26th April 2010

THE IMPACT OF GLOBAL IMBALANCES: DOES THE CURRENT ACCOUNT BALANCE HELP TO PREDICT BANKING CRISES IN OECD COUNTRIES?

R Barrell[1], E P Davis, D Karim, I Liadze[2]
NIESR and Brunel University

Abstract: Given the magnitude of "global imbalances" in the run-up to the subprime crisis, we test for an impact of the current account balance on the probability of banking crises in OECD countries since 1980. This variable has been neglected in most early warning models to date, despite its prominence in theory and in case studies of crises. We find that a current account variable is significant in a parsimonious logit model also featuring bank capital adequacy, liquidity and changes in house prices, thus showing the patterns immediately preceding the subprime crisis were not unprecedented. Our model, even if estimated over an earlier period such as 1980-2003, could have helped authorities to forecast the subprime crisis accurately and take appropriate regulatory measures to reduce its impact.

Keywords: Banking crises, logit, current account, banking regulation

JEL Classification: C52, E58, G21

[1] We would like to thank the ESRC for funding for this research and colleagues at the FSA in the UK for comments received on earlier versions, as well as Charles Goodhart and Martin Weale for comments on the current paper.
[2] E-mail addresses: rbarrell@niesr.ac.uk (R Barrell), e_philip_davis@msn.com (E P Davis), dilruba.karim@brunel.ac.uk (D Karim), iliadze@niesr.ac.uk, (I Liadze).

1 Introduction

The recent sub-prime related financial crises have frequently been linked with the emergence of global imbalances, which entailed large current account deficits in countries such as the US, UK and Spain, balanced by surpluses in China, Japan and Germany. These were thought in turn to induce downward pressure on real asset returns, prompting price bubbles and a "hunt for yield", as well as large scale cross border capital flows which helped finance banks' expansion. Whereas current account imbalances and related heavy net capital inflows are a well established feature of emerging market banking crises, they have not been seen as an indicator of systemic risk for OECD countries, partly because being more creditworthy they are less susceptible to "sudden stops" in overall inflows. Nevertheless, the question arises whether the patterns seen prior to the subprime crisis were unique to the current period or whether capital inflows corresponding to weak current accounts were common features of financial crises in OECD countries in the past. Accordingly, in this paper we seek to assess whether current account balances are helpful predictors of banking crises in logit models of OECD banking crises when tested alongside control variables common in the literature.

The paper is structured as follows. In the first section, we discuss the case for the relevance of the current account for OECD country banking crises generally, and establish that there is a strong case for assessing it, although much of the empirical literature omits it from consideration. In the second section we consider variables that need to be included to allow us to determine the most likely factors associated with financial crises and also to avoid omitted variables bias. Typically different sets of variables are found significant in global samples (see for example Demirguc Kunt and Detragiache (2005)) and in work on OECD crises (Barrell et al 2009 and 2010a). In the third section we outline our methodology, dataset (which includes both global and OECD-specific variables) and sample (OECD only from 1980-2008).

In the fourth section, we go on to test for precursors of crises, starting from a general equation. In line with Barrell et al (2010a), we find a role for unweighted bank capital adequacy, banks' (narrow) liquidity ratios and lagged house price growth as independent variables, but also for the current account/GDP ratio. The in-sample performance of our equation is very good. In the fifth section, we test the robustness of the specification by excluding countries and observations, and find it to be remarkably stable. Furthermore, the subprime crises in the US, UK, Belgium and France were predictable using parameters estimated on data up to 2003 with actual outturns for (the lagged) right hand side variables. In the final section, we focus on the US and derive the factors underlying growing vulnerability in the run up to the subprime crisis, as well as using the model to show the degree of regulatory policy tightening needed to offset the risks presented by developments in the other predictor variables. The optimal degree of tightening has to be evaluated by comparing expected costs and expected benefits, as Barrell et al (2009) do for the UK in the run up to crisis that developed in 2007 and 2008. This paper provides one side of such an analysis, and further work on the costs of regulatory tightening is needed.

1 The current account and banking crises

There has been considerable comment on the growth of global imbalances as determinants of the most recent crisis. For example, Barrell and Davis (2008) cited "low global interest rates, arising in turn from high levels of global liquidity as countries such as China built up current account surpluses and foreign exchange reserves, maintaining artificially low exchange rates and a positive saving investment balance. As a result of such pressure, global real interest rates fell after 2001Q1 and long-term real rates were probably 100 or more basis points below their level of the previous decade. This in turn contributed to rapid credit expansion and rising asset prices

which preceded the crisis". The pattern of current accounts over the sample is shown in Table 1. The longstanding deficit patterns in Spain, the UK and US as well as Italy towards the end of the sample are noteworthy.

Table 1: Current account balance as a per cent of GDP

	Belgium	Canada	Denmark	Finland	France	Germany	Italy	Japan	Neths	Norway	Sweden	Spain	UK	USA
1980	-3.4	-2.1	-3.5	-2.5	-0.6	-1.7	-2.3	-1.1	-0.5	1.5	-3.2	-2.4	0.7	0.1
1981	-3.5	-4.2	-3.2	-0.9	-0.8	-0.8	-2.4	0.4	2.4	3.0	-2.3	-2.6	1.9	0.2
1982	-2.3	0.6	-4.0	-1.8	-2.2	0.7	-1.8	0.7	3.4	0.9	-3.1	-2.3	0.8	-0.2
1983	-0.4	-0.7	-2.4	-2.2	-0.9	0.5	0.2	1.7	3.5	2.9	-0.7	-1.7	0.4	-1.1
1984	-0.1	-0.4	-3.1	0.0	-0.2	1.3	-0.8	2.8	4.8	4.3	0.7	1.1	-0.4	-2.4
1985	0.7	-1.6	-4.6	-1.3	-0.1	2.5	-1.0	3.7	3.2	4.4	-1.0	1.5	-0.2	-2.8
1986	2.2	-3.0	-5.4	-1.0	0.3	3.9	0.3	4.2	2.4	-5.0	0.0	1.6	-0.9	-3.3
1987	1.6	-3.2	-2.8	-1.8	-0.5	3.5	-0.3	3.5	1.8	-3.7	0.0	0.0	-1.7	-3.4
1988	1.9	-3.0	-1.2	-2.5	-0.5	4.0	-0.8	2.7	2.9	-3.3	-0.3	-1.0	-4.1	-2.4
1989	1.9	-3.9	-1.0	-4.8	-0.5	4.2	-1.4	2.2	4.2	0.2	-1.5	-2.7	-4.9	-1.8
1990	1.5	-3.4	1.0	-5.0	-0.8	2.8	-1.5	1.6	2.7	2.6	-2.5	-3.4	-3.8	-1.4
1991	2.0	-3.7	1.5	-5.3	-0.5	-1.3	-2.0	2.1	2.4	3.4	-1.8	-3.5	-1.8	0.1
1992	2.5	-3.6	2.8	-4.6	0.3	-1.1	-2.3	2.8	2.1	2.8	-3.2	-3.5	-2.1	-0.8
1993	4.4	-3.9	3.4	-1.3	0.7	-1.0	0.8	3.0	4.0	2.3	-2.0	-1.1	-1.9	-1.3
1994	4.4	-2.3	2.1	1.1	0.5	-1.4	1.2	2.8	4.9	2.2	0.4	-1.2	-1.0	-1.7
1995	4.2	-0.8	1.1	3.9	0.7	-1.2	2.2	2.2	6.2	2.6	2.0	-0.3	-1.2	-1.5
1996	4.2	0.6	1.7	3.9	1.3	-0.6	3.2	1.4	5.1	5.2	2.1	-0.4	-0.8	-1.6
1997	4.8	-1.3	0.5	5.4	2.7	-0.5	2.7	2.3	6.5	4.8	2.9	-0.1	-0.1	-1.7
1998	4.1	-1.2	-1.1	5.6	2.6	-0.8	1.6	3.1	3.2	0.0	1.8	-1.1	-0.4	-2.5
1999	4.9	0.3	1.8	6.2	3.2	-1.3	0.7	2.6	3.8	4.3	2.3	-2.9	-2.4	-3.2
2000	3.8	2.7	1.4	8.7	1.7	-1.8	-0.5	2.5	1.9	12.9	2.7	-4.0	-2.6	-4.3
2001	5.0	2.3	3.0	9.6	1.9	0.0	-0.1	2.2	2.4	13.8	3.0	-4.0	-2.1	-3.8
2002	4.7	1.7	2.0	8.8	1.4	2.0	-0.8	2.9	2.5	10.4	5.2	-3.3	-1.7	-4.4
2003	4.1	1.2	3.3	5.1	0.8	1.8	-1.3	3.2	5.5	10.2	7.3	-3.5	-1.6	-4.8
2004	3.5	2.3	2.5	6.5	0.6	4.6	-0.9	3.7	7.5	11.0	6.8	-5.3	-2.1	-5.3
2005	2.6	1.9	4.4	3.6	-0.6	5.2	-1.7	3.7	7.3	15.3	7.0	-7.4	-2.6	-5.9
2006	2.0	1.4	2.9	4.5	-0.7	6.1	-2.6	3.9	9.3	17.4	8.4	-8.9	-3.4	-6.0
2007	1.7	0.9	1.0	4.0	-1.2	7.5	-2.4	4.8	7.7	15.7	8.4	-10.1	-2.8	-5.3

A number of potential links can be traced from current account deficits to risk of banking crises. For example, deficits may be accompanied by monetary inflows that enable banks to expand credit excessively and they may accompany an overheating economy. This may both generate and reflect a high demand for credit, as well as boosting asset prices in an unsustainable manner. These trends may be exacerbated by lower real interest rates than would otherwise be the case. The existence of a current account deficit may also indicate a shortfall of national saving over investment and hence a need for the banking sector to access the potentially volatile international wholesale market. In addition foreigners may cease to be willing to finance deficits in domestic currency if they consider their assets are vulnerable to monetization via inflation, and such a cessation can disrupt asset markets and banks' funding.[3].

There remain arguments that OECD countries should be less vulnerable to external pressures leading to banking crises than are emerging market and developing countries. For example, given typically low inflation, sound accounting systems and legal frameworks in OECD countries, there is scope for local firms to borrow abroad in domestic currency and the domestic currency can be used domestically to finance long-term borrowing As noted by Eichengreen and Rose (1998), OECD countries should be less vulnerable to terms of trade shocks affecting the external sector, given more diversified industrial structures. There is scope for hedging exchange rate risk in derivatives markets. The quality of bank supervision and regulation should be higher and bank liabilities are longer-maturity on average.

[3] See Haldane et al (2007) for an assessment of the impact of such a hypothetical unwinding in the US.

Reinhart and Rogoff (2009) suggest that widening current account imbalances have been common forerunners of banking crises in OECD, and a significant portion of the international finance literature links difficulties in the external account to financial crises. A typical example is McKinnon and Pill (1994) who show capital inflows in a weakly regulated banking system with a safety net may lead to overlending cycles, consumption booms, rising asset prices and further increases in current account deficits. This pattern leads in turn to exchange rate appreciation and loss of competitiveness and a slowdown in growth, much as we saw in the US in the middle of the last decade. It is also common that this leads to a banking crisis and a collapse in the currency, again much as we saw in the US toward the end of the last decade.

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. Indictors 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. 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. In terms of simple statistical calculations. Reinhart and Reinhart (2008) derive a global sample of "capital flow bonanzas" which are based on the 20th percentile of levels of the current account/GDP ratio. They find that countries with such bonanzas are significantly more likely to have a banking crisis in the three years before or after such a bonanza[4].

2 Other key banking crisis determinants

We wish to systematically test the current account/GDP ratio in the context of other key banking crisis predictors so that positive estimation results are robust. The tradition in the literature is to estimate global samples of banking crises using key macroeconomic and financial variables (see Demirguc Kunt and Detragiache 2005), so part of our assessment of the current account is to test against the set of variables used in such studies. The possible set of variables, not all of which are relevant to this OECD oriented study can be usefully divided into macroeconomic, banking, policy and institutional variables.

- In terms of macroeconomic indicators, as discussed in Beck et al (2006), variables such as growth of real GDP, changes in terms of trade and inflation can be seen to capture macroeconomic developments that affect banks' asset quality.[5]
- The vulnerability of the banking system to sudden capital outflows may be indicated by the ratio of their deposits to foreign exchange reserves. Credit growth may indicate lax lending standards as well as potentially triggering an asset boom.
- 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

[4] Kaminsky and Reinhart (1999) do not use the balance of payments as a leading indicator but they do use terms of trade, foreign reserves and exports which do relate to the balance of payments

[5] We note that depreciation and the terms of trade were not significant in our comparator paper, Demirguc Kunt and Detragiache (2005).

of crises by overheating the economy. A large fiscal deficit also reduces scope to recapitalise banks should difficulties emerge, making a systemic crisis more likely.

- Institutional variables such as a deposit insurance scheme may lead to greater moral hazard for banks. Structural features of bank regulation, the legal framework and economic freedom (Barth et al 2004) may also be used as institutional controls, but many of these indicators vary little across the OECD.

Some of these may be seen as defences against crises and others as indicators of risk, and this distinction is important in Barrell et al (2010a) who assess crises in OECD countries. They were able to test not only the above indicators but also to utilise some key variables that are subject to regulatory influence and that are regarded as defences against crises and where historically low levels are commonly considered to be precursors to crises (Brunnermeier et al 2009). These are unweighted capital adequacy and bank liquidity ratios, although they are not typically available across a global sample. Capital is a buffer that protects banks against losses, so a higher level of capital makes banks more robust to shocks. Lower capital not only leaves banks more vulnerable to shocks but also offers incentives for risk taking due to the moral hazard generated by the mispriced "safety net" of lender of last resort and deposit insurance. Equally, liquidity ratios show the degree to which banks are robust to sudden demands for withdrawal by depositors. Crises are often the result of poor quality lending, especially in real estate markets, as is discussed in Reinhart and Rogoff (2009) but residential property prices are only available consistently for OECD countries[6]. Barrell et al (2010a) found a significant role for house prices, and we investigate their role further below.

3 Methodology and data

We utilise the multinomial logit, the workhorse 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:

$$\mathrm{Prob}(Y_{it}=1)=F(\beta X_{it})=\frac{e^{\beta' X_{it}}}{1+e^{\beta' X_{it}}} \qquad (1)$$

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

$$Log_e\ L=\sum_{i=1}^{n}\sum_{t=1}^{T}\left[\left(Y_{it}\log_e F(\beta' X_{it})\right)+\left(1-Y_{it}\right)\log_e\left(1-F(\beta' X_{it})\right)\right] \qquad (2)$$

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 do not follow the tradition in the literature of estimating a global sample, since our interest is in the potentially distinctive features of crises in OECD countries, following the argument that

[6] 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).

different predictors may be relevant. 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, as well as Eichengreen et al (1998) who as noted argue crises in developed countries have distinct precursors. Our earlier work cited above (Barrell et al 2009 and 2010a) focused only on the OECD countries and found distinctive determinants of crises. We contend that this partly reflects differences in financial structure in advanced countries vis a vis emerging market and developing economies, but also the availability of consistent data on property prices, bank capital adequacy and liquidity that are not generally available for non-OECD countries.

Table 2: List of systemic and non-systemic crises

	BG	CN	DK	FN	FR	GE	IT	JP	NL	NW	SP	SD	UK	US
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	1	0	0	**1**	0	0	0	0
1991	0	0	0	**1**	0	0	0	**1**	0	0	0	**1**	1	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**
2008	1	0	0	0	1	1	0	0	1	0	0	0	**1**	**1**

Note:BG-Belgium, CN-Canada, DK-Denmark, FN-Finland, FR-France, GE-Germany, IT-Italy, JP-Japan, NL-Netherlands, NW-Norway, SP-Spain, SD-Sweden, UK-United Kingdom, US-USA.

Our dataset includes 20 systemic and non systemic crises in OECD countries. The bulk of crises are from the World Bank database of banking crises from 1974-2002, dated 2003. This was updated using the IMF Financial Crisis Episodes database, which show the US and UK only as having crises in 2007.[7] In extending the estimation further to 2008, which is not covered by these

[7] Note that in preferring the World Bank data for the pre-2002 period, we are retaining a 1991 onset date for the crisis in Japan rather than 1997 in the IMF work and 1990 for Norway rather than 1991 as in the IMF data. We note that other authors such as Demirguc Kunt and Detragiache (2005) and Reinhart and Rogoff (2009) concur with an earlier date for the Japanese crisis onset (in their case 1992) – 1997 was more an aggravation of an existing crisis situation. Meanwhile for Norway, the banks' guarantee fund was already depleted in 1990, serious problems of loan

databases, we have used definitions from Borio and Drehmann (2009), whose Definition 1 suggests a crisis occurs in "countries where the government had to inject capital in more than one large bank and/ or more than one large bank failed". By the end of January 2009 this definition classified the US, the UK, Belgium, France, Germany 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. The full set of crises is shown in Table 2, with systemic crises shown in bold.

Following the discussion above, we include macroeconomic, banking-sector and policy variables from the existing literature as potential predictors to control for omitted variables bias. Besides the current account/GDP ratio (CBR), macroeconomic variables are real GDP Growth (%) (YG), inflation (%) (INFL), and real house price growth (RHPG). Banking variables are the ratio M2/ Foreign Exchange Reserves (%) (M2RES), real domestic credit growth (%) (DCG), unweighted bank capital adequacy (LEV) and bank narrow liquidity/assets (NLIQ). Policy variables are the real interest rate (%) (RIR) and the fiscal surplus/GDP ratio (%) (BB). 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. Institutional features of bank supervision as well as banking sector concentration were found insignificant in our earlier work (Barrell et al 2010a). Meanwhile 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.

The above macroeconomic and financial data are from the IMF's IFS database, with the following exceptions. House prices are from NIESR's NiGEM database, while banks' unweighted capital adequacy (LEV) is obtained from the OECD Bank Income and Balance Sheet database, except for the UK where data are obtained from the Bank of England. Unlike Barrell et al (2010a) we use narrow liquidity[8] (NLIQ) derived from IFS[9] rather than the broad measure provided in the OECD Bank Income and Balance Sheet database. This is because OECD broad liquidity includes private sector securities, whose illiquidity was an Achilles heel of banks in the recent crisis.

---

losses had appeared at the larger banks, while the government announced the setting up of a Government Bank Insurance Fund at the end of that year.

[8] 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.

[9] Narrow liquidity is calculated based on IFS series for all countries (except for the UK where the source is the FSA). The lowest ratio averaged over the whole sample is in the UK ratio where it averaged 5%, comparable nonetheless with other countries such as Finland (7%) and the US (11%). Some countries had high ratios on this basis particularly in the early years of the sample, which may be attributable to high holdings of government bonds by EU banks in countries such as Italy, Spain and Belgium. It is notable that there has been a convergence in most countries on much lower levels of narrow liquidity in the most recent data shown. In 2007, 9 countries including the UK had narrow liquidity ratios of below 10%. We note that EU member countries report only aggregated data on banking institutions which include money market funds, unlike non-EU countries where disaggregated data is available and depository banks series are used for calculations. Money market funds are important retail outlets in the US, and need to be distinguished from other institutions. They are less important in most EU countries, with the possible exception of France. Their inclusion must remain an empirical matter. Furthermore, a currency regime switch in 1999 (from national to Euro) may have caused a break in some country series, but we cannot check our sample for a break in 1999 as from 1999 to 2006 there have been no occurrences of the crises and logit estimation over this period cannot be ran. At the same time there are no overlapping series available at our disposal in 1999 which could have allowed us to assess the scale of a change in the underlying data. On the other hand since we are using ratios, the problem caused by the redenomination may not be so great as if we were using levels or differences of the raw data.

4 Estimation

Using these data, in line with the discussion above, we tested for effect of the current account in a logit model of OECD banking crises over 1980-2008, undertaking nested testing of the equation, starting from a full set of variables typically included in global banking crisis models such as Demirguc Kunt and Detragiache (2005) as well as the earlier work on the OECD of Barrell et al (2009 and 2010a). Hence our independent variables, as above, are the current account/GDP ratio (CBR), real GDP Growth (%) (YG), inflation (%) (INFL), real house price growth (RHPG), the ratio M2/Foreign Exchange Reserves (%) (M2RES), real domestic credit growth (%) (DCG), unweighted bank capital adequacy (LEV), bank narrow liquidity/assets (NLIQ), the real interest rate (%) (RIR) and the fiscal surplus/ GDP ratio (%) (BB)

Table 3: Nested testing of the crisis model, 1980-2008

Step	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LEV(-1)	-0.33 (-2.8)	-0.32 (-2.9)	-0.33 (-3.0)	-0.35 (-3.6)	-0.34 (-3.5)	-0.31 (-3.5)	-0.34 (-4.1)
NLIQ(-1)	-0.13 (-2.8)	-0.13 (-2.9)	-0.14 (-3.1)	-0.14 (-3.1)	-0.12 (-3.3)	-0.11 (-3.3)	-0.11 (-3.3)
RHPG(-3)	0.1 (2.6)	0.1 (2.6)	0.1 (2.6)	0.1 (2.6)	0.09 (2.6)	0.08 (2.5)	0.08 (2.4)
CBR(-2)	-0.24 (-2.5)	-0.24 (-2.5)	-0.24 (-2.5)	-0.25 (-2.7)	-0.26 (-2.9)	-0.23 (-2.8)	-0.24 (-2.8)
DCG(-1)	-0.06 (-1.2)	-0.06 (-1.2)	-0.06 (-1.2)	-0.06 (-1.2)	-0.06 (-1.2)	-0.03 (-0.8)	-
YG(-1)	0.17 (1.1)	0.17 (1.1)	0.17 (1.1)	0.16 (1.1)	0.14 (1.0)	-	-
BB(-1)	-0.05 (-0.5)	-0.05 (-0.6)	-0.05 (-0.6)	-0.04 (-0.5)	-	-	-
M2RES(-1)	-0.00003 (-0.5)	-0.00003 (-0.5)	-0.00003 (-0.5)	-	-	-	-
INFL(-1)	-0.06 (-0.4)	-0.02 (-0.2)	-	-	-	-	-
RIR(-1)	0.03 (0.3)	-	-	-	-	-	-

Note: estimation period 1980-2008; t-statistics in parentheses; NLIQ-banks' net liquidity ratio, LEV- banks' unweighted capital adequacy ratio, RHPG change in real house prices,, CBR current balance to GDP ratio, YG-real GDP growth, RPHG-real house price inflation, BB-budget balance to GDP ratio, DCG-domestic credit growth, M2RES-M2 to reserves ratio, RIR-real interest rates, INFL-inflation.

We started our analysis with all of these 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. As can be seen in Table 3, all of the variables typically used in global samples are insignificant while the current account/GDP ratio (CBR) [10], real house price growth (RHPG), unweighted bank capital adequacy (LEV), and bank narrow liquidity/assets (NLIQ) are significant in all specifications. The

[10]We investigated the effect of the current account on banking crises, testing first for the appropriate lag. Up to four lags of the variable were included and the least significant ones eliminated one by one, until the most significant lag was left. We found that only the second lag was significant so retained it in subsequent estimation.

estimation is consistent with our earlier work (Barrell et al 2010a) for a longer sample (2008 instead of 2006) and with narrow instead of broad liquidity, while also showing the importance of the current account, which was omitted from the earlier exercise.[11]

Among the noteworthy exclusions in this testing-down process are credit growth and real interest rates. Although lax monetary policy and credit booms may at times contribute to banking crises, the nested test suggests that they are not the most powerful discriminators between times of crisis onset and other periods in OECD countries. [12] Crises are much more likely to result from the growth of low quality lending in asset price booms or from reliance on foreign borrowing when there is a current account deficit rather than on the growth of lending itself. Equally, the variable M2/reserves, often used in the literature to show risks to the banking sector arising from potential currency crises is not significant for the OECD countries. It is reasonably clear that in OECD countries asset price booms, lax bank regulation and an accompanying current account imbalance are most important factors driving the probability of a banking crisis[13].

Table 4A: Logit estimation results with current account balance, estimated over 1980-2008

Variable	Coefficient	z-Statistic
LEV(-1)	-0.342	-4.1
NLIQ(-1)	-0.113	-3.3
RHPG(-3)	0.079	2.4
CBR(-2)	-0.236	-2.8

Table 4B: In sample model performance based on correct calls

	Dep=0	Dep=1	Total
P(Dep=1)<=C	247	5	252
P(Dep=1)>C	97	15	112
Total	344	20	364
Correct	247	15	262
% Correct	71.80	75.00	71.98
% Incorrect	28.20	25.00	28.02

As can be seen in Table 4A, the current account (CBR) is significant in addition to capital adequacy (LEV), the liquid asset ratio (NLIQ) and the growth rate of real house prices (RHPG) which were the variables in Barrell et al (2010a). A deficit (i.e. a negative current balance) has a major positive effect on the probability of a crisis[14]. The in-sample performance is very good, as shown in Table 4B, with a false call rate when there is no crisis (a Type II error) of only 28% and a false call rate when there is a crisis (a Type I error) of 25%. There is an overall successful call rate is 72%. There are 97 false alarms, and 15 of the 20 crisis episodes are captured at a cutoff of 0.0555, which is the sample mean for onset of crises i.e. 20/364.[15]

[11] A comparison of the equation excluding the current account with the result from Barrell et al (2010a) is shown in Appendix Table A3.
[12] 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.
[13] We also tested for the joint exclusion of all these variables using a Wald variable deletion test, and we found that they could all be dropped with 90 per cent probability.
[14] Appendix Table 2 shows that these variables are not strongly correlated suggesting multicollinearity is not an issue
[15] As shown in Appendix Table A4, the performance of this equation is notably better than that of an equation excluding the current account balance ratio.

We examined in more detail the in sample performance of the model from 1996 onwards, during which there were no new crises up to 2007. This period contains exactly half of the total observations (182). The UK, US, Denmark and the Netherlands have the largest number of crises called over the period, which in the case of the first two countries is partly a sign of a build up of vulnerabilities in the economies, leading to the sub-prime crises in 2007. The first two have one third of all false calls in this period, suggesting they had faced systematic stress for some time. For the latter countries it reflects earlier house price booms that gave rise to unrealized concerns over systemic risk.[16] There were also calls around 1997 and 1998 in Japan, which we do not record as a crisis unlike Laeven and Valencia (2007). The subprime crisis itself was correctly called for four countries, the US, UK, France and Belgium. Our model does not call the Netherlands and Germany in 2008. The former had a crisis because the Belgian domiciled but cross border operating Fortis bank had to be bailed out by both countries. The lack of a call Germany reflects the international rather than domestic source of its problems, which were based on excessive exposure to the US securitized mortgage market and associated structured investment vehicles.

5 Robustness tests

We undertook a set of robustness tests, first dropping groups of countries, second by varying lags on variable that are emphasised by others, and then changing the time period of estimation. We first eliminated the US and Japan separately and together, then we exclude the UK which has 5 crises (considerably more crisis occurrences than any other country in the sample). We then went on to delete the Nordic countries (which had systemic crises) and Canada (the remaining non European country in the sample). These tests are reported in Table 5. In none of these cases was there a noticeable changes in coefficients on our driving variables and they remain significant at 95 per cent significance level, apart from real house price growth (RHPG) which is significant at 90 per cent level when Norway and Finland are excluded.

Table 5: Robustness tests based on country elimination

	Final panel	US not included	Japan not included	US and Japan not included	UK not included	Norway not included	Finland not included	Sweden not included	Canada not included
LEV(-1)	-0.342	-0.405	-0.344	-0.408	-0.373	-0.317	-0.301	-0.329	-0.319
	(-4.05)	(-4.15)	(-4.09)	(-4.21)	(-3.92)	(-3.54)	(-3.44)	(-3.85)	(-3.84)
NLIQ(-1)	-0.113	-0.101	-0.108	-0.096	-0.115	-0.118	-0.12	-0.114	-0.113
	(-3.26)	(-2.87)	(-3.14)	(-2.75)	(-3.13)	(-3.13)	(-3.36)	(-3.26)	(-3.32)
RHPG(-3)	0.079	0.093	0.078	0.092	0.109	0.066	0.066	0.074	0.073
	(2.36)	(2.51)	(2.33)	(2.48)	(2.83)	(1.9)	(1.77)	(2.16)	(2.15)
CBR(-2)	-0.236	-0.182	-0.232	-0.176	-0.217	-0.224	-0.236	-0.223	-0.228
	(-2.84)	(-2.15)	(-2.73)	(-2.05)	(-2.59)	(-2.54)	(-2.79)	(-2.6)	(-2.75)

A second aspect is to test further the importance of credit growth and GDP growth, which are considered to be important macroprudential indicators that should be incorporated in policy rules, see for example Brunnermeier et al (2009). As with house prices and the current account, we tested the robustness of our specification in the general equation by including the first three lags

[16] For instance, for the Netherlands, there were certainly concerns over asset price developments in the late 1990s, also expressed in official circles (De Nederlandsche Bank 2000), that help justify the estimated crisis probability in that period.

of each of these variables in turn, to see whether the first lag we have chosen is appropriate. For the case of credit it was indeed the first lag that was most significant of the three, whereas for GDP growth it was the third lag (with a negative sign). Accordingly, we re-estimated the nest shown in Table 3 with the third lag of GDP instead of the first. It proved insignificant, further justifying our specification, as shown in Appendix Table A5.

A further test is to assess whether the equation's success stems from the inclusion of the 8 of the 20 crises that occurred in the subprime period. This period might be responsible for the significance of the current account, and it might be argued that the run up to the subprime crisis had other specific features such as global imbalances that may have influenced the choice of variables. To test this, we excluded the last five observations, estimating only up to 2003. This implies that our coefficients depend upon the probabilities of crises occurring between 1983 and 1995, as there were none over a decade from 1996 to 2006 in these 14 OECD countries. As the model uses the third lag of house price growth we avoid the latest period of increase in property prices, while current account imbalances were somewhat less marked in 2001 (at the second lag) than later in the decade. Tables 6A and 6B illustrate estimated parameters together with the strong in-sample performance of the model (given an in-sample cut off given by the proportion of crises in the reduced sample space of 0.0408), with 9 out of 12 crises correctly called. The model and its parameters remain remarkably stable even with 5 years of the observations dropped.

Table 6A: Equation estimated over 1980-2003

Variable	Coefficient	z-Statistic
LEV(-1)	-0.48	-4.1
NLIQ(-1)	-0.097	-2.5
RHPG(-3)	0.08	2.1
CBR(-2)	-0.43	-2.9

Table 6B: In-sample model performance based on correct calls

	Dep=0	Dep=1	Total
P(Dep=1)<=C	209	3	212
P(Dep=1)>C	73	9	82
Total	282	12	294
Correct	209	9	218
% Correct	74.11	75.00	74.15
% Incorrect	25.89	25.00	25.85

Given we have data for 2007 and 2008, it is straightforward to use the equation in Table 6A to forecast over the subprime crisis using actual values for right hand side variables. The ex ante probability of crisis, which we use as a cutoff, was 0.0408 over the 1983-2003 estimation period. As can be seen from Table 7, the model predicts crises in both 2007 and 2008 in the UK and US, as well as the French and Belgian crises of 2008. The false calls in Spain occur in the context of a major property slump in that country, apparently partly offset by the "dynamic provisioning" policy adopted by banks at the supervisors' behest, and because many of the losses that were incurred fell in the provincial state owned savings bank system and hence were covered by provincial taxpayers without obvious central government action taking place. Nevertheless many analysts would concur with the model's warnings for Spain from 2005. We note that other than the 5 countries cited, the model does not give false alarms elsewhere (apart from the Netherlands

in 2004 and Denmark in 2008[17]). Indeed, in countries such as Japan and Norway, which were little touched by the crisis, the probabilities are close to zero in both 2007 and 2008.

Table 7: Out of sample predictions using 1980-2003 model

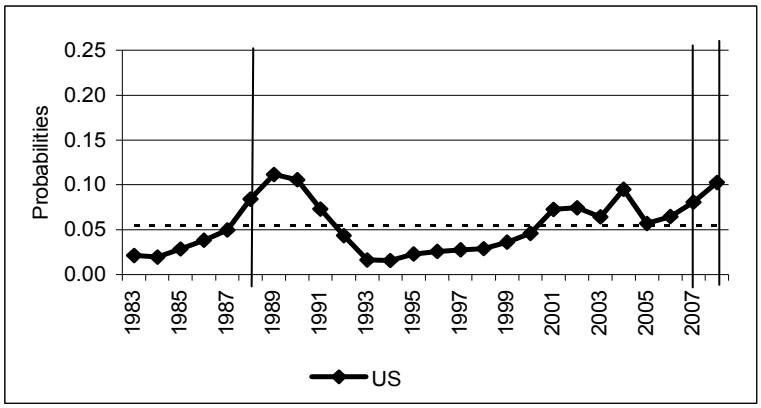
	2004	2005	2006	2007	2008
BG	0.003	0.008	0.015	0.031	**0.043**
CN	0.014	0.021	0.015	0.019	0.023
DK	0.021	0.013	0.020	0.011	**0.051**
FN	0.000	0.001	0.001	0.002	0.002
FR	0.019	0.034	**0.072**	**0.154**	**0.180**
GE	0.010	0.013	0.003	0.003	0.003
IT	0.016	0.026	0.021	0.037	0.013
JP	0.002	0.001	0.000	0.001	0.001
NL	**0.047**	0.013	0.007	0.007	0.002
NW	0.001	0.001	0.001	0.000	0.000
SD	0.006	0.001	0.003	0.003	0.002
SP	0.033	**0.066**	**0.232**	**0.531**	**0.637**
UK	**0.077**	**0.142**	**0.217**	**0.228**	**0.229**
US	**0.070**	**0.042**	**0.052**	**0.069**	**0.091**

Note:BG-Belgium, CN-Canada, DK-Denmark, FN-Finland, FR-France, GE-Germany, IT-Italy, JP-Japan, NL-Netherlands, NW-Norway, SP-Spain, SD-Sweden, UK-United Kingdom, US-USA.

7 Factors affecting the development of crisis in the US

As a case study, using the 1980-2008 model from Table 4A, we focused on the long term pattern for the United States, where as noted the model predicts the subprime crisis well. In Chart 1, we show the pattern of US crisis probabilities, showing that besides the subprime crisis, the model predicts the peak of the Savings and Loans debacle and accompanying banking crisis in 1988, remains high in the run up to the credit crunch in 1991, and also indicates heightened risks in 2001-2 (during the equity bear market) and in 2004.

Chart 1: US crisis probability in-sample



[17] As discussed above, these signals were linked to earlier house price booms which generated concerns for systemic stability.

It is possible to decompose the changes in the probabilities according to their drivers, and we do that in Table 9 for the 5 years preceding the sub-prime crisis, using the main logit estimate from 1980 to 2008 as shown in Table 4A. The final equation for calculating the probability for the US in year *t* is shown below

$$pcrisis_{US,t} = \frac{1}{1+e^{-\left(-0.34lev_{US,t-1}-0.11nliq_{US,t-1}+0.08rphg_{US,t-3}-0.24cbr_{US,t-2}\right)}} \quad (3)$$

The contribution of each variable to a change in the probability between the adjacent years (taking LEV for example) is calculated as follows:

$$pcrisis_{US,t} - pcrisis_{US,l,t-1} = \frac{1}{1+e^{-\left(-0.34\,lev_{US,t-1}-0.11\,nliq_{US,t-1}+0.08\,rphg_{US,t-3}-0.24\,cbr_{US,t-2}\right)}} - \frac{1}{1+e^{-\left(-0.34\,lev_{US,t-2}-0.11\,nliq_{US,t-1}+0.08\,rphg_{US,t-3}-0.24\,cbr_{US,t-2}\right)}} \quad (4)$$

Similar calculations were done for the other three remaining variables. As the relationship is not linear, the sum of all contributions from the right hand side variables do not exactly equal to the change in a dependent variable. The remaining term accounts for the interaction between the independent variables which we can calculate by summing two or three individual marginal contributions and comparing that to a marginal contribution where two or three of the driving variables are allowed to vary. We call the sum of these terms the adjustment (Adj for interaction) and add it to the direct contributions of the right hand side variables. The cumulative change in the probability and its contributing variables over a certain time period is just a sum of the changes in the probabilities and the sum of contributions by each variable over that time span.

Table 8: Incremental contribution to change in US crisis probabilities from 2005-2008

	Initial level	Contribution from					TOTAL after adj
		NLIQ	LEV	RHPG	CBR	Adj for Interaction	
05-04	0.057	-0.019	-0.017	-0.002	0.005	0.003	-0.038
06-05	0.065	0.003	-0.000	-0.003	0.008	-0.000	0.007
07-06	0.081	0.002	-0.009	0.013	0.009	-0.000	0.016
08-07	0.103	0.005	0.005	0.012	0.003	0.002	0.022
cum change	0.046	0.010	-0.004	0.022	0.019	0.001	0.046

Note: Cumulative change in the initial level of probability refers to the difference between cells "08-07" and "05-04", while for all contributing components it is the sum of all cells from "06-05" to "08-07".

The first column of Table 8 shows the crisis probability level for the US in each year whilst the next five columns give the contributions of the year-by-year changes in the independent variables for the United States from 2005 to 2008. Looking at the cumulative effect from 2005-2008, it is

evident that the largest contributions overall are from the change in real house prices and the current account, followed by narrow liquidity, with capital adequacy contributing negatively (i.e. better capitalisation according to the data, reducing the risk of crisis). However, in the interim between the initial and later crisis in 2007-8, all variables were heightening crisis risk, including lowering of unweighted capital adequacy. Meanwhile, the adjustment term is non zero, and there are interactions between variables, which are mainly between real house price growth and the current account balance and not between either of these, and capital adequacy and liquidity.

We can use the same structure to estimate the extent to which banking regulation in the US could have been tightened sufficiently to reduce the probability of a crisis to the sample mean in 2007 and 2008 or to some other crisis probability level. In order to do this we construct counterfactual changes in order to assess how much tightening might have been needed to offset risks arising from external variables as well as to compensate for low levels of these variables themselves. As shown in Table 9, we calculate the impact of capital adequacy and liquidity on crisis probability by increasing requirements first for both variables and then one at a time. The overall pattern suggests that a balanced tightening of around 1.0 in the first year and 1.6 percentage points in the second year in both ratios would be sufficient to reduce the risk of crisis to the sample mean.

Table 9: Regulatory tightening required in the US to reduce crisis probabilities in 2007 and 2008 to sample mean of 0.0555.

	initial probability	initial level of nliq(-1)	initial level of lev(-1)	increase in					
				nliq(-1)	lev(-1)	nliq(-1)	lev(-1)	nliq(-1)	lev(-1)
2007	0.081	7.202	10.345	0.95	0.95	3.75	0	0	1.25
2008	0.103	6.750	10.195	1.55	1.55	6.1	0	0	2.05

The above is quite a modest policy adjustment since it only reduces the risk of crisis to the sample mean, which at 0.0555 is around one crisis every 18 years. It might be thought that this still puts the economy at too great a risk from the consequences of systemic banking crises (see Barrell et al (2010b) for a review of the literature on costs of crises). A more demanding criterion is to reduce the risk of crises to one in 100 years, reducing the probability to 0.01. As shown in Table 10, this necessitates a considerable rise in capital or liquidity if the relevant lever is utilized alone, requiring a 7 percentage point increase in unadjusted capital adequacy or a 21 percentage point rise in liquidity ratios. On the other hand, a balanced approach would need about 5 percentage points on each ratio, still a quite demanding rise from the point of view of the banks.

Table 10: Regulatory tightening required in the US to reduce crisis probabilities in 2007 and 2008 to one in 100 years (i.e. 0.01).

	initial probability	initial level of nliq(-1)	initial level of lev(-1)	increase in					
				nliq(-1)	lev(-1)	nliq(-1)	lev(-1)	nliq(-1)	lev(-1)
2007	0.081	7.202	10.345	4.7	4.7	18.8	0	0	6.2
2008	0.103	6.750	10.195	5.3	5.3	21.3	0	0	7

It is important to note that regulatory tightening would not be costless for the wider economy, since higher capital and liquidity requirements induce banks to raise lending margins, and hence

adversely affecting the user cost of capital, investment and the capital stock. As derived in detail for the UK in Barrell et al (2009), deciding on the appropriate level of regulatory tightening necessitates a balancing of such costs of regulation with the benefits of lower crisis risk that we have estimated in this paper. Global agreement will necessitate assessing the differing effects of regulation between countries also and finding an appropriate compromise.

8 Conclusion

We have shown that bank regulatory variables and asset prices along with the current balance impacted on the probability of banking crises in OECD countries over 1980-2008. The specification we uncover with these variables is stable to the exclusion of individual countries and of the last 5 years of data. This exercise illustrates that the patterns preceding the recent subprime crisis were in many ways not unprecedented, and a model such as that outlined here could have helped the authorities to forecast the crisis and to take appropriate regulatory measures. This was notably the case for the US, the epicenter of the subprime crisis, as well as the UK, the country hardest hit. Indeed we have shown that the crisis would have been predicted a number of years ahead if the actual values of right hand side variables were employed, using logit estimates developed on data available up to 2003. Decomposing the estimates, we find that the 2005-2008 period was characterized by a rise in risk largely from aspects external to the banking system, namely current account imbalances and asset prices. But in the last year before Lehman's failure, regulatory slackness was also a contributing factor, as unweighted capital adequacy and narrow liquidity ratios were allowed to decline.

We have calculated the degree of tightening of regulation that would be needed to bring the probability of a crisis down to one every 18 years, using the US as an example. We find it entails a rise of up to 2 percentage points in capital adequacy or around 6 percentage points in liquidity, or alternatively, there could be a 1.6 percentage point rise in both. However, reducing probabilities to 1 crisis in 100 years for that country requires a much more substantial regulatory tightening, of around 7 percentage points on capital or no less than 21 percentage points more liquidity. Whereas this would be very challenging to the banking system, and would itself adversely affect the real economy via widening of bank margins, such a policy should not be ruled out a priori, given the extremely high costs of banking crises.[18] These prescriptions could be either "levels" increases in capital and liquidity to be sustained at all times or a "target" level to be attained at the peak of the boom in a countercyclical macroprudential policy.

[18] A calculation of overall costs and benefits of regulatory tightening in the UK is provided in Barrell et al (2009).

REFERENCES

Barrell, R., and Davis. E.P., (2008) 'The Evolution of the Financial Crisis in 2008' *National Institute Economic Review* October 2008 no 206 pp 5 -14

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 (2010a), "Bank regulation, property prices and early warning systems for banking crises in OECD countries", NIESR Working Paper No 331 and forthcoming in *Journal of Banking and Finance*

Barrell R, Davis E P, Karim D and Liadze I (2010b), "The effects of banking crises on potential output in OECD countries"*, mimeo, NIESR, London*

Barrell, R., Hurst, A.I., and Kirby, S., (2008) "Financial Crises, Regulation and Growth", *National Institute Economic Review* October 2008 no 206 pp 56 -65

Barth J R, Caprio G, and Levine R (2004), "Bank supervision and regulation, what works best?", *Journal of Financial Intermediation*, 13, 205-248

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

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

Breusch, T.S., and Pagan, A., (1980). "The Langrange Multiplier test and its application to model specifications in econometrics". *Review of Economic Studies* 47, 239-53.

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.

Davis, E P (2009), "The lender of last resort and liquidity provision- how much of a departure is the sub-prime crisis", paper presented at the LSE Financial Markets Group conference on the Regulatory Response to the Financial Crisis, 19th January 2009

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

Davis E P, Karim D and Liadze I (2010), "Should multivariate early warning systems for banking crises pool across regions?" Brunel University Working Paper

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

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.

De Nederlandsche Bank, 2000. Asset price inflation on the equity and real estate markets; risks and policy implications. DNB Bulletin, December 2000, 25-36.

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

Glick R and Hutchinson M (2001), "Banking and currency crises – how common are the twins?", in Glick R, Moreno R and Spiegel M (eds) " *Financial Crises in Emerging Markets*, Cambridge University Press

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

Kaminsky L., Reinhart C.M. (1999), "The twin crises; the causes of banking and balance-of-payments problems", *American Economic Review*, 89, 473-500

Laeven, L., and Valencia, F., 2007. Systemic banking crises: A new database. IMF Working Paper No. WP/08/224

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

McKinnon R and Pill H (1994), "Credible liberalization and international capital flows; the overborrowing syndrome" *in* T. Ito and A.O. Krueger, eds., *Financial Deregulation and Integration in East Asia*, University of Chicago Press, Chicago

Reinhart C M and Reinhart K S, "Capital flow bonanzas, and encompassing view of the past and present", in J Frankel and F Giavazzi (Eds), "*NBER International Seminar in Macroeconomics* 2008, Chicago 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.

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

APPENDIX 1: CRISIS SAMPLE

Table A1: Crisis onset dates

Crisis	JBF	WB	LV	DD	CK systemic	CK non systemic	BD
Belgium	2008						2008
Canada	1983	1983				1983	
Denmark	1987	1987				1987	
Finland	1991	1991	1991	1991	1991		
France	1994, 2008	1994				1994	2008
Germany	2008						2008
Italy	1990	1990				1990	
Japan	1991	1991	**1997**	**1992**	1991		
Netherlands	2008						2008
Norway	1990	1990	**1991**	**1987**	**1987**		
Sweden	1991	1991	1991	**1990**	1991		
UK	1984, 1991, 1995, 2007, 2008	1984, 1991, 1995	2007			1984, 1991, 1995	2008
US	1988, 2007, 2008	1988	1988, 2007	1980		**1984**	2008

WB – World Bank (2003)
LV – Laeven and Valencia (2007)
DD – Demirguc Kunt and Detragiache (2005)
CK – Caprio and Klingebiel (2003)
BD – Borio and Drehmann (2009)

APPENDIX 2: CORRELATIONS

It can be seen from Table A2 below, that correlations between the independent variables are low, thus reducing concern about multicollinearity. More systematically, as in Barrell et al (2010a), we use the Breusch Pagan (1980) test for cross section dependence to investigate the orthogonality of regressors. According to the test, the correlation coefficients are distributed as a standard normal variate where N is the cross section dimension and T is the time dimension

$$CD = (1/(N(N-1))^{**}(1/2)^{*}(\sum_{i=1,N}\sum_{j=i+1,\,N-1}(T\,\rho_{ij}^{\,**2} - 1)$$

In neither case below is there any significant indication of correlation, In the first case of contemporaneous variables the standard normal deviate is -0.73 and in the case of the chosen lags it is -0.71 whereas the 95 percent two sided bound is 1.96. Hence we can be certain there are no interdependences in the data set.

Table A2: Correlations between independent variables

Contemporaneous correlations

	LEV	NLIQ	RHPG
NLIQ	-0.14		
RHPG	0.17	-0.13	
CBR	-0.22	-0.06	0.08

Correlations of chosen lags

	LEV(-1)	NLIQ(-1)	RHPG(-3)
NLIQ(-1)	-0.14		
RHPG(-3)	0.15	-0.20	
CBR(-2)	-0.22	-0.07	-0.03

APPENDIX 3: COMPARISON WITH EARLIER ESTIMATES

The results of estimation of the specification excluding the current account from Barrell et al (2010a), using data up to 2008 and narrow liquidity, are shown in Tables A3 and A4. Variables are all significant and the in-sample performance is good, despite the inclusion of data for 2007 and 2008, with significant numbers of additional crises. As in Barrell et al (2010a), the key estimate from which is shown for reference on the right of the table, unweighted capