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Abstract: We characterize the effects of financial liberalization indices on OECD banking crises, controlling for the standard macro prudential variables that prevail in the current literature. We use the Fraser Institute's Economic Freedom of the World database. This yields a variable that captures credit market regulations which broadly measures the restrictions under which banks operate. We then test for the direct impacts of some of its components, deposit interest rate regulations and private sector credit controls, on crisis probabilities and their indirect effects via capital adequacy. Over the period 1980 – 2012, we find that less regulated markets are associated with a lower crisis frequency, and it appears that the channel comes through strengthening the defence that capital provides. Deposit interest rate liberalisation adds to the strength of capital in protecting against crises. However, private sector credit liberalisation, appears to increase the probability of having a crisis, albeit not significantly. If policy makers are concerned about the costs of low risk events, they may wish to control private sector credit even if it has a probability of affecting significantly crises of between 10 and 20 per cent.

Keywords: Banking crises, logit, current account, financial liberalisation

JEL Classification: C52, E58, G21

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1. Introduction

If we are to learn enduring lessons from the sub-prime crisis we need to know whether it was in some way unique, or whether it shared features in common with earlier banking crises. It has been linked to some factors, which are unprecedented in a narrow sense, such as "originate and distribute" models of lending and incorrectly-rated opaque financial instruments held in off-balance-sheet subsidiaries. Owing to international holdings, they generated losses across a range of banking systems, including countries whose economies showed no signs of financial stress. These innovative aspects can at most be compared in a qualitative manner with other innovations that preceded earlier crises and led to similar errors in pricing risk.[2]

Other factors can more readily be compared with earlier events. For example, in 2001-2007 there was widespread discussion of the emergence of global imbalances (large current account deficits in countries such as the US, UK and Spain, balanced by surpluses in China, Japan and Germany). Such imbalances put downward pressure on real asset returns, prompting asset price bubbles and a "hunt for yield" through financial innovation. Additionally, large scale cross border capital flows helped finance banks' expansion and raised vulnerability to the subprime crisis. Real estate prices had an impact on crisis probabilities in 2007-8, having risen sharply up to 2005-6 before falling, first in the US, then elsewhere. Rapid GDP and credit growth with low short term interest rates also preceded the subprime episode and their patterns are comparable with other crises.

The search for common macro determinants of crises has underpinned recent early warning systems (EWS) models. Logit models have shown that a high proportion of OECD crises can be explained by capital adequacy, liquidity, house price and current account imbalances (Barrell, et al., 2010; 2013). However by definition, these impacts are conditional on the regulatory environment under which banks operate since the data on crises are drawn from a distribution that is jointly determined by the regulatory architecture. Given the established links between financial liberalisation and banking system development, crises and efficiency[3], the relevance of capital and liquidity may change once regulatory variables are included. To our knowledge previous crises prediction models have ignored variables that capture the regulatory environment although studies such as Chortareas et al, (2013) imply that they should be explicitly controlled for.

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This paper constitutes the first attempt, to our knowledge, to specifically characterize the effects of financial liberalization indices on OECD banking crises between 1980 and 2012, controlling for the standard macro prudential variables that prevail in the current literature (see Barrell et. al. 2010). Over the last 30 years we have seen progressive liberalization and deregulation in most, if not all, financial markets in these economies. Changes in regulation may change bank risk taking behavior and hence change the probability of crises. To capture these dynamics we utilize the Fraser Institute's Economic Freedom of the World database. This yields a variable that captures credit market regulations which broadly measures the restrictions under which banks operate. We then test for the direct impacts of some of its components, deposit interest rate regulations and private sector credit controls, on crisis probabilities and their indirect effects via capital adequacy.

[2] Such as the syndicated loans in the Latin American debt crisis of 1982 (see FDIC, 1997).
[3] See Barth et al, (2006) and Chortareas et al, (2013).

The reminder of the paper is structured as follows. Section 2 presents some background issues which justifies our choice of explanatory variables, ensuring we avoid omitted variables bias. Section 3 presents the empirical methodology and the data. Section 4 discusses the empirical results, and Section 5 concludes.

2. Banks and the factors driving bank crises

Financial crises happen when banks lose the ability to pay their creditors and face bankruptcy either when there are depositor bank runs or because borrowers default in such large numbers that the buffer of capital is exhausted. A very simplified discussion of banks balance sheets may help us understand what we should look for in the factors determining crises. Banks take in deposits (D) in some form on which they pay interest at a rate r_d and make loans (L) or enter into other credit provision arrangements on which they charge interest r_l. Depositors may randomly withdraw these deposits and hence liquid assets (LA with a rate of return r_{ra}) have to be held. The desired liquid asset ratios will depend on the variance of deposits (var(D)) and on the availability of wholesale market liquidity.

We may write the asset side of the bank's balance sheet (AS) as

$$AS = L + LA \text{ where } LA/D = f(var(D), wholesale) \quad (1)$$

When banks make loans they take risks, and the loan book will face a default rate that will vary over time with economic conditions. The expected default rate (b) should be covered by the spread between borrowing and lending rates. Given that banks may make larger than anticipated loses on their loan portfolio in some periods they have to carry both contingency reserves and finance some of their loan book with equity. The amount of equity held will depend in part on the variance of loan losses (var(BL)) and on the cost of generating equity. The larger the quantity of equity relative to loans (E/L) the lower the probability of a bankruptcy for a given var(BL) and hence the lower the cost of capital to the bank. As bank failure may involve external social costs regulators may require banks to hold more capital to absorb losses than the banks themselves may choose.

A banking crisis might emerge either because banks do not have enough on book liquidity to meet the needs of depositors, and cannot access the wholesale market, or because loan losses have built up (or are expected to have built up) to the point where capital is expected to be exhausted. This would require a run of periods where provisions had been less than subsequent charge offs. The higher is LA/D for a given var(D) the less likely is a liquidity crisis, and the higher E/L for a given var(BL) the less likely a solvency crisis will emerge. Hence in any relatively simple banking crisis model we must include the liquid assets ratio and the equity ratios as explanatory variables. In addition we should add the determinants of the var(BL) and var(D) in any such model, as we do below.

Owing to data limitations, variables that are subject to regulatory influence, such as (weighted or unweighted) capital adequacy and bank liquidity ratios are rarely used in the existing literature. This is a paradox since these are regarded by both economists and regulators as defences against crises and where historically low levels are commonly considered to be precursors to crises (Brunnermeier et al 2009), with some commentators expressing concern about them prior to the subprime, especially the downtrend in bank liquidity. For the OECD countries included here (and

for no others) the OECD database of country-aggregates for banks' balance sheets and profit and loss does include capital, and that determines our country choice.

Indicators that would affect var(BL), as discussed in Beck et al (2006), such as growth of real GDP, changes in terms of trade and the rate of inflation can be seen to capture macroeconomic developments that affect banks' asset quality. Rapid credit growth may also indicate lax lending standards as well as potentially triggering an asset boom, as was commonly suggested prior to the subprime crisis. Lax monetary policy, as indicated by the short term real interest rate may also induce lax lending and feed asset bubbles. Fiscal deficits may also affect the risk of crises by overheating the economy. A large fiscal deficit also reduces the scope available to recapitalise banks should difficulties emerge, making a systemic crisis more likely. Fiscal difficulties were not present prior to the subprime but emerged afterwards, as the economy slowed and authorities had to recapitalise banks.

Results using these types of variables in global samples vary between papers. For example, depreciation and the terms of trade were not significant in our comparator paper, Demirguc Kunt and Detragiache (2005) as well as Beck et al (2006). Furthermore, both papers generally use contemporaneous values, and they find GDP has a negative sign, capturing the recession that typically accompanies a crisis rather than rapid growth in the lead-up to it. Correspondingly, contemporaneous interest rates and inflation have positive signs as is typical during the immediate run up to a crisis. On the other hand credit growth lagged two years has a positive sign. The use of contemporaneous variables naturally provides models without early warning properties, which we avoid by consistent use of lags in our own work outlined below.

A further problem with these traditional variables is that existing research shows that they were poor predictors of the subprime crisis when used in econometric estimation, perhaps because they have to exclude capital ad liquidity. Davis and Karim (2008) estimated a multivariate logit model for crises using a sample of 105 countries over 1979-1999, featuring 72 systemic banking crises, of which 65 were in emerging markets and 7 in OECD countries. Their significant variables were GDP growth, changes in terms of trade, GDP per capita and the M2/reserves ratio. Their logit model estimated up to 1999 is very poor at picking up the crises in 2007 and 2008 when run forward from 2000 to 2007. It predicts the lowest crisis probability in the US in 2007 (0.99 per cent) even given it uses recent values for the explanatory variables. Borio and Drehmann (2009) have similarly poor out of sample performance using credit and output as indicators. This does imply a need to look more widely that the traditional variables for banking crisis predictors in the OECD, also informed by analyses of the subprime period.

Other factor may directly affect var(BL), and the rapid growth in real estate prices was a cause for concern prior to 2007, and indeed falling US real estate prices are key background to the subprime crisis, as house prices falling below loan values let to significant levels of default. Crises are often the result of poor quality lending, especially in real estate markets, as is discussed in Reinhart and Rogoff (2009), and such variables should be included in studies of crises, but residential property prices are again only available consistently for OECD countries[4]. A boom in real estate prices frequently foreshadows a crisis since in the upturn rising asset prices provide collateral for excessive lending (the financial accelerator) while when prices fall from unsustainable levels, this process goes into reverse, sharply tightening credit conditions, while

[4] We note that house prices are correlated with prices of commercial property, which has also been a source of major bank losses during financial crises, see Davis and Zhu (2009).

overextended borrowers in the personal and construction sectors as well as property developers have strong incentives to default. Reinhart and Rogoff (2009) suggest that property price developments can change crisis probabilities, and Barrell, Davis, Karim and Liadze (2010) do find a role for these in OECD crises.

Global imbalances were a key background feature in the run up to the subprime crisis, and they may also raise var(BL). Reinhart and Rogoff (2009) suggest that widening current account imbalances have been common forerunners of banking crises in OECD, and they discuss the international finance literature which links difficulties in the external account to financial crises. Current account deficits may be accompanied by monetary inflows that enable banks to expand credit excessively, generating and reflecting a high demand for credit, as well as boosting asset prices in an unsustainable manner.[5] These trends may be exacerbated by lower real interest rates than would otherwise be the case. The existence of a current account deficit also indicates a shortfall of national saving over investment and hence a need for the banking sector to access the potentially volatile international wholesale market..

However, in the empirical literature, the balance of payments itself is not commonly employed in logit models predicting banking crises, although some variables showing external pressures on the economy and financial system are usually included.[6] When it is included it is often not significant. Hardy and Pasarbasioglu (1999) estimate logit models of crises for both advanced and developing countries and find that the current account was not significant, although the change in the gross foreign liabilities of the banking sector (which may accompany a current account deficit) is often significant with a positive sign at a longer lag and a negative sign as the crisis nears. Using a probit approach, Eichengreen and Rose (1998) again find the current account insignificant as a predictor of banking crises in developing countries. The vulnerability of the banking system to sudden capital outflows may be indicated by the ratio of their deposits to foreign exchange reserves, and this has been found to be significant in global samples, although in most countries affected in the subprime, the level of reserves was quite high.

One focus of this paper is on financial liberalisation and its effects. The idea that the liberty of individuals to pursue their economic goals is welfare improving for the whole society is as old as economics as a science itself. The development of quantitative indices of economic freedom over the last two decades, however, has allowed to explicitly analysing the effects of liberal economic institutions (or the lack of them) on economic welfare. Indeed the indices of economic freedom and the analyses based on them have uncovered the potential of economic liberalization to promote growth opportunities and wealth creation.

Using the economic freedom indices, extensive empirical evidence has been produced focusing on the effect of economic freedom on growth (e.g., De Haan and Sturm, 2000, 2003; Gwartney, 2009; Justesen, 2008; Paldam, 2003; Williamson, 2009). Other studies consider the effects of economic freedom on prosperity (Faria and Montesinos, 2009), inequality (Sala-i-Martin, 2007, Ashby and Sobel, 2008), income convergence (Xu and Haizheng, 2008) entrepreneurship (Nystrom, 2008; Bjornskov and Foss, 2008), labour markets (Feldmann, 2009) and migration flows (Ashby, 2010). Indices of economic freedom have also been used as an explanatory

[5] In addition foreigners may cease to be willing to finance deficits in domestic currencies if they consider their assets are vulnerable to monetization via inflation, and such a cessation can disrupt asset markets and banks' funding. See Haldane et al (2007) for an assessment of the impact of such a hypothetical unwinding in the US

[6] Indicators of external pressures have been used for global samples in Demirguc Kunt and Detragiache (2005) and in Beck et al (2006) which also highlights the impact of bank concentration on the risk of banking rises.

variable in financial economics (e.g., Roychoudhury and Lawson, 2010; Jones and Stroup, 2010) and in characterizing the effects of the recent global recession (Giannone, et. al., 2011).

Similarly, other studies investigate the relationship between capital adequacy and regulation however the literature on bank regulatory practices is copious. Theoretical studies emphasize the relative importance of capital adequacy requirements in bank regulation (Dewatripont and Tirole, 1993). One of the main functions of capital is the 'risk sharing function' which views capital as a buffer that allows for the orderly disposal of assets and shields debt holders from losses. If capital is adequate then assets will not have to be sold in 'fire sale', a situation that would affect both depositors' losses and, as a consequence, deposit insurance. A second key function of bank capital is that it provides owners and managers with incentives to take less risk (Gale, 2010). Nevertheless, analysts disagree as to whether the imposition of a minimum capital requirement actually reduces risk-taking incentives (Blum, 1999).

More recently, the banking literature focuses on investigating the impact of bank regulations, market structure and national institutions on banking system development, banking crises, and bank efficiency (see e.g. Demirguc-Kunt et al., 2004; Barth et al., 2006; Chortareas et al., 2012; 2013). On balance, a common thread that emerges from the abovementioned studies is that economies enjoying a high degree of economic freedom can boost bank efficiency, reduce corruption in lending, or lower banking system fragility thus achieving better economic outcomes.

Moreover, the existing research mainly focuses on aggregate freedom and not on the specific financial freedom counterparts, which gives rise to the possibility of misspecification bias (Heckelman and Stroup, 2000). To our knowledge, only one study exists that explicitly investigates various aspects of economic freedom and governance effectiveness in banking performance (Chortareas et al., 2013). Evidence suggests that the higher the degree of an economy's financial freedom, the higher the benefits for banks in terms of cost advantages and overall efficiency. From this perspective to assess the impact of economic freedom, the usefulness of regulation as a signal, and to understand the role of national institutional developments is important both for bank managers, regulators and policy makers.

Finally there is the issue of whether a constant should be included in estimation, which has not been systematically examined in the literature to date. This would allow the probability of crises to have an exogenous element, i.e. some of crises are inevitable and the subprime crisis could have been one such. This is implicit in early theoretical models of bank failures and banking crises such as Diamond and Dybvig (1983) which assumed bank failures were a form of "sunspot", arising from random shocks to depositor perceptions of the underlying solvency of banks. However, empirical work soon began to show that crises were not random, but tended to occur during recessions, and this tradition is followed in the empirical literature such as Demirguc Kunt and Detragiache (2005) cited above. As a result much of the literature does not allow for any exogenous element by omitting a constant (or similar effect) from estimation.

We do not follow the tradition in the literature of estimating a global sample, since our interest is in the role of policy instruments, capital and liquidity, and these are not available for such large samples. In addition the subprime crisis is in our view more likely to resemble average OECD crises than average global ones, which are mainly in emerging market countries. In rejecting the global approach we follow Hardy and Pararbasioglu (1999) who showed there were distinctive features of crises in Asia compared to other developed, emerging and developing countries,

Davis, Karim and Liadze (2011) who show major differences in crisis predictors between Asia and Latin America, as well as Eichengreen et al (1998) who as noted argue crises in developed countries have distinct precursors.

3. Methodology and data

We utilise the logit model which has been the standard approach to predicting crises (Demirguc Kunt and Detragiache (2005), Davis and Karim (2008)). The logit estimates the probability that a banking crisis will occur in a given country with a vector of explanatory variables X_{it}. The banking crisis variable Y_{it} is a zero-one dummy which is one at the onset of a banking crisis, and zero elsewhere. Then we have the equation:

$$\text{Prob}(Y_{it} = 1) = F(\beta X_{it}) = \frac{e^{\beta' X_{it}}}{1 + e^{\beta' X_{it}}} \tag{7}$$

where β is the vector of unknown coefficients and $F(\beta X_{it})$ is the cumulative logistic distribution. The log likelihood function is:

$$Log_e\ L = \sum_{i=1}^{n}\sum_{t=1}^{T}\left[(Y_{it} \log_e F(\beta' X_{it})) + (1 - Y_{it}) \log_e (1 - F(\beta' X_{it}))\right] \tag{8}$$

Coefficients show the direction of the effect on crisis probability, although its magnitude is conditional on values of other explanatory variables at time t. $ß_i$ represents the effect of X_i when all other variables are held at their sample mean values. We include an intercept in the regression as an indicator of the exogenous probability of a crisis. We have 29 observations in the time domain and 14 in the cross section domain, which would suggest that we might have 406 degrees of freedom (less the number of coefficients estimated) but it might be better to see the degrees of freedom as closer to 19+14 than 29*14. Hence we have to be careful not to over specify the model or include too many variables. In particular, we eschew the temptation to 'cross' variables unless we have a strong case to do so.

Our dataset includes 23 systemic and non systemic crises in OECD countries. The crises between 1980 and 2003 are from Barrell, Davis Karim, and Liadze (2010) who identified them in Canada (1983), Denmark (1987), Finland (1991 – a systemic crisis), France (1994). Italy (1990), Japan (1991 – a systemic crisis), Norway (1990 - a systemic crisis), Sweden (1991 – a systemic crisis), the UK (1984, 1991, 1995) and the US (1988). In extending the estimation further to 2008 we have used definitions from Laeven and Valencia (2010), who classified the US, the UK, Belgium, France, Germany, Denmark, Spain, Sweden (marginally) and the Netherlands as in crises. We date crises in these countries in 2008 with the UK and US having distinct crises in both 2007 and 2008. We evaluate our model using forecasts tests for 2009 to 2012, with crises taken from Laeven and Valencia in Germany and Denamark in 2009 and Spain in 2011.

