. Introducing a counter-cyclical capital buffer for instance requires time for statistics to be collected and for the decision-making process, and then the banks need to be given time to change their exposures or operations (Behn *et al.*, 2013). This process may require eight quarters or more in total.
2. See for example Alessi and Detken (2011), Betz *et al.* (2014), Babecký *et al.* (2012), Behn *et al.* (2013), Bussiere and Fratzcher (2006) and Demirgüç-Kunt and Detragiache (1998).
3. Some studies, such as Messai and Gallali (2015), examine indeed whether non-performing loans function as a leading indicator for financial distress.
4. Unlike early warning models where the dependent variable is typically discretionary, the non-performing loans variable is a continuous variable and so no information is thrown away.
5. While the right-hand side variables in early warning models enter with a long lag, additional lags of the variables are typically not included. If, for instance, a variable enters with a lag of eight quarters, then the lags of nine and ten quarters are typically *not* included since their information contents is very limited and there is a risk of over-parameterisation.
6. The approach does nevertheless identify the causal effect of the variables on NPL; the interpretation is in line with the local projection conception in Jorda (2005) where the impulse response functions are estimated using separate models for each horizon.
7. Luxembourg is excluded because of its status as a financial centre, and the United Kingdom is excluded because data on total private non-financial loans are not available in the ECB database.
8. The group WEST is made up of Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Malta, Netherlands, Portugal, Spain and Sweden. The group CEE is made up of Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.
9. GDP growth is used in almost every paper analysing non-performing loans, including Anastasiou *et al.* (2019), Beck *et al.* (2015), Kjosevski and Petkovski (2016), Klein (2013), Louzis *et al.* (2012), Makri *et al.* (2014), Messai and Jouni (2013), Nkusu (2011) and Skarica (2014).
10. The variable is also been used by Anastasiou *et al.* (2019), Kjosevski and Petkovski (2016), Klein (2013), Louzis *et al.* (2012), Makri *et al.* (2014), Messai and Jouni (2013) and Nkusu (2011).
11. The variable is used in many papers considering the dynamics of NPL, including Anastasiou *et al.* (2019), Kjosevski and Petkovski (2016), Klein (2013) and Makri *et al.* (2014).
12. Credit variables have been used in many studies including Anastasiou *et al.* (2019), Klein (2013), Makri *et al.* (2014), Messai and Jouni (2013), Rinaldi and Sanchis-Arellano (2006) and Skarica (2014).
13. The variable has also been used by Nkusu (2011) and Rinaldi and Sanchis-Arellano (2006).
14. A negative short-term negative relationship is found in Anastasiou *et al.* (2019), Kjosevski and Petkovski (2016), Louzis *et al.* (2012), Makri *et al.* (2014), Messai and Jouni (2013), Nkusu (2011) and Skarica (2014). Beck *et al.* (2015) find a contemporaneous negative relationship but a positive relationship when GDP growth is included with a one-year lag.
15. A positive sign for short horizons has previously been found by Anastasiou *et al.* (2019), Kjosevski and Petkovski (2016), Klein (2013), Louzis *et al.* (2012), Makri *et al.* (2014), Messai and Jouni (2013) and Nkusu (2011).
16. The sign cannot be due to the denominator of NPL increasing when the inflation rate increases as this denominator effect would have resulted in a negative effect.
17. A positive sign for the level has also been found by Klein (2013) and Makri *et al.* (2014).
18. A negative sign is found between the change of house prices and NPL in the short term by Nkusu (2011) and Rinaldi and Sanchis-Arellano (2006).
19. In the case where the prediction horizon is only one-quarter ($h = 1$), the estimated coefficients may be subject to the Nickell bias (Nickell, 1981). Simulation studies suggest that the least squares fixed

effect estimator perform better than various GMM estimators when the number of time periods is large and the number of cross section is small (Judson and Owen, 1999). This is indeed the case for the present sample. We have nevertheless run System GMM estimations and found that the results are very close to those obtained using fixed effect OLS and reported in Figure 1 for $h = 1$. (The System GMM results are available upon request.)

