IMPROVING EWS FOR BANKING CRISES: ROC AND AUROC ANALYSIS

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Abstract

     Constructing a meaningful forecast requires the selection of the explanatory variables. We show that banking specific variables and macroeconomic indicators have direct implications for the crisis prediction. Based on these statement, we assess the relative performance of these indicators using ROC and AUROC methodology. We find that gdp per capita, the share of common shareholders equity are informative indicators in predicting crises periods, while unemployment rate, inflation rate (price index data, 2005), direct investment and international investment are somewhat informative in predicting crises only in the period 2002-2004.

Keywords: *early warning system, ROC, AUROC*

1. Introduction

Macroprudential policy can only succeed if turbulance periods are detected early enough for preventive action to be taken. We highlight the importance of constructing an effective early warning indicators (EWIs) by choosing the most representative explanatory variables. In doing so, we propose a number of novel extensions to existing techniques and EWIs: ROC and AUROC methodology. The ROC curve summarizes all potential type I – type II trade-offs that a prediction model for binary variables generates. Clearly, a model with fewer classification errors is better, and this is reflected

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in a larger area under the ROC curve (AUROC). As such, AUROC can be used as a summary measure to judge the forecast performance of any binary prediction model. We investigate the temporal performance of established EWIs. In particular, we calculate the AUROC separately for each year in the forecast interval and compare the resulting time profiles.

We apply our approach to assess the performance of 16 selected EWIs on a sample of 73 european commercial banks from 11 countries, covering quarterly time-series starting in the early 2002's. The set of potential EWIs includes banking specific indicators, macroeconomic and financial variables.

We structure the paper as follows, in Section 2 we outline the specialized literature. In Section 3 we describe the data used in our paper and the ROC and AUROC methodology we have estimated. In Section 4 we provide the results. Section 5 concludes and makes some suggestions regarding policy implications.

2. Literature Review

There are numerous explanatory variables used in the literature choose to forecast the likelihood of a crisis (Eray Yucel,2011). In this paper we intend to analyse the predicting performance of this indicators with ROC and AUROC methodology.

Dimas B. Wiranata Kusuma and AbuAsif (2012) analyzed Islamic banking sectors over the period January 2004-December 2006.They build Islamic banking sector fragility index (IBSF) in order to determine the crisis period. The independent variables used in their paper are the same as in the model of Herrera-Garcia: M2/reserve growth, credit growth, real effective exchange rate and inflation rate. All selected leading indicators indicate the ability for correctly forecasting the crises occurance with at least 24 months before the onset of crises. Kibritcioglu, Aykut (2002) used a similar approach for 22 countries for different periods in 1961-2001.

E. Philip Davis, Dilruba Karim, Iana Liadze (2011) analyzed 20 countries in Latin America and Asia that have emerging financial systems. The banking crisis dependent variable is similar to Demirgu̇ç-Kunt and Detragiache (2005) model. Authors used explanatory variables used in previous studies: Demirgu̇ç-Kunt and Detragiache (2005) and Davis and Karim (2008a): real GDP growth (%) (DGDP), real interest rate (%) (RIR), inflation (%) (INFL), fiscal surplus/GDP (%) (FISCY), M2/foreign exchange reserves (%) (M2RES),real domestic credit growth (%) (DCRED),real GDP

per capita (GDPPC),domestic credit/GDP (%) (DCREDY), depreciation (%) (DEPREC),change in Terms of Trade (%) (DTT). Using logit methodology and binary tree recognition it is found different crisis determinants across regions, implying inappropriate global samples.

Barrell, R., E.P. Davis, D. Karim and I. Liadze (2010) used logit methodology on 14 OECD countries during the period 1970-2007. The authors used a similar approach as Demirgüc-Kunt and Detragiache (2005) but they introduced three specific explanatory variables: liquidity ratio (%) (LIQ), unweighted capital adequacy ratio (%) (LEV) and real property price growth (%) (RHPG). It is finding strong effects from capital adequacy and liquidity ratios as well as property prices, and an unsignificant impact from traditional variables.

Davis, E.P. and D. Karim (2008) used a global panel with 105 countries. Also, they used the Demirg˙uc˛-Kunt and Detragiache (1998) explanatory variables. Variables highlighted include terms of trade, GDP growth, the fiscal balance, M2/reserves and credit growth, alone or leveraged with deposit insurance.

Daley J. K. Matthews and K. Whitfield (2005) used the total population of banks in Jamaica between 1992 and 1998. A total of 34 banks was assessed, 18 of which were classified as failed. The independent variables are financial strength (proxied by capital adequacy, asset quality, earnings and liquidity ratios), the quality of management (proxied by inefficiency ratios), and other variables representing size, audit status, ownership, bank risk and the general macroeconomic state. Several indicators – particularly inefficiency, size and the proxy for the macroeconomic state – discriminate between failed and non-failed banks.

Bongini, P., L. Laeven and G. Majnoni (2002) analyzed a sample that include a total of 29 banks, during the period January 1996-December 1998. Independent variables comprise the CAMEL specification estimated in Bongini, Claessens and Ferri (2001).Balance sheet indicators, integrated with information about banks' ownership structure, was the most effective predictor of bank distress. Ratings, on the other side showed a much lower predictive.

Demirgüç-Kunt, A. and E. Detragiache (1998) analyzed a panel that include developed and developing economies over the period 1980-1994 using multivariate logit crisis models. Authors used a large number of indicators: real gdp growth, rate of change of the NER, nominal interest rate minus the

contemporaneous rate of inflation, rate of change of the gdp deflator, budget surplus/gdp, m2/reserves, domestic credit to private sector/gdp, bank liquid reserves/assets, real domestic credit growth, dummy for an explicit deposit insurance scheme, real gdp per capita, index of the quality of law enforcement. It is found that banking crises tend to appear when the macroeconomic environment is weak, especially when inflation and real interest rate is high and growth is low.

Table 1: Literature review and the variables used

Explanatory variables used in our paper	Literature review and the variables used
Loans net growth	1) Daley, J., K. Matthews and K. Whitfield (2005): *%ΔLoans/GDP;*
Total assets growth	1) Daley, J., K. Matthews and K. Whitfield (2005): *SIZE (Total Assets deflated);* 2)G. Lanine & R. Vander Vennet, 2005: *log(ta);* 3) Lewis, J (draft paper) : *Asset Growth*
Loans to total assets ratio	1)G. Lanine & R. Vander Vennet, 2005: *Loans to total assets ratio;*
The share of common shareholders equity	1) Lewis, J (draft paper) :*Regulatory Capital/RWA*
Credit growth (aggregate index)	1) Barrell, R., E.P. Davis, D. Karim and I. Liadze (2010): *Credit Growth (%);* 2) Demirg̈uc̨-Kunt and Detragiache (1998): *Credit to private sector/GDP (%);*
Real Property Price Growth	1) Barrell, R., E.P. Davis, D. Karim and I. Liadze (2010): *Real Property Price Growth (%) (RHPG);*
Real/Nominal effective exchange rate	1) DIMAS Bagus Wiranata Kusuma, ABU Asif (2012): *Real Effective Exchange Rate;*
GDP per capita	1) E. Philip Davis, Dilruba Karim, Iana Liadze (2011): 2) Davis, E.P. and D. Karim (2008): *GDP per capita;* 2) Demirg̈uc̨-Kunt and Detragiache (1998): *GDP per capita;*
GDP growth	1) Demirg̈uc̨-Kunt and Detragiache (1998): *Gdp growth;*
Unemployment rate	1) Lewis, J (draft paper)