Following Demirguc Kunt and Detragiache (2005), macroeconomic variables include real GDP growth (per cent) and inflation (per cent), Banking variables are the ratio M2/ Foreign Exchange Reserves (per cent) and real domestic credit growth (per cent). We follow Barrell, Davis, Karim and Liadze (2010) and include unweighted bank capital adequacy and bank narrow liquidity/assets. Other variables included are real house price growth, the real interest rate (per

cent) and the fiscal surplus/GDP ratio (per cent) and the current account as a ratio to GDP. We include a constant to allow for the hypothesis that there is an exogenous probability of a crisis occurring. We do not include some typical institutional variables because they are clearly irrelevant to OECD countries, for example, GDP per capita is broadly comparable across OECD countries, while virtually all OECD countries have some form of deposit insurance scheme Variations in the level of credit/GDP (as opposed to credit growth) may reflect the differing nature of the financial system in OECD countries (i.e. bank versus market dominated) rather than risk of crisis, and we exclude this variable as well. The above macroeconomic and financial data are from the IMF's IFS database, with the following exceptions. House prices are from the BIS database, while banks' unweighted capital adequacy is obtained from the OECD Bank Income and Balance Sheet database, except for the UK where data are obtained from the Bank of England. We use narrow liquidity[7] derived from IFS rather than the broad measure provided in the OECD Bank Income and Balance Sheet database.

Data for economic freedom are collected from the Fraser Institute (2012). There exist two major attempts to measure economic freedom producing the corresponding indexes, namely the Economic Freedom of the World Annual Reports produced by the Fraser Institute and the Index of Economic Freedom created by the Heritage Foundation and the Wall Street Journal. Although the two indexes are not identical, both are highly credible and their results are compatible in general (e.g., De Haan & Sturm, 2000).

In particular, the Fraser Institute's Economic Freedom of the World focuses explicitly on the "regulation of credit", while the Heritage Foundation focuses on the components of "financial freedom". In this paper we use the Fraser Institute for two main reasons: Firstly, the Fraser index has been extensively used in the literature when examining the relationship between banking crises and economic freedom (see e.g. Gwartney, Lawson, and Hall, 2011). As the authors point out, economic freedom can be defined as having "personal choice, voluntary exchange coordinated by markets, freedom to enter and compete in markets, and protection of persons and their property from aggression by others" as its central elements (Gwartney, Lawson, and Hall, 2011: 1). Secondly for practical purposes, data on the Heritage Foundation's variables are only available after 1995, therefore not in particular useful for the scope of the present study.

Economic Freedom of the World is an indicator for economic freedom. It measures the extent to which the policies and institutions of countries are supportive of economic freedom. Variables range in value from 0 to 10, with greater values signifying better protection of freedoms. In particular, Credit Market Regulation (CMR) is an overall indicator private versus government ownership of banks; government borrowing compared to private borrowing; and interest rate controls and the magnitude of negative real interest rates if present[8].

Moreover, we also explicitly control for the sub-components of CMR. In particular, the variable on interest rates/negative real interest rates is constructed by using data on credit-market controls and regulations. Countries with interest rates determined by the market, stable monetary policy, and positive real deposit and lending rates received higher ratings. On the other hand, a zero rating was assigned when the deposit and lending rates were fixed by the government and real rates were persistently negative by double-digit amounts or hyperinflation had virtually

[7] Narrow liquidity is defined as a sum of banks' claims on general government and the central bank, while total assets comprise foreign assets, claims on general government, central bank and private sector.
[8] See Appendix A for more details on the Fraser variables.

eliminated the credit market. The Private Sector Credit (PSC) sub-component measures the extent to which government borrowing crowds out private borrowing. If available, this sub-component is calculated as the government fiscal deficit as a share of gross saving. Since the deficit is expressed as a negative value, higher numerical values result in higher ratings. Finally, ownership of banks (OWN) variable equals the percentage of deposits held in privately owned banks. Greater values here imply more freedom in the domestic credit market.

4. Results

4.1 Estimation of a baseline model

Using these data, in line with the discussion above, we, undertook nested testing of a logit model of OECD banking crises over 1980-2008, starting from a full set of variables typically included in global banking crisis models discussed above as well as the overall liberalisation indicator. We started our analysis with all variables included, and eliminated them one at a time, removing the least significant each time and repeating the reduced regression. This procedure was terminated when only significant regressors were left in our set. Unlike Demirguc-Kunt and Detragiache (2005), all variables are lagged at least one period to provide a model able to give early warnings of crises.[9] We follow Barrell et al (2010) and lag house prices for 3 years and AIC tests suggest that for other variables the appropriate lag length could be set at one for all other variables. In general current dated variables were better on the AIC, but they could not form apart of an early warning system as they are noy known in advance. Lag length does not affect our testing procedure results, except in the case of house prices where it is clear prior events were important.

As can be seen in Table 1, all of the variables typically used in global samples are insignificant – including factors highlighted prior to the subprime such as GDP growth, credit growth and real interest rates - while the current account/GDP ratio, real house price growth, unweighted bank capital adequacy, and bank narrow liquidity/assets are significant in all specifications. The first variable to be eliminated was inflation, followed by the constant, which would suggest that there is no strong evidence that crises are inevitable and unexplainable. If they were the unexplained constant would remain significant The next variable to be deleted was the M2 to reserves indicator, which is not surprising as FX reserves take on a different function in sophisticated financial markets as compared to emerging ones. The same might be argued for the lack of significance of credit, much as we discuss in Barrell and Karim (2013) [10]. The next variables to disappear (in order) were the government budget balance, real GDP growth and the real interest rate. The capital market regulation variable disappears last, suggesting that it might have some explanatory power, and we should not e that it has the same sign as capital adequacy, suggesting that perhaps less regulated markets are less prone to crises. We are left with two defences, capital adequacy and liquidity, and two problems, previous real house price booms and significant current account deficits, as the precursors of crises in OECD countries between 1980 and 2008.

[9] As noted above, they only lag credit growth, with other variables being contemporaneous.

[10] Our result for insignificance of credit expansion is nevertheless consistent with Mendoza and Terrones (2008) who found that credit booms often link to banking crises in emerging market economies but less often in OECD countries.

Table 1: Nested testing of the crisis model, 1980-2008

Dependent Variable: Crisis Onset	Regression Stage								
	1	2	3	4	5	6	7	8	9
Capital Adequacy Ratio (-1)	-0.132 (0.41)	-0.131 (0.407)	-0.134 (0.388)	-0.137 (0.376)	-0.129 (0.395)	-0.15 (0.306)	-0.144 (0.323)	-0.158 (0.274)	-0.288 (0)
Liquidity Ratio (-1)	-0.126 (0.012)	-0.127 (0.012)	-0.129 (0.002)	-0.131 (0.002)	-0.131 (0.002)	-0.12 (0.001)	-0.117 (0.001)	-0.113 (0.002)	-0.131 (0)
□ Real House Price (-3)	0.109 (0.003)	0.109 (0.003)	0.11 (0.002)	0.109 (0.002)	0.109 (0.002)	0.101 (0.002)	0.1 (0.003)	0.102 (0.002)	0.096 (0.004)
Current Account Balance (% of GDP) (-1)	-0.098 (0.25)	-0.097 (0.244)	-0.098 (0.227)	-0.103 (0.198)	-0.104 (0.195)	-0.12 (0.1)	-0.118 (0.105)	-0.132 (0.055)	-0.156 (0.018)
Credit Market Regulation (-1)	-0.132 (0.737)	-0.129 (0.739)	-0.169 (0.176)	-0.159 (0.178)	-0.165 (0.157)	-0.149 (0.187)	-0.132 (0.225)	-0.105 (0.289)	
Real Interest Rate (-1)	0.045 (0.631)	0.041 (0.537)	0.038 (0.528)	0.036 (0.544)	0.037 (0.531)	0.037 (0.527)	0.033 (0.571)		
ΔGDP (-1)	0.092 (0.493)	0.093 (0.481)	0.092 (0.487)	0.092 (0.485)	0.089 (0.495)	0.068 (0.583)			
Budget Balance (% of GDP) (-1)	-0.039 (0.64)	-0.04 (0.624)	-0.039 (0.629)	-0.043 (0.592)	-0.043 (0.593)				
Δ Domestic Credit (-1)	0 (0.833)	0 (0.838)	0 (0.784)	0 (0.806)					
M2 Money/ Forex Reserves (-1)	0 (0.861)	0 (0.859)	0 (0.861)						
Constant	-0.4 (0.923)	-0.443 (0.912)							
Inflation (-1)	-0.008 (0.958)								

Note: Coefficient (probability). Estimation Period: 1980 - 2008

We leave the evaluation of the performance of the model to a later section where we compare it to other possible approaches to explaining crises. The in sample performance of this model is good, with 17 of the 23 crises 'called' at the sample average cut off of 0.0631 per cent, with only 28 per cent false calls. It performs particularly well in the sub-prime period on this basis, calling 8 out of 11 crises at the sample cut off. As we would expect from our discussion of banks balance sheets above, higher levels of capital and liquidity allow the banking system to absorb larger shocks. Increasing the ability to cope with deposit runs indicated by var(D) and bad loan sequences indicated by var(BL) is clearly important. In house price booms the quality of lending is likely to deteriorate, given lending assets the banks take on in such booms will sharply deteriorate in the ensuing downturn.

Crises often stem from the accumulation of foreign assets where risks are not fully appreciated, and it is possible that this accumulation shows up directly in the current account. House price booms are often generated by overoptimistic expectations and unwise lending, and they also normally are reversed. When this happens debts can turn bad, and losses may mount.[11] It is interesting to note that the penultimate deletion involved dropping the regulatory indicator, and there is a strong case for crossing it with capital to see if there is an interaction between the two variables, and we do this in Table 2 below. Our elimination sequence suggest that credit market regulation as an indicator on its own is not particularly strong, and nor is the capital adequacy ratio, but that their joint product is significant. The indicator used here is a composite, and when

[11] However, not all asset price booms and current account deficits can be treated as harbingers of crises.

used on its own, when it is larger the probability of a crisis is reduced. It is worth investigating whether this is true for its components, and we turn to those next.

Table 2: Interaction Between Credit Market Regulation and Capital Adequacy

Dependent Variable: Crisis Onset	Regression Stage									
	1	2	3	4	5	6	7	8	9	10
Credit Market Regulation*Capital Adequacy(-1)	-0.073 (0.712)	-0.073 (0.71)	-0.078 (0.685)	-0.07 (0.713)	-0.027 (0.702)	-0.015 (0.346)	-0.017 (0.258)	-0.017 (0.272)	-0.019 (0.2)	-0.03 (0)
Liquidity Ratio (-1)	-0.129 (0.011)	-0.129 (0.011)	-0.129 (0.011)	-0.129 (0.01)	-0.129 (0.01)	-0.125 (0.004)	-0.116 (0.004)	-0.114 (0.005)	-0.114 (0.006)	-0.139 (0)
Real House Price (-3)	0.107 (0.003)	0.107 (0.003)	0.107 (0.003)	0.106 (0.003)	0.108 (0.002)	0.107 (0.003)	0.1 (0.003)	0.099 (0.003)	0.101 (0.002)	0.098 (0.004)
Current Account Balance (% of GDP) (-1)	-0.103 (0.239)	-0.102 (0.232)	-0.103 (0.233)	-0.106 (0.208)	-0.103 (0.214)	-0.103 (0.214)	-0.119 (0.11)	-0.119 (0.113)	-0.135 (0.051)	-0.156 (0.019)
Constant	-3.546 (0.712)	-3.565 (0.708)	-4.028 (0.65)	-3.656 (0.675)	-1.548 (0.199)	-1.562 (0.195)	-1.381 (0.233)	-1.192 (0.286)	-0.86 (0.374)	
Real Interest Rate (-1)	0.042 (0.652)	0.041 (0.538)	0.043 (0.515)	0.04 (0.532)	0.04 (0.53)	0.042 (0.505)	0.04 (0.516)	0.035 (0.571)		
ΔGDP (-1)	0.093 (0.489)	0.094 (0.48)	0.093 (0.48)	0.094 (0.477)	0.093 (0.481)	0.093 (0.48)	0.071 (0.567)			
Budget Balance (% of GDP) (-1)	-0.036 (0.671)	-0.036 (0.66)	-0.036 (0.658)	-0.04 (0.616)	-0.043 (0.593)	-0.043 (0.595)				
Capital Adequacy Ratio (-1)	0.523 (0.769)	0.524 (0.767)	0.58 (0.738)	0.499 (0.77)	0.117 (0.861)					
Credit Market Regulation (-1)	0.224 (0.832)	0.225 (0.83)	0.271 (0.786)	0.24 (0.807)						
M2 Money/ Forex Reserves (-1)	0 (0.829)	0 (0.828)	0 (0.834)							
Δ Domestic Credit (-1)	0 (0.902)	0 (0.903)								
Inflation (-1)	-0.003 (0.986)									

Note: Coefficient (probability). Estimation Period: 1980 - 2008

4.2 Decomposing Financial Market regulations

Our indicator of regulatory intensity is a composite, made up of measures of the intensity of interest rate regulations and of private sector credit restrictions as well as including a public/private sector ownership indicator. We first replace our composite indicator with our measure of interest rate regulation, which increases over time indicating fewer regulations on deposit interest rates. We repeated our elimination procedure, and credit growth, M2 to reserves, Inflation, Real Interest Rates, the Budget balance and GDP growth all dropped out before the constant, as we can see from Table 3. The last three variables to drop out were the constant, the Capital Adequacy ratio and the Current Account. Our new variable, interest rate regulation 'knocks out' two of the explanatory variables from Table 1. We should note that the regulatory variable has a negative and significant sign suggesting that more deposit rate liberalisation reduces the risk of banking crises, perhaps because the pressure to find off balance sheet vehicles is reduced.

Table 3: Including Interest Rate Regulation in the crisis model

Dependent Variable: Crisis Onset	Regression Stage									
	1	2	3	4	5	6	7	8	9	10
Interest Rate Regulation (-1)	-0.287 (0.196)	-0.287 (0.194)	-0.283 (0.199)	-0.245 (0.223)	-0.268 (0.148)	-0.267 (0.149)	-0.266 (0.15)	-0.148 (0.13)	-0.212 (0)	-0.226 (0)
Liquidity Ratio (-1)	-0.112 (0.011)	-0.112 (0.011)	-0.114 (0.009)	-0.118 (0.005)	-0.117 (0.005)	-0.107 (0.005)	-0.106 (0.005)	-0.099 (0.007)	-0.096 (0.007)	-0.093 (0.008)
Real House Price (-3)	0.117 (0.002)	0.117 (0.002)	0.117 (0.002)	0.115 (0.002)	0.116 (0.001)	0.109 (0.001)	0.107 (0.002)	0.105 (0.002)	0.103 (0.002)	0.116 (0)
Current Account Balance (% of GDP) (-1)	-0.104 (0.219)	-0.104 (0.218)	-0.108 (0.195)	-0.101 (0.213)	-0.108 (0.157)	-0.126 (0.063)	-0.124 (0.067)	-0.121 (0.074)	-0.103 (0.087)	
Capital Adequacy Ratio (-1)	-0.102 (0.525)	-0.103 (0.503)	-0.106 (0.49)	-0.1 (0.508)	-0.107 (0.473)	-0.129 (0.366)	-0.123 (0.389)	-0.106 (0.45)		
Constant	1.006 (0.683)	1.008 (0.682)	1.077 (0.657)	0.647 (0.771)	1.016 (0.573)	1.194 (0.502)	1.302 (0.461)			
ΔGDP (-1)	0.077 (0.573)	0.077 (0.573)	0.078 (0.571)	0.089 (0.513)	0.083 (0.54)	0.06 (0.638)				
Budget Balance (% of GDP) (-1)	-0.034 (0.692)	-0.034 (0.692)	-0.038 (0.652)	-0.045 (0.574)	-0.045 (0.578)					
Real Interest Rate (-1)	0.049 (0.596)	0.049 (0.596)	0.046 (0.614)	0.019 (0.777)						
Inflation (-1)	-0.072 (0.671)	-0.072 (0.669)	-0.072 (0.668)							
M2 Money/ Forex Reserves (-1)	0 (0.847)	0 (0.846)								
Δ Domestic Credit (-1)	0 (0.991)									

Note: Coefficient (probability). Estimation Period: 1980 - 2008

It is of course not possible to say at this stage which is the 'better' model in terms of performance, as we need to look at the ability to capture crises without making false calls at various thresholds, and we delay making these comparisons until later. We first note that the interest rate regulation variable 'knocked' out the core regulatory variable, capital, and if it were the case that the two were proxies for each other the policy implications would be significant. Hence we expand the model by adding an extra variable where we multiplicatively 'cross' interest rate regulation with capital as they both entered with a negative sign,[12] and we report the results in Table 4.

Insignificant variables drop out in a similar way to the previous tests, with credit growth, M2 to reserves going first. The regulation variable on its own drops out early on when we include the cross variable for capital and regulation,. The last two insignificant variables are the unweighted capital adequacy ratio and the constant in that order. The remaining variables are the current account, the lagged growth of real house prices and liquidity along with unweighted capital adequacy multiplied by the interest rate regulation variable.

[12] As our time domain is 19 units, and our cross se tion is 14, we have to be careful about over specifying the model and hence we restrict the number of 'crosses'

Table 4: Interaction Between Interest Rate Regulation and Capital Adequacy

Dependent Variable: Crisis Onset	Regression Stage									
	1	2	3	4	5	6	7	8	9	10
Interest Rate Regulation*Capital Adequacy Ratio (-1)	-0.125 (0.418)	-0.123 (0.418)	-0.124 (0.415)	-0.074 (0.13)	-0.067 (0.143)	-0.071 (0.092)	-0.069 (0.097)	-0.069 (0.097)	-0.021 (0.12)	-0.031 (0)
Liquidity Ratio (-1)	-0.113 (0.011)	-0.113 (0.011)	-0.115 (0.009)	-0.113 (0.009)	-0.117 (0.005)	-0.116 (0.006)	-0.106 (0.006)	-0.104 (0.006)	-0.108 (0.007)	-0.13 (0)
□ Real House Price (-3)	0.121 (0.001)	0.121 (0.001)	0.12 (0.001)	0.12 (0.001)	0.118 (0.001)	0.12 (0.001)	0.111 (0.001)	0.11 (0.001)	0.104 (0.002)	0.101 (0.003)
Current Account Balance (% of GDP) (-1)	-0.112 (0.197)	-0.111 (0.198)	-0.115 (0.178)	-0.113 (0.182)	-0.105 (0.199)	-0.111 (0.15)	-0.132 (0.052)	-0.129 (0.056)	-0.14 (0.043)	-0.158 (0.018)
Constant	-4.037 (0.551)	-4.002 (0.552)	-3.953 (0.556)	-1.642 (0.165)	-1.705 (0.146)	-1.58 (0.13)	-1.361 (0.167)	-1.248 (0.191)	-0.771 (0.384)	
Capital Adequacy Ratio (-1)	1.091 (0.46)	1.083 (0.461)	1.089 (0.458)	0.604 (0.234)	0.541 (0.261)	0.575 (0.211)	0.53 (0.237)	0.537 (0.23)		
ΔGDP (-1)	0.081 (0.559)	0.081 (0.559)	0.081 (0.556)	0.078 (0.571)	0.088 (0.518)	0.083 (0.538)	0.058 (0.649)			
Current Account Balance (% of GDP) (-1)	-0.043 (0.617)	-0.043 (0.614)	-0.047 (0.579)	-0.042 (0.613)	-0.049 (0.54)	-0.05 (0.54)				
Real Interest Rate (-1)	0.044 (0.637)	0.044 (0.638)	0.041 (0.657)	0.042 (0.645)	0.015 (0.818)					
Inflation (-1)	-0.062 (0.722)	-0.06 (0.725)	-0.062 (0.719)	-0.07 (0.677)						
Interest Rate Regulation (-1)	0.241 (0.732)	0.235 (0.735)	0.243 (0.727)							
M2 Money/ Forex Reserves (-1)	0 (0.81)	0 (0.813)								
Δ Domestic Credit (-1)	0 (0.948)									

Note: Coefficient (probability). Estimation Period: 1980 - 2008

As the interest rate regulation variable was 'stronger' than the overall composite indicator, it is worth looking at its other components to see if they in some ways offset the effects on interest rate liberalisation. We looked at both the private sector credit controls indicator and the ownership indicator, and it was clear that in this sample at least ownership, which varied little over time, had little effect on the incidence of crises and we do not report the results.

Table 5 reports on the result of including the private sector capital controls indicator rather than the overall composite indicator. In the process of sequential elimination the credit control variable remains significant until two steps before the end when it is eliminated before the constant. It has a positive sign, suggesting that a reduction in private sector credit controls increases the frequency of crises, but not statistically significantly. If we are to proceed and 'cross' this variable with capital, as we have above then we must divide the capital indicator (which has a negative sign) by the privates sector credit controls indicator (which has a positive sign) in order to construct the relevant variable.

Table 5: Private Sector Credit Regulation and the Crisis model

Dependent Variable: Crisis Onset	Regression Stage								
	1	2	3	4	5	6	7	8	9
Capital Adequacy Ratio (-1)	-0.133 (0.406)	-0.132 (0.401)	-0.122 (0.418)	-0.124 (0.412)	-0.143 (0.333)	-0.175 (0.217)	-0.168 (0.235)	-0.17 (0.229)	-0.288 (0)
Liquidity Ratio (-1)	-0.099 (0.045)	-0.1 (0.041)	-0.1 (0.039)	-0.102 (0.033)	-0.1 (0.037)	-0.091 (0.051)	-0.091 (0.052)	-0.107 (0.008)	-0.131 (0)
Real House Price (-3)	0.11 (0.002)	0.11 (0.002)	0.11 (0.002)	0.109 (0.002)	0.112 (0.002)	0.101 (0.003)	0.099 (0.003)	0.1 (0.003)	0.096 (0.004)
Current Account Balance (% of GDP) (-1)	-0.092 (0.273)	-0.091 (0.268)	-0.091 (0.271)	-0.094 (0.251)	-0.113 (0.142)	-0.137 (0.045)	-0.134 (0.049)	-0.133 (0.052)	-0.156 (0.018)
Constant	-3.738 (0.181)	-3.746 (0.179)	-3.743 (0.18)	-3.638 (0.18)	-3.293 (0.214)	-2.512 (0.292)	-2.273 (0.333)	-0.947 (0.323)	
Private Sector Credit Controls (-1)	0.201 (0.406)	0.201 (0.406)	0.193 (0.421)	0.193 (0.416)	0.197 (0.398)	0.146 (0.504)	0.134 (0.536)		
ΔGDP (-1)	0.114 (0.404)	0.115 (0.395)	0.113 (0.399)	0.114 (0.394)	0.103 (0.444)	0.066 (0.597)			
Budget Balance (% of GDP) (-1)	-0.061 (0.495)	-0.061 (0.484)	-0.061 (0.484)	-0.065 (0.452)	-0.066 (0.451)				
Real Interest Rate (-1)	0.047 (0.616)	0.044 (0.493)	0.046 (0.469)	0.042 (0.493)					
M2 Money/ Forex Reserves (-1)	0 (0.799)	0 (0.797)	0 (0.811)						
Δ Domestic Credit (-1)	0 (0.821)	0 (0.823)							
Inflation (-1)	-0.006 (0.971)								

Note: Coefficient (probability). Estimation Period: 1980 - 2008

In our experiment inflation and M2 to Reserves drop out first, followed by the growth of domestic. As Barrell and Karim (2012) stress there appears to be no role for credit growth , credit to GDP or the gap between trend credit and trend GDP in any OECD based models of banking crises, at least when capital and liquidity are included it as well. Budget balances rates and GDP growth are eliminated next, followed by real interest. All 'traditional indicators are absent, and we are left with the ration of capital to privates sector credit controls, the level of the credit control variable, the constant and our four core variable, the current account, house price growth, liquidity and capital.

We can see in table 6 that private sector credit controls have a positive but insignificant impact on crisis probabilities, as does the ration of capital to controls. As we can see from Table 7 the controls indicator increases in value over time and reaches almost 10. Hence to crossed variable indicates that the majority of the impact of capital we see is offset by the cross with the private sector credit control. An increase in the indicator implies less credit restriction ,a and there is evidence that loosening restrictions raises the probability of a crisis occurring given the level of capital. The credit controls indicator and its cross with capital are clearly correlated, but when we eliminate the cross ratio (with a z of 0.184) we find that the significance level of the levels indicator of controls become less significant and we eliminate it. Clearly, these is some evidence that the reduction of credit controls raise crisis probabilities , but that evidence is not strong.

Table 6: The Effect of Capital to Private Sector Credit Ratios as Crisis Determinants

Dependent Variable: Crisis Onset	Regression Stage									
	1	2	3	4	5	6	7	8	9	10
Capital Adequacy Ratio (-1)	-1.43 (0.113)	-1.396 (0.113)	-1.362 (0.12)	-1.264 (0.138)	-1.309 (0.12)	-1.264 (0.131)	-1.243 (0.132)	-0.168 (0.235)	-0.17 (0.229)	-0.288 (0)
Liquidity Ratio (-1)	-0.106 (0.03)	-0.107 (0.027)	-0.11 (0.023)	-0.111 (0.022)	-0.102 (0.028)	-0.1 (0.03)	-0.097 (0.035)	-0.091 (0.052)	-0.107 (0.008)	-0.131 (0)
Real House Price (-3)	0.102 (0.004)	0.102 (0.004)	0.101 (0.005)	0.102 (0.004)	0.092 (0.005)	0.091 (0.006)	0.094 (0.005)	0.099 (0.003)	0.1 (0.003)	0.096 (0.004)
Current Account Balance (% of GDP) (-1)	-0.113 (0.2)	-0.109 (0.202)	-0.111 (0.184)	-0.11 (0.195)	-0.132 (0.08)	-0.132 (0.084)	-0.15 (0.036)	-0.134 (0.049)	-0.133 (0.052)	-0.156 (0.018)
Constant	-11.586 (0.06)	-11.474 (0.061)	-11.159 (0.067)	-10.713 (0.076)	-10.106 (0.086)	-9.477 (0.101)	-8.973 (0.114)	-2.273 (0.333)	-0.947 (0.323)	
Private Sector Credit Controls (-1)	1.149 (0.102)	1.128 (0.103)	1.108 (0.109)	1.086 (0.126)	1.001 (0.134)	0.956 (0.148)	0.934 (0.152)	0.134 (0.536)		
Ratio of Capital to Private Sector Credit Controls (-1)	10.477 (0.141)	10.25 (0.143)	9.996 (0.152)	9.361 (0.173)	9.465 (0.163)	9.132 (0.174)	8.816 (0.184)			
Real Interest Rate (-1)	0.062 (0.502)	0.049 (0.449)	0.043 (0.493)	0.048 (0.439)	0.047 (0.44)	0.04 (0.506)				
ΔGDP (-1)	0.12 (0.383)	0.124 (0.364)	0.125 (0.359)	0.122 (0.368)	0.087 (0.486)					
Budget Balance (% of GDP) (-1)	-0.051 (0.563)	-0.054 (0.529)	-0.059 (0.488)	-0.059 (0.488)						
Δ Domestic Credit (-1)	0 (0.606)	0 (0.626)	0 (0.651)							
M2 Money/ Forex Reserves (-1)	0 (0.719)	0 (0.708)								
Inflation (-1)	-0.033 (0.843)									

Note: Coefficient (probability). Estimation Period: 1980 - 2008

As deposit interest rate controls and private sector credit controls have opposite signs I our experiments, it is clear why the interest rate control variable is stronger that the composite of these two opposites.. As we can see from Table 7 the indicator of credit controls rises from the mid 1990s, and there is some evidence this may have raised crisis incidence. However, the interest rate regulation indicator also rose over time, and it has an offsetting effect on the crisis probability. Overall it looks as if liberalisation reduced the probability of a crisis occurring, but this was more because liability side restraints were reduced rather than coming from a change in assets side restrictions.

Table 7 Average values in six sequential periods

	1	2	3	4	5
Capital Adequacy	4.43	5.26	5.54	5.83	6.00
Interest rate regulation Indicator	8.38	9.67	9.93	9.95	9.90
Private sector Credit controls Indicator	7.77	7.75	7.78	8.61	9.09

4.3 Model Selection and the use of ROC Curves

Receiver operating characteristic (ROC) curves test the "skill" of binary classifiers and hence can be used to discriminate between competing models. In the context of logit estimators, probabilistic forecasts can be classified for accuracy against a continuum of thresholds. This generates a true positive rate and true negative rate for each threshold and correspondingly a false positive and false negative rate. In the terminology of ROC analysis, the two variables of interest are: sensitivity (true positive rate) and 1 – specificity (which is equal to the false positive rate). Sensitivity is plotted on the y-axes and 1 – specificity on the x- axes, as shown in Figure 1. At a threshold of predicted probability of a crisis being 0.001 almost all crises would be correctly called, because they have a probability in excess of this low number in the model. However, almost all other periods would face a false positive call and we would see ourselves at the top right hand corner of the diagram. As the cut off threshold falls the true positive rate falls, but in a good model it falls much less rapidly than the false positive rate.

The true positive and false positive rates encapsulate the correspondence between probabilistic forecasts and actual binary events and generate a two dimensional co-ordinate in the ROC space. In turn, the mapping between these co-ordinates and the thresholds (or decision criterion), define the ROC curve. Hence ROC curves are closely associated with the "power" of a binary predictor[13].

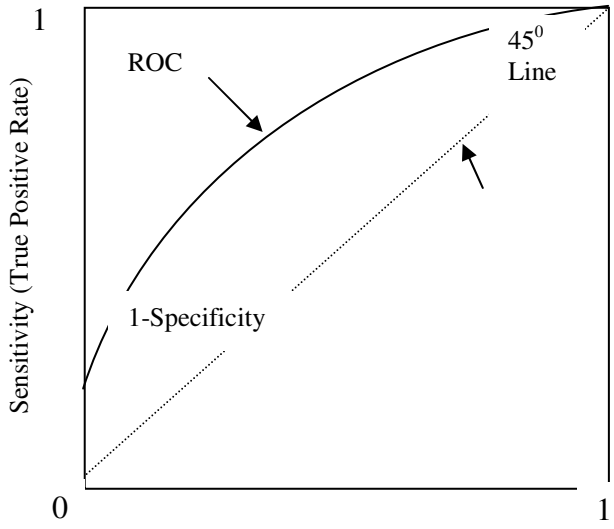


Figure 1: Receiver Operating Characteristic Curves

ROC curves have been widely used in medical research and are considered to be the most comprehensive measure of diagnostic accuracy available[14]. This is because they impound all combinations of sensitivity and specificity that the diagnostic test can provide as the decision criterion varies (Metz, 2006). Since false positive and false positive errors have very different costs in clinical terms, evaluating a predictor based solely on true positive rates can be inefficient. Similarly, in the context of early warning systems for crisis prediction, these two errors will have

[13] In practice, the ROC curve is rarely "smooth" as drawn in Figure 1 since the relationship between the true positive and false negative rates to the threshold is not necessarily monotonic over the range of thresholds.
[14] For a recent example of ROC curve usage in the context of crises, see Schularick and Taylor (2012).

different social consequences; an EWS that has a high level of sensitivity at the cost of high false positive rates may lead to "tail events" being missed with commensurate economic costs.

Since the true positive and false positive rates are functions of the threshold, a policy makers' risk attitude to crises may influence the choice of threshold and thus optimal model. Moreover once this optimal threshold is selected, an increase or decrease in the prevalence of crises will not affect the true positive or false negative rates. Thus the ranking of models based on ROC curves will vary depending on the chosen threshold range which in turn is a function of the policy maker's preferences.

To separate out preferences from the decision making process, an alternative but related "global" measure of model skill can be used to select between competing models: the Area Under the Curve (AUC). If the true positive rate declines more slowly than the false positive rate when the threshold is raised then the AUC is above a half. The larger the difference between these two rates of decline the higher the AUC. This avoids evaluating or the ranking of models at particular thresholds. An AUC of 0.5 is equivalent to a "naïve" estimator that replicates a random coin toss (corresponding to the 45^0 line) so an AUC above 0.5 implies the model adds value in terms of the ability to call crises correctly with low false negative rates.

Table 8: Area Under the Curve (AUC) and model skill

AUC = 0.5	No discrimination (equivalent to coin toss)
$0.7 \leq$ AUC < 0.8	Acceptable discrimination
$0.8 \leq$ AUC < 0.9	Excellent discrimination
AUC ≥ 0.9	Outstanding discrimination (not possible in logit frameworks)

Source: Hosmer and Lemeshow, (2000)

Table 9 indicates discrimination performance in terms of the AUC. Hosmer and Lemeshow (2000) indicate that an AUC ≥ 0.9 is highly improbable for logit models since this level of discrimination would require complete separation of the crisis and non-crisis event and the logit coefficients could not be estimated. Hence for our EWS approach we would accept models with AUCs ≥ 0.7.

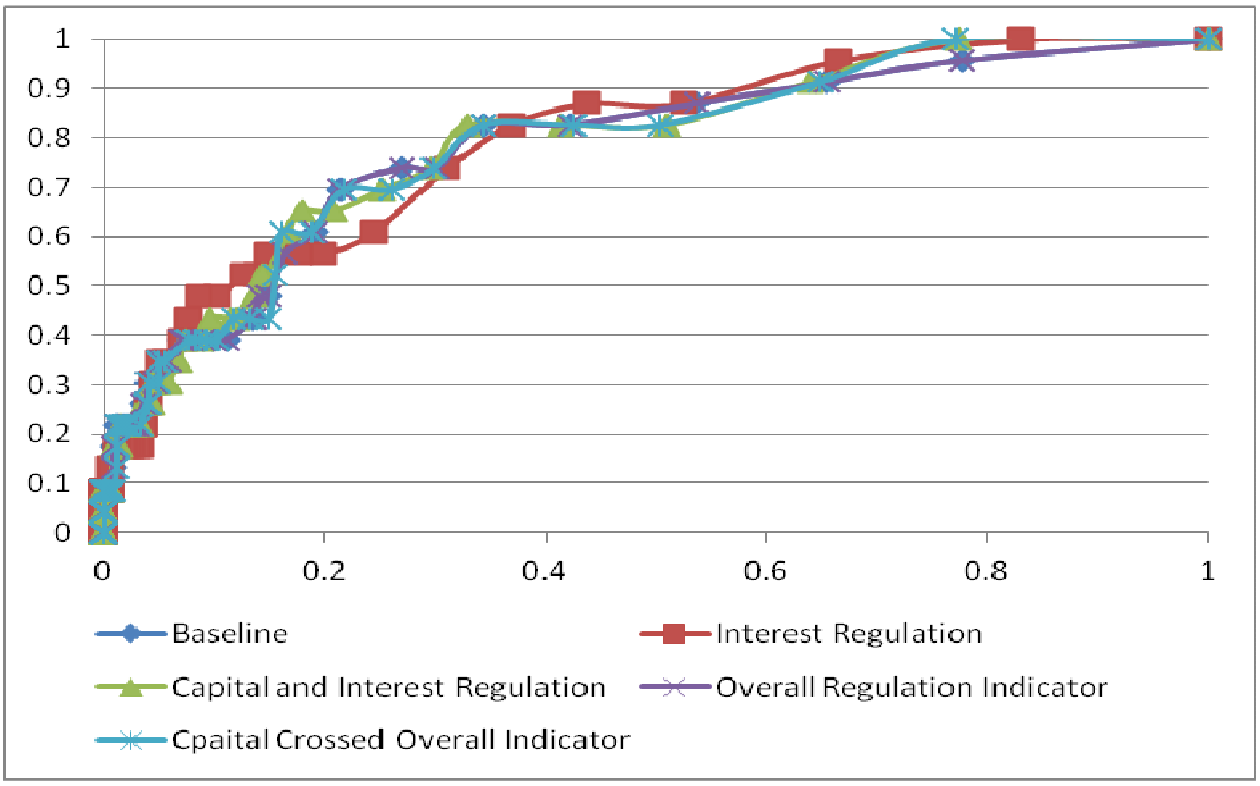
Table 9 Estimated AUCs for model selection

MODEL	Baseline		Capital and overall regulation crossed	Interest rate regulation	Capital and Interest rate regulation crossed	
AUC	0.785		0.789	0.774	0.792	

The AUCs for our competing models are given in Table 7 whilst the corresponding ROC curves are given in figure 2. All the fitted models have AUCs well above 0.70, and the baseline model outperforms that with interest rate regulation in instead of capital adequacy and it also marginally outperforms the signal to noise ratio given by the model where capital is crossed with private sector credit liberalization indices. However, the crossed models with capital and overall regulation and capital and interest rate regulation both outperform the baseline model, suggesting

that these crosses increase the generalised information content of our analysis. The model with the cross between interest rate regulation an unweighted capital adequacy contains the most generalised information, and we would say that it is our preferred model. We plot the ROC curves for our baseline model and our preferred specification, and it is clear that the interest rate regulation and its cross with capital both have marginally better discrimination at low thresholds, and given the AUC the model including capital crossed with interest rate regulation might be strongly preferred by a policy maker who was looking to operate at these low levels of probability of a crisis, which one might want to do if crises are expensive events

Figure 2 ROCs for Fitted Models



4.4 In Sample and Forecast Performance

It is common to evaluate models by their specific call rates (did they have an above sample mean predicted probability when there was a crisis) both within sample and out of sample, and it is also common to look at out of sample ROCs. We can use these to evaluate the forecast performance of our chosen model, a cross of capital with interest rate de-regulation, and we can also look at a comparison to our baseline model. We first discuss in sample call rates, especially in relation to the sub-prime crisis, and then we look at out of sample performance.

Over the period 1980 to 2008 the frequency of banking crises was 0.0631 in 406 country-years, and we can denote a predicted probability in excess of this as a 'correct call' if it took place either in the year a crisis happened or the year before the crisis occurred. On this basis the model with the interest rate liberalisation cross with capital called 11 out of 12 crises in the sub-prime period, with only one missed crisis in Germany. The German crisis did not follow on from domestic problems, but rather form excessive exposure to US sourced MBSs. On the same basis there were

only two false calls, and both occurred in Canada, where the combination of an oligopolistic banking system, a well organized central bank and close knowledge of US mortgage markets meant that fewer risks were taken than elsewhere.

	Table 9 In-sample prediction						
	Belgium	Canada	Denmark	Finland	France	Germany	Italy
2007	?	?	?	×	?	×	?
2008	?	?	?	×	?	×	×
	Japan	Neths	Norway	Sweden	Spain	UK	US
2007	×	?	×	?	?	?	?
2008	×	?	?	×	?	?	?
	Notes: The red circle highlights the Systemic Banking Crises in Laeven and Valencia						

Out of sample performance is perhaps more revealing at this threshold, and we plot calls and crises in Table 10. Laeven and Valencia (2012) suggest that there were three systemic crises after 2008, in Germany and Denmark in 2009 and in Spain in 2011. At the in sample threshold we once again fail to call Germany, but using a current or immediately prior call measure of accuracy we are able to give an early warning of the other two crises. There were 22 false crisis calls, with the largest number being in Canada (4) and in 2009 (8 out of 14). The true crisis call rate is 2/3rds whilst the false crisis call rate is just under 40 per cent. Both of which are good by the standards of the early warning literature.

Table 10 Out of sample predictions prediction

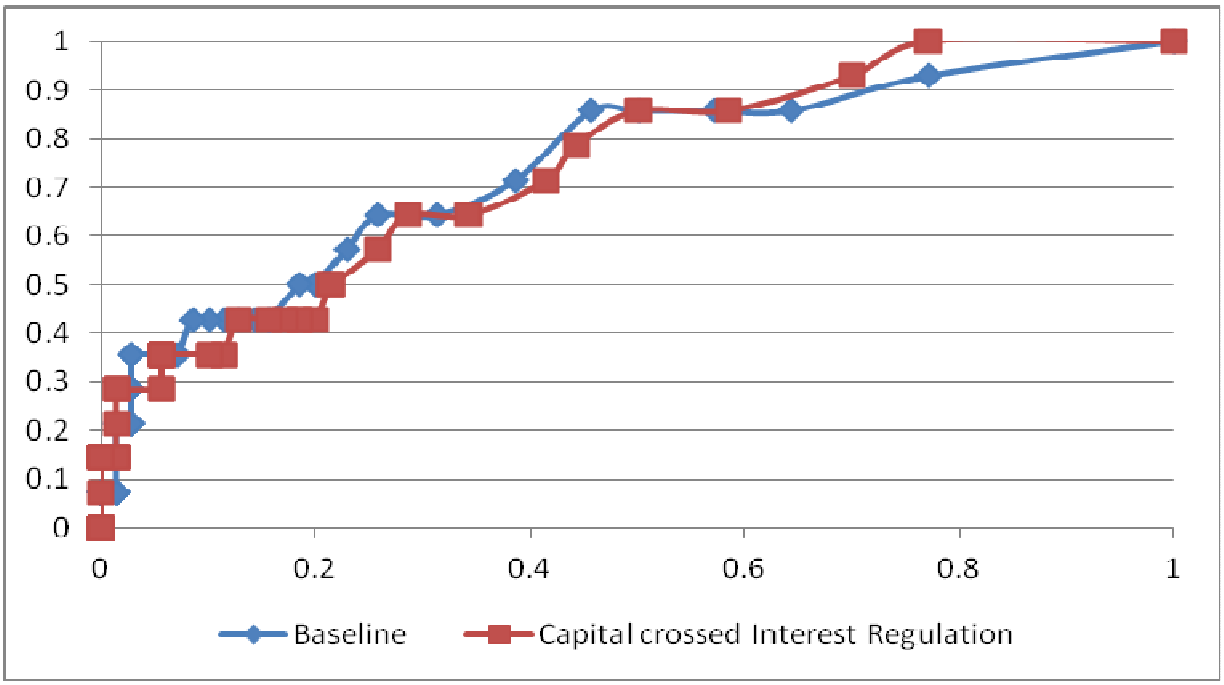
	Years			
Countries	2009	2010	2011	2012
Belgium	?	?	×	×
Canada	?	?	?	?
Denmark	?	?	×	×
Finland	?	?	×	×
France	?	?	×	×
Germany	×	×	×	×
Italy	×	×	×	×
Japan	×??	×	×	×
Neths	?	?	×	×
Norway	×	×	×	×
Sweden	?	×	×	×
Spain	?	**?**	×	×
UK	?	?	×	×
US	×	×	×	×

Notes: The red circle highlights the Systemic Banking Crises in Laeven and Valencia, with a tick/question mark denoting a call

It is best to compare the two models using ROC curves and AUC indicators. As we can see from Figure 3 the model with capital crossed with the interest rate liberalisation indicator perfoms noticeably better at low thresholds with fewer false crisis calls, but as the threshold rises the two ROCs cross, and the forecast AUC for the crossed model of 0.741 is marginally worse that the

baseline model with no regulatory indicator which has a forecast AUC of 0.743. It is hard to distinguish between these models, but if policy makers are particularly worried about low probability events they might well be better using the crossed model.

Figure 3 Forecast ROC Curves for the baseline and crossed models



5. Conclusion

It is often thought liberalisation is associated with an increased incidence of financial crises, and we test for this over the period 1980 to 2012. We have shown that the bank regulatory variables, capital and liquidity, along with asset prices and the current balance impacted on the probability of banking crises in OECD countries over 1980-2008, as did indicators of financial market liberalisation. We look at a composite indicator, and it has a role, but its components do not all have the same effect. Using the overall or composite indicator of financial liberalisation we find that less regulated markets are associated with a lower crisis frequency, and it appears that the channel comes through strengthening the defence that capital provides. Our composite indicator has three components, deposit interest rate liberalisation, private sector credit liberalisation and a private sector ownership indicator. The latter has no role in crisis determination, but the first two appear to be significant, but with opposite effects. Deposit interest rate liberalisation added to the strength of capital in protecting against crises, and its inclusion crossed with capital adequacy provides our preferred model. Controls on deposit taking and the interest paid on deposits may have induced banks into shadow markets and off balance sheet activities that were inherently more risky, and hence this liberalisation strengthened financial markets. However, when we follow the same procedure with private sector credit liberalisation, it appears to increase the probability of having a crisis, albeit not significantly. As private sector credit provision is liberalized, banking systems appear to take on more risk, and crises become more likely. If policy makers are concerned about the costs of low risk events, they may wish to control private sector credit even if it has a probability of affecting significantly crises of between 10 and 20 per cent.

REFERENCES

Abiad, A., E. Detragiache and T.Tressel (2008), "A New Database of Financial Reforms", IMF Working Paper No. 08/266, Washington, DC.

Acharya, V. and Richardson, M. (2009), "Causes of the Financial Crisis", *Critical Review*, Vol. 21, Issue 2 & 3, pages 195 – 210, June 2009.

Altunbas, Y., Gambacorta, L. and Marques-Ibanez, D. (2009), "Securitisation and the bank lending channel," *European Economic Review*, Vol. 53, No.8, 996-1009.

Ashby, N.J., 2010. Freedom and international migration. Southern Economic Journal 77(1), 49-62.

Barrell R, Davis E P, Fic T., Holland D., Kirby S., and Liadze I (2009) "Optimal regulation of bank capital and liquidity: how to calibrate new international standards" *FSA Occasional Paper no. 38, October*

Barrell R, Davis E P, Karim D and Liadze I (2010), "Bank regulation, property prices and early warning systems for banking crises in OECD countries", *Journal of Banking and Finance,* 34, 2455-64

Barrell R, Davis E P, Karim D and Liadze I (2013) Off Balance Sheet Exposures and Banking Crises in OECD Countries' *Journal of Financial Stability* (forthcoming) available as a Brunel Discussion Paper Economics discussion paper 12.05)

Barrell, R, and Karim D., (2012) 'The Role of Capital, Liquidity and credit Growth in Financial Crises in Latin America and East Asia'. Brunel University Discussion Paper

Barth, J.R., Caprio, G., Levine, R., 2006. Rethinking Bank Regulation: Till Angels Govern. Cambridge University Press, New York.

Beck, T., Demirgüc-Kunt, A., and Levine, R., (2006), "Bank concentration, competition and crises, first results", *Journal of Banking and Finance* 30, 1581-1603.

Bjornskov, C., Foss, N., 2008. Economic freedom and entrepreneurial activity: Some cross-country evidence. Public Choice 134(3-4), 307-328.

Blum, J., 1999. Do bank capital adequacy requirements reduce risks? Journal of Banking and Finance 23, 755-771.

Borio C and Drehmann M (2009) "Assessing the risk of banking crises - revisited", *BIS Quarterly Review*, March, pp 29-46.

Borio C, Drehmann M, Gambacorta L, Jimenez G and Trucharte C (2010), "Countercyclical capital buffers; exploring options", *BIS Working Paper* no. 317.

Boyd, John H., Gomis, Pedro, Kwak, Sungkyu and Smith, Bruce D. (2001). "A User's Guide to Banking Crises." *University of Texas Working Paper*.

Brunnermeier, M., A. Crockett, C. Goodhart C, A. Persaud and H. Shin (2009), "*The Fundamental Principles of Financial Regulation*", Geneva Reports on the World Economy 11, International Center for Monetary and Banking Studies and Centre for Economic Policy Research.

Caprio, G., and Klingebiel, D., (2003). "Episodes of systemic and borderline financial crises". World Bank Research Dataset.

Caprio, Gerard, Klingebiel, Daniela, Laeven, Luc and Noguera, Guillermo (2003). "Banking Crisis Database" in Honohan, Patric and Laevan, Luc (eds), "Systemic Financial Crises: Containment and Resolution", The World Bank, pp 307-340.

Chortareas, G., Girardone, C., Ventouri, A., 2012. Bank supervision, regulation, and efficiency: Evidence from the European Union. Journal of Financial Stability 8, 292-302.

Chortareas, G., Girardone, C., Ventouri, A., 2013. Financial freedom and bank efficiency: Evidence from the European Union. Journal of Banking and Finance 37(4), 1223-1231.

Cook, Nancy (2007). "Use and Misuse of Receiver Operating Characteristic Curve in Risk Prediction", Journal of the American Heart Association, 115:928-935.

Davis E P and Zhu H (2009), "Commercial property prices and bank performance", *Quarterly Review of Economics and Finance*, 49, 1431-59

Davis, E.P., and Karim, D., (2008). "Comparing early warning systems for banking crises". *Journal of Financial Stability* 4, 89 – 120.

De Haan, J., Sturm, J.E., 2003. Does more democracy lead to greater economic freedom? New evidence for developing countries. European Journal of Political Economy 19(3), 547-563.

Demirguc-Kunt, A. and Detragiache, E., 1998. The determinants of banking crises in developed and developing countries. *IMF Staff Paper*, Vol. 45, no.1.

Demirguc-Kunt, A., Laeven, L., Levine, R., 2004. Regulations, market structure, institutions and the cost of financial intermediation. Journal of Money, Credit and Banking 36, 593-622.

Demirgüç-Kunt, A and Detragiache, E (2005). "Cross-Country Empirical Studies of Systemic Bank Distress: A Survey.", IMF Working Papers 05/96, International Monetary Fund.

Dewatripont, M., Tirole, J., 1993. The Prudential regulation of banks. Cambridge: Cambridge University Press.

Diamond, Douglas W and Dybvig, Philip H, (1983). "Bank Runs, Deposit Insurance, and Liquidity," Journal of Political Economy, University of Chicago Press, vol. 91(3), pages 401-19, June.

Eichengreen, B and Rose A (1998). "Staying Afloat When the Wind Shifts: External Factors and Emerging-Market Banking Crises," NBER Working Paper 6370 (January).

Faria, H.J., Montesinos, H.M., 2009. Does economic freedom cause prosperity? An IV Approach. Public Choice 141(1-2), 103-127.

Feldmann, H., 2009. The unemployment effects of labor regulation around the world. Journal of Comparative Economics 37(1), 76-90.

Gale D. 2010. Capital regulation and risk sharing. International Journal of Central Banking 6(4), 187-204.

Giannone D., Lenza, M., Reichlin, L., 2011. Market freedom and the global recession. IMF Economic Review 59(1), 111-135.

Gwartney, D.J., 2009. Institutions, economic freedom, and cross-country differences in performance. Southern Economic Journal 75(4), 937-956.

Haldane A, Hall S and Pezzini S (2007)_, "A new approach for assessing risks to financial stability" Financial Stability Paper No 2

Hardy, D. C; Pazarbasioglu, C (1999), "Leading Indicators of Banking Crises: Was Asia Different?", *IMF Staff Papers*, 46, 247-258

Heckelman, J.C., Stroup, M.D., 2000. Which economic freedom contributes to growth?. Kyklos 53, 527-544.

Hosmer, D.W. and Lemeshow, S. (2000). "Applied Logistic Regression". 2nd ed. John

Jones, S.K., Stroup, M.D., 2010. Closed-end country fund premiums and economic freedom. Applied Financial Economics 20(21), 1639-1649.

Jorda, O., M.Schularick, and A. M. Taylor (2012) 'Financial Crises, Credit Booms, and External Imbalances:140 Years of Lessons ' IMF Economic Review:

Justesen, M.K., 2008. The effect of economic freedom on growth revisited: New evidence on causality from a panel of countries 1970-1999. European Journal of Political Economy 24(3), 642-660.

Kaminsky, L.G. and Reinhart, C.M. (1999). "The Twin Crises; the Causes of Banking and Balance of Payments Problems", *American Economic Review*, Vol. 89, No. 3,

Kaufmann, S and Valderrama, M T (2007). "The Role of Credit Aggregates and Asset Prices in the Transmission Mechanism: a Comparison between the Euro area and the US", *ECB Working Paper Series* No.816.

Laeven, L., and Valencia, F., (2012). Resolution of banking crises. IMF Working Paper No. WP/12/146

Laeven, L., and Valencia, F.,(2010), Resolution of Banking Crises: The Good, the Bad, and the Ugly, IMF working paper 10/146.

Mendoza, E. G. and Terrones, M. E., (2008). "An anatomy of credit booms: evidence from macro aggregates and micro data". *NBER Working Paper*, no.14049.

Metz, Charles, E. (2006). "Receiver Operating Characteristic Analysis: A Tool for the

Nystrom, K., 2008. The institutions of economic freedom and entrepreneurship: Evidence from panel data. Public Choice 136(3-4), 269-282.

Paldam, M., 2003. Economic freedom and the success of the Asian tigers: An essay on controversy. European Journal of Political Economy 19(3), 453-477.

Quantitative Evaluation of Observer Performance and Imaging Systems". Journal of the American College of Radiology, Volume 3, Issue 6, June 2006, Pages 413-422.

Reinhart, Carmen M. and Kenneth S. Rogoff. (2009) "*This Time it's Different: Six Centuries of Financial Folly*", Princeton University Press

Reinhart, M.C., and Rogoff, S.K., (2008), "Is the 2007 US sub-prime financial crisis so different? An international historical comparison", *American Economic Review* vol 98 issue 2, 339-44.

Repullo, R., and Saurina, J., (2012) 'The Countercyclical Capital Buffer in Basel III; a critical assessment' in The Crisis Aftermath: M. Dewatripoint and Xavier Freixas CEPR

Roychoudhury, S., Lawson. R.A., 2010. Economic freedom and sovereign credit ratings and default risk. Journal of Financial Economic Policy 2(2), 149-162.

Sala-i-Martin, X., 2007. Global inequality fades as the global economy grows. In T. Kane, Holmes, K.R., O'Grady, M.A. (eds) 2007. Index of economic freedom: The link between economic opportunity and prosperity. The Heritage Foundation and Dow Jones & Company Inc.

Saurina, J., (2011) 'Countercyclical macro prudential tools' *National Institute Economic Review* April 2011 no 216 pp r 16-28

Williamson, C.R., 2009. Informal institutions rule: Institutional arrangements and economic performance. Public Choice 139(3), 371-387.

Xu, Z., Haizheng, L., 2008. Political freedom, economic freedom, and income convergence: Do stages of economic development matter? Public Choice 135(3-4), 183-205.

Appendix A:

Variable	Category	Description
Economic Freedom - Fraser Variables		
CMR	Credit Market Regulations	The indicators included in the index for credit market freedom are: (1) private versus government ownership of banks; (2) government borrowing compared to private borrowing; and (3) interest rate controls and the magnitude of negative real interest rates if present.
OWN	Ownership of Banks	Data on the % of bank deposits held in privately owned banks are used to construct rating intervals. Countries with higher shares of privately held deposits received higher ratings.
PSC	Private Sector Credit	This variable measures the extent to which government borrowing crowds out private borrowing. Since the deficit is expressed as a negative value, higher values are associated in higher ratings.
IR_REG	Interest rate controls/negative real interest rates	This variable is constructed using data on credit-market controls and regulations. Greater values are allocated to countries where interest rates determined by the market, monetary policy is stable, and there are positive real deposit and lending rates.

Sources: 2012 Economic Freedom Dataset, published in Economic Freedom of the World: 2012 Annual Report
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