References

Alessi, L. and Detken, C. (2011), "Quasi real time early warning indicators for costly asset price boom/bust cycles: a role for global liquidity", *European Journal of Political Economy*, Vol. 27 No. 3, pp. 520-533.

Anastasiou, D., Louri, H. and Tsionas, E. (2019), "Nonperforming loans in the euro area: are core-periphery banking markets fragmented?", *International Journal of Finance and Economics*, Vol. 24 No. 1, pp. 97-112.

Babecký, J., Havránek, T., Matějů, J., Rusnák, M., Šmídková, K. and Vašíček, B. (2012), "Leading indicators of crisis incidence: evidence from developed countries", *Journal of International Money and Finance*, Vol. 35, pp. 1-19.

Beck, R., Jakubik, P. and Piloiu, A. (2015), "Key determinants of non-performing loans: new evidence from a global sample", *Open Economies Review*, Vol. 26 No. 3, pp. 525-550.

Behn, M., Detken, C., Tuomas, P. and Schudel, W. (2014), "Setting countercyclical capital buffers based on early warning models: would it work?", Working Paper Series, No. 1604, ECB.

Betz, F., Oprică, S., Tuomas, P. and Sarlin, P. (2014), "Predicting distress in European banks", *Journal of Banking and Finance*, Vol. 45 No. C, pp. 225-241.

Blanchard, O. (1990), "Leads and lags", in Eatwell, John, Milgate, Murray and Newman, Peter (Eds), *Econometrics. The New Palgrave*, Palgrave Macmillan.

Bussiere, M. and Fratzscher, M. (2006), "Towards a new early warning system of financial crises", *Journal of International Money and Finance*, Vol. 25 No. 6, pp. 953-973.

Cesa-Bianchi, A., Cespedes, L. and Rebucci, A. (2015), "Global liquidity, house prices, and the macroeconomy: evidence from advanced and emerging economies", *Journal of Money, Credit and Banking*, Vol. 47 No. S1, pp. 301-335.

Cuestas, J. and Staehr, K. (2017), "The great leveraging in the European crisis countries. Domestic credit and net foreign liabilities", *Journal of Economic Studies*, Vol. 44 No. 6, pp. 895-910.

Demirgüç-Kunt, A. and Detragiache, E. (1998), "The determinants of banking crises in developing and developed countries", *IMF Staff Papers*, Vol. 45 No. 1, pp. 81-109.

Demirgüç-Kunt, A. and Detragiache, E. (2005), "Cross-country empirical studies of systemic bank distress: a survey", *National Institute Economic Review*, Vol. 192 No. 1, pp. 68-83.

Epstein, R.A. and Jacoby, W. (2014), "Eastern enlargement ten years on: transcending the east-west divide?", *Journal of Common Market Studies*, Vol. 52 No. 1, pp. 1-16.

Ghosh, A. (2015), "Banking-industry specific and regional economic determinants of non-performing loans: evidence from US states", *Journal of Financial Stability*, Vol. 20, pp. 93-104.

Hollo, D., Kremer, M. and Lo Duca, M. (2012), "CISS–A composite indicator of systemic stress in the financial system", Working Paper Series, No. 1426, ECB.

Jorda, O. (2005), "Estimation and inference of impulse responses by local projections", *American Economic Review*, Vol. 95 No. 1, pp. 161-182.

Judson, R. and Owen, A. (1999), "Estimating dynamic panel data models: a guide for macroeconomists", *Economics Letters*, Vol. 65 No. 1, pp. 9-15.

Kjosevski, J. and Petkovski, M. (2016), "Non-performing loans in the Baltic states: determinants and macroeconomic effects", *Baltic Journal of Economics*, Vol. 17 No. 2, pp. 25-44.

Klein, N. (2013), "Non-performing loans in CESEE: determinants and impact on macroeconomic performance", Working Papers, No. WP/13/72, IMF.

Lainà, P., Nyholm, J. and Sarlin, P. (2015), "Leading indicators of systemic banking crises: Finland in a panel of EU countries", *Review of Financial Economics*, Vol. 24 No. 1, pp. 18-35.