Net lending (+) /net borrowing (-) as percentage in GDP	1) E. Philip Davis, Dilruba Karim, Iana Liadze (2011): *Fiscal surplus/GDP (%);* 2) Barrell, R., E.P. Davis, D. Karim and I. Liadze (2010): *Fiscal surplus/GDP (%)* 3) Davis, E.P. and D. Karim (2008): *Fiscal surplus/GDP (%)* 4)Demirg̈uc ̧-Kunt and Detragiache (1998): *Fiscal surplus/GDP (%)*
Inflation rate	1)DIMAS Bagus Wiranata Kusuma, ABU Asif (2012): *inflation rate;* 2) E. Philip Davis, Dilruba Karim, Iana Liadze (2011): *inflation rate;* 3) Barrell, R., E.P. Davis, D. Karim and I. Liadze (2010): *inflation rate;* 4) Demirg̈uc ̧-Kunt and Detragiache (1998): *inflation rate;*
Change in terms of trade	1) E. Philip Davis, Dilruba Karim, Iana Liadze (2011): *change in terms of trade;* 2) Davis, E.P. and D. Karim (2008): *change in terms of trade;* 3) Demirg̈uc ̧-Kunt and Detragiache (1998): *change in terms of trade;*
Direct investment / International investment	Jahn, Nadya & Kick, Thomas, 2012: *Gross fixed investments.*

Source: authors' calculation

3. Data And Methodology

3.1. Data analysis

We analyse quarterly data from 73 european commercial banks and 11 countries: Austria (2), Danemark (21), Finland (2), France (8), Germany (3), Greece (2), Italy (12), Netharland (1), Norway (12), Portugal(4), Czech Rep. (1).The period of analysis is 2002q1-2011q4.

We define a banking crisis when provision for loan losses on total assets ratio exceeds a certain threshold. The proposed threshold is the value corresponding to the 90th quantile of the distribution of provision for loan losses on total assets ratio. Thus, the banking crisis period are the ones that register a ratio above the corresponding value of the 90th quantile. The

dependent variable is determinate based on data provided by Worldscope. The distribution of the crisis periods is presented on the bellow table.

Table 2:The distribution of the crisis periods

An	Dummy90==1
2002	22
2003	20
2004	13
2005	4
2006	2
2007	1
2008	27
2009	52
2010	34
2011	35
Total	210

Source: authors' calculation

Banking specific indicators are collected from Worldsope database and macroeconomic and fianacial variables are collected from national authorities, Eurostat data statistics and the BIS database.

Table 3: List of variables (with variable key)

	Explanatory variables	Unit of measure	Source
Banking specific indicators	Loans net growth	Growth from the previous quarter and from the last year	Worldsope
	Total assets growth	Growth from the previous quarter and from the last year	Worldsope
	Loans to total assets ratio		Worldsope
	The share of common shareholders equity to total assets		Worldsope

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	Credit growth (aggregate indicator)	Growth from the previous quarter and from the last year	BIS database
	Real Property Price Growth (residential property prices,all dwellings, pure price,q-all,nsa)	(Index= 2010) Growth from the previous quarter and growth from the last year	BIS database
	Nominal effective exchange rate (BIS effective exchange rate, Nominal, Broad Indices)	Volatility estimation based on monthly data; 2010=100	BIS database
	Real effective exchange rate (BIS effective exchange rate, Real, Broad Indices)	Volatility estimation based on monthly data; 2010=100	BIS database
	GDP per capita	Percentage change on previous period	Eurostat
	GDP per capita	Euro per inhabitant/ Percentage change on previous period	Eurostat
	GDP growth	GDP growth	Eurostat
	Unemployment rate	Unemployment rate, quarterly average, by sex and age groups (%)	Eurostat
	Net lending (+) /net borrowing (-)	Percentage of GDP (%)	Eurostat
	Inflation rate	Volatility of Growth rate on previous period (t/t-1) datas/ HICP - All items	Eurostat
	Inflation rate	Volatility of harmonized consumer price index datas, 2005=100/ HICP -All items	Eurostat
	Change in terms of trade (=Exports of goods and services/Imports of goods and services*100)	Chain-linked volumes, reference year 2000, / Percentage change t/t-4	Eurostat
	Direct investment	Percentage of the previous period	Eurostat