Louzis, D.P., Vouldis, A. and Metaxas, V. (2012), "Macroeconomic and bank-specific determinants of non-performing loans in Greece: a comparative study of mortgage, business and consumer loan portfolios", *Journal of Banking and Finance*, Vol. 36 No. 4, pp. 1012-1027.

Makri, V., Tsagkanos, A. and Bellas, A. (2014), "Determinants of non-performing loans: the case of Eurozone", *Panoeconomicus*, Vol. 61 No. 2, pp. 193-206.

Messai, A.S. and Jouini, F. (2013), "Micro and macro determinants of non-performing loans", *International Journal of Economics and Financial Issues*, Vol. 3 No. 4, pp. 852-860.

Messai, A.S. and Gallali, M.I. (2015), "Financial leading indicators of banking distress: a micro prudential approach–evidence from Europe", *Asian Social Science*, Vol. 11 No. 21, pp. 78-90.

Nickell, S. (1981), "Biases in dynamic models with fixed effects", *Econometrica*, Vol. 49 No. 2, pp. 1417-1426.

Nkusu, M. (2011), "Non-performing loans and macrofinancial vulnerabilities in advanced economies", Working Papers, No. 11/161, IMF.

Rinaldi, L. and Sanchis-Arellano, A. (2006), "Household debt sustainability: What explains household non-performing loans? an empirical analysis", Working Paper No. 570, ECB.

Skarica, B. (2014), "Determinants of non-performing loans in Central and Eastern European countries", *Financial Theory and Practice*, Vol. 38 No. 1, pp. 37-59.

Vermeulen, R., Hoeberichts, M., Vašícek, B., Žigraiová, D., Šmídková, K. and de Haan, J. (2015), "Financial stress indices and financial crises", *Open Economies Review*, Vol. 26 No. 3, pp. 383-406.

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Appendix

Data	Source
Non-performing loans to total gross loans and advances (NPL), quarterly	ECB
Bank nonperforming loans to total gross loans, annual	World Bank
Loans to domestic household and non-financial institutions private sector (stock)	ECB
Loans to households, reported by monetary and financial institutions (stock)	ECB
Mortgage loans as lending to households for house purchase, reported by monetary and financial institutions (stock)	ECB
Real house price index	ECB, Cesa-Bianchi *et al.* (2015)
Current account balance	Eurostat, ECB, IMF IFS
Consumer price index	IMF IFS
Nominal GDP	Eurostat and Datastream
Real GDP	Eurostat and Datastream
Unemployment rate	Eurostat and Datastream

Table AI.
Data sources

Table BI.
Estimation of models of leading indicators with variables omitted, EU

	(B1.1)	(B1.2)	(B1.3)	(B1.4)	(B1.5)	(B1.6)	(B1.7)
NPL (−8)	0.670*** (0.031)	0.652*** (0.033)	0.758*** (0.027)	0.649*** (0.033)	0.673*** (0.027)	0.704*** (0.029)	0.643*** (0.031)
GDP growth (−8)	−0.297*** (0.026)		−0.316*** (0.026)	−0.284*** (0.027)	−0.462*** (0.026)	−0.305*** (0.026)	−0.294*** (0.026)
Unemployment (−8)	0.252*** (0.045)	0.320*** (0.047)		0.221*** (0.047)	0.261*** (0.042)	0.219*** (0.043)	0.239*** (0.045)
Inflation (−8)	0.585*** (0.054)	0.558*** (0.057)	0.566*** (0.054)		0.319*** (0.051)	0.554*** (0.053)	0.679*** (0.051)
Total private loans (−8)	0.050*** (0.004)	0.069*** (0.004)	0.055*** (0.004)	0.049*** (0.005)		0.050*** (0.004)	0.052*** (0.004)
Real house prices (−8)	−0.752 (0.701)	−1.395* (0.733)	−1.432** (0.698)	−1.395* (0.733)	2.834*** (0.614)		0.761 (0.627)
Current account (−8)	−0.175*** (0.033)	−0.174*** (0.035)	−0.160*** (0.034)	−0.295*** (0.033)	−0.117 (0.031)	−0.164 (0.029)	
R^2	0.655	0.621	0.647	0.623	0.576	0.658	0.647
Countries	26	26	26	26	26	26	26
Observations	1,287	1,287	1,287	1,287	1,484	1,313	1,304