Macroeconomic and financial variables (row label, rotated, spanning left column)

(Net position/All countries of the world)		
International investment (Net position/All countries of the world)	Percentage of the previous period	Eurostat

Source: authors' calculation

In line with other studies (Mathias Drehmann , Mikael Juselius:2012), we derive gap measures by subtracting a one-sided Hodrick-Prescott filtered trend from the level of a series. We use these methodology for macroeconomic and financial variables. This is achieved by recursively extending the sample by one period and retaining the difference between the actual value of the variable and the value of the trend at the new point.

3.2. ROC (Reciever Operating Characteristic) and AUROC (Area under Reciever Operating Characteristic) Methodology

All ROC curves are estimated non-parametrically and it shows the tradeoff between sensitivity and specificity (any increase in sensitivity will be accompanied by a decrease in specificity). The closer the curve follows the left-hand border and then the top border of the ROC space, the more accurate the test. Also, the closer the curve comes to the 45-degree diagonal of the ROC space, the less accurate the test. The area under the curve is a measure of text accuracy. This is discussed further in the next pharagraph.. (*Ploting and interpretinc ROC curve: http://gim.unmc.edu/dxtests/roc2.htm*). The accuracy of the test depends on how well the test separates the group period with turbulence and without turbulance. Accuracy is measured by the area under the ROC curve. An area of 1 represents a perfect test; an area of 0.5 represents a worthless test. A rough guide for classifying the accuracy of a diagnostic test is the traditional academic point system. For financial and banking systems a value of 0.7-0.8 is quite high. Jorda (2011) cites other studies showing that a widely used prostate-specific antigen (PSA) blood test has an AUROC of

around 0.8 and that the S&P 500 has an AUROC of 0.86 for detecting in current time whether the economy is in recession or not.

4. Results

Before conducting our tests and estimating ROC curves and AUROC area we analyzed the behaviour of candidate variables around banking crises. After an analysis of the independent variables we found that the estimated effects is the same as we expected in the most of the cases. The unemployment rate is low before the crisis and than registered an increase in all countries. The share of common shareholder equity on total assets increase if the likelihood of a crisis increase and the Gdp per capita decrease if the likelihood of a crisis increase. In the figure below (Figure 1) we estimate ROC curves for a 2 year forecast horizon and we present only the relevant results.

Unsurprisingly, the graph mirrors the above statement. In particular, the unemployment rate, the share of common shareholder equity on total assets and the gdp per capita issue quite powerful signals. Their AUROCs are 0.64, 0.69, and 0.78, respectively (see Table 3).

Figure1   is only indicative of the performance of different indicator variables as it only looks at one particular forecast horizon. In this sub-section, we therefore derive AUROC for each year individually. Such an approach provides clear information about the time-profile and the persistency of each indicator variable.