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table BII. Estimation of models of leading indicators with variables omitted, Western European sample

	(B2.1)	(B2.2)	(B2.3)	(B2.4)	(B2.5)	(B2.6)	(B2.7)
NPL (−8)	0.734*** (0.036)	0.708*** (0.036)	0.866*** (0.032)	0.690*** (0.036)	0.621*** (0.037)	0.765*** (0.035)	0.716*** (0.036)
GDP growth (−8)	−0.259*** (0.039)		−0.325*** (0.040)	−0.227*** (0.040)	−0.370*** (0.040)	−0.289*** (0.039)	−0.315*** (0.038)
Unemployment (−8)	0.417*** (0.055)	0.495*** (0.055)		0.343*** (0.055)	0.611*** (0.056)	0.465*** (0.053)	0.358*** (0.053)
Inflation (−8)	0.534*** (0.082)	0.465*** (0.083)	0.404*** (0.083)		0.373*** (0.088)	0.569*** (0.082)	0.546*** (0.083)
Total private loans (−8)	0.037*** (0.004)	0.047*** (0.004)	0.045*** (0.004)	0.037*** (0.004)		0.033*** (0.004)	0.040*** (0.004)
Real house prices (−8)	−3.413*** (0.886)	−4.387*** (0.888)	−4.807*** (0.888)	−3.842*** (0.901)	−1.277 (0.855)		−1.188 (0.797)
Current account (−8)	−0.245*** (0.044)	−0.324*** (0.044)	−0.165*** (0.044)	−0.253*** (0.045)	−0.234*** (0.045)	−0.179*** (0.040)	
R^2	0.757	0.744	0.740	0.744	0.693	0.757	0.745
Countries	15	15	15	15	15	15	15
Observations	848	848	848	848	882	848	865

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table BIII.
Estimation of models of leading indicators with variables omitted, Central and Eastern European sample

	(B3.1)	(B3.2)	(B3.3)	(B3.4)	(B3.5)	(B3.6)	(B3.7)
NPL (−8)	0.485*** (0.051)	0.420*** (0.052)	0.356*** (0.046)	0.486*** (0.054)	0.661*** (0.036)	0.595*** (0.040)	0.486*** (0.051)
GDP growth (−8)	−0.211*** (0.035)		−0.181*** (0.036)	−0.197*** (0.038)	−0.470*** (0.033)	−0.251*** (0.033)	−0.211*** (0.035)
Unemployment (−8)	−0.381*** (0.073)	−0.311*** (0.074)		−0.364*** (0.077)	−0.267*** (0.063)	−0.494*** (0.067)	−0.379*** (0.071)
Inflation (−8)	0.539*** (0.072)	0.515*** (0.076)	0.526*** (0.075)		0.344*** (0.065)	0.480*** (0.070)	0.530*** (0.060)
Total private loans (−8)	0.140*** (0.014)	0.187*** (0.012)	0.146*** (0.014)	0.165*** (0.014)		0.122*** (0.011)	0.140*** (0.013)
Real house prices (−8)	−1.210 (1.011)	−1.266** (1.035)	−1.271 (1.043)	−1.417 (1.073)	3.005*** (0.825)		−1.299 (0.906)
Current account (−8)	0.010 (0.051)	0.012 (0.054)	−0.039 (0.052)	−0.208*** (0.045)	−0.006 (0.044)	−0.002 (0.045)	
R^2	0.663	0.634	0.641	0.619	0.562	0.675	0.663
Countries	11	11	11	11	11	11	11
Observations	439	439	439	439	602	465	439

Note(s): Panel data estimations with country fixed effects. Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$