Figure 1. ROC curves for a 2 year forecast horizon
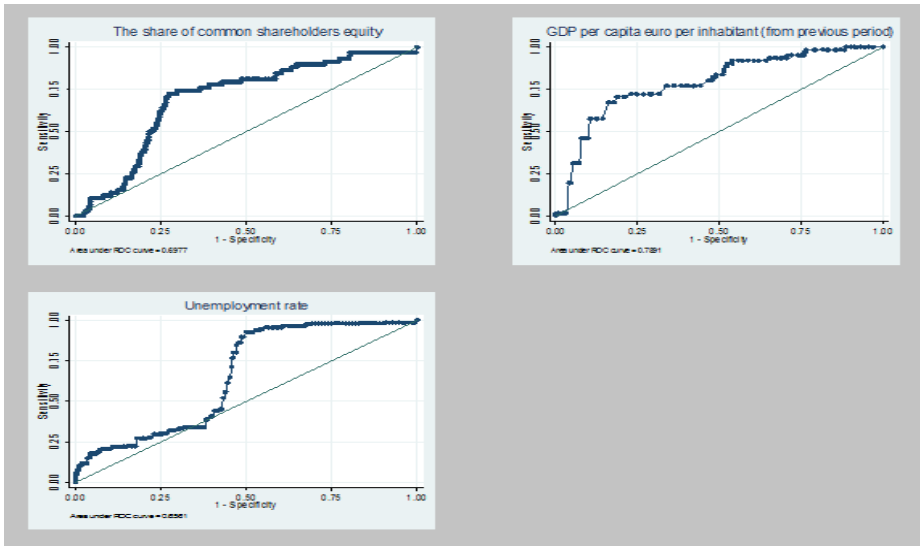
Source: authors' calculation

Table 4: AUROCs for all forecast horizons

	Independent variables	2002	2003	2004	2005	2006	2007
Banking specific indicators	Loans net growth (from previous period)	0,5610	0,6815	0,6408	0,5281	0,5168	0,4984
	Loans net growth (from previous years)		0,6192	0,5246	0,4148	0,3658	0,3304
	Total assets growth (from previous period)		0,6149	0,5893	0,4670	0,4458	0,4277
	Total assets growth (from previous year)		0,7154	0,6166	0,5138	0,4683	0,4462
	Loans to total assets ratio	0,3090	0,3257	0,4021	0,4314	0,4350	0,4271
	The share of common shareholders equity	**0,7869**	**0,7732**	**0,7108**	**0,6934**	**0,6977**	**0,7083**
and financ	Credit growth (from previous period)	0,5795	0,4625	0,3766	0,3175	0,2786	0,2917

Credit growth (from previous year)	0,5000	0,4247	0,3422	0,2848	0,2448	0,2286
Real Property Price Growth (previous period)	0,5000	0,4895	0,5110	0,5254	0,5109	0,4938
Real Property Price Growth(previous year)	0,5000	0,4895	0,5110	0,5252	0,5318	0,5106
Nominal effective exchange rate	0,1705	0,2031	0,3009	0,3574	0,3676	0,3550
Real effective exchange rate	0,5000	0,4895	0,51110	0,5254	0,5109	0,4938
GDP per capita (from previous period)	0,3481	0,4117	0,3795	0,3376	0,3283	0,3450
GDP per capita euro per inhabitant	**0,8509**	**0,8031**	**0,7695**	**0,7679**	**0,7891**	**0,8174**
GDP growth	0,6325	0,5780	0,4500	0,3642	0,3035	0,2546
Unemployment rate	**0,5877**	**0,6360**	**0,6300**	**0,6423**	**0,6463**	**0,6452**
Net lending on net borrowing	0,4506	0,4095	0,4040	0,3863	0,3718	0,3782
Inflation rate /Growth rate on previous period	0,3235	0,3341	0,3393	0,3203	0,3131	0,2992
inflation rate/ price index data, 2005	**0,8602**	**0,8249**	**0,7209**	**0,5732**	**0,4560**	**0,3765**
Change in terms of trade	0,5554	0,5777	0,5307	0,5116	0,5073	0,5037
Direct investment	**0,8050**	**0,6380**	**0,6188**	**0,5956**	**0,5401**	**0,4921**
International investment	**0,8305**	**0,6412**	**0,6202**	**0,6104**	**0,5828**	**0,5400**

Source: authors' calculation

Table 3 highlights that the time-profile of the different indicator variables differs substantially. GDP per capita's (euro per inhabitant) early warning properties are especially strong in the first two years of the analysis period (2002 and 2003). In 2002, the AUROC is 0.85% and in 2003 is about 0,80%. AUROC then drops continuously the longer the forecast horizon gets. But the performance in year 2006 and 2007 is still very good, with an AUROC

on average of 0.78 and 0.81 respectively. Thus, it is nearly a perfect indicator. The share of common shareholders equity shows a markedly different pattern. Across the 6 years, AUROC fluctuates between 0.69 and 0.79. Given the length of the forecast horizon, this performance is quietly good.

Unemployment rate shows a markedly similar pattern, the AUROC area increase over the analysed period. Across the 6 years, AUROC fluctuates between 0.58 and 0.64.

The inflation rate (price index data, 2005), direct investment and international investment is broadly similar.They are somewhat informative in predicting crises only in the period 2002-2004. However, as seen in table above they tend to decrease ahead of crisis somewhat and thus their reliability as crisis indictor decreases as well. All others indicators are essentially ineffective as EWIs.

5. Conclusions

In this paper, we argue that an important procedures used to construct and evaluate EWIs should be the selection of the independent variables. Among the considerations which seem particularly important are the relative trade-offs between type I and type II errors, as well as the timing and consistency of the EWI signals. We analyse – the ROC curve and its associated AUROC value – for assessing the performance of different EWIs. We also make novel use of these techniques to assess the timing and consistency of the EWIs over time. We find that gdp per capita, the share of common shareholders equity, unemployment rate, inflation rate (price index data, 2005), direct investment and international investment are informative variables in predicting crises periods. Our findings indicate that EWIs can have vastly different performance over time. Given the importance of consistent and timely signals for policymakers, this aspect cannot be ignored.

6. References

- Dimas Bagus Wiranata Kusuma, ABU Asif (2012) Building an Early Warning System for Islamic Banking Crisis in Indonesia Signal Approach Model, draft paper;
- E. Philip Davis; Dilruba Karim; Iana Liadze (2011) Should multivariate early warning systems for banking crises pool across regions; Rev World Econ (2011) 147:693–716;

- Barrell, R., E.P. Davis, D. Karim and I. Liadze (2010) "Bank Regulation, Property Prices and EarlyWarning Systems for Banking Crises in OECD Countries", *NIESR Discussion Paper* No.330;
- Dieter Gramlich, Gavin L. Miller , Mikhail V. Oet , Stephen J. Ong (2010), Early warning systems for systemic banking risk critical review and modeling implications, Banks and Bank Systems, Volume 5, Issue 2,
- Davis, E.P. and D. Karim (2008) ,Comparing early warning systems for banking crises, *Journal of Financial Stability* 4:89–120
- Daley, J., K. Matthews and K. Whitfield (2005) ,Too-Big-To-Fail Bank Failure and Banking Policy in Jamaica, *Cardiff Business School Working Papers*, E2006/4
- Halim, L. (2000) ,Reviving the Indonesian Banking Sector? Indonesia's Economic Crisis: Impact on Financial and Corporate Sectors 1997-1999, *Institute of Southeast Asian Studies, Visiting Researchers Series* No.7 (2000)
- Jorda, O (2011): "Anchoring countercyclical capital buffers: The role of credit aggregates: Discussion", *International Journal of Central Banking,* 7, 241-259.
- Jorda, O, M Schularick and A M Taylor (2011): "When credit bites back: Leverage, business cycles and
- Demirgüç-Kunt, A. and E. Detragiache (1998) ,Determinants of Banking Crises in Developing and Developed Countries, *Staff Papers - International Monetary Fund* 45(1):81-109
- Aharony, J. and I. Swary (1983) "Contagion Effects of Bank Failures Evidence from Capital Markets",*The Journal of Business* 56(3):305-322
- Lewis, J. An Early Warning Model of Bank Failure in Jamaica: An Information Theoretic Approach",Financial Stability Department, Research and Economic Programming Division, Bank of Jamaica
- Mathias Drehmann and Mikael Juselius, (2012): Improving EWIs for banking crises - satisfying policy requirements, draft paper;
- http://gim.unmc.edu/dxtests/roc2.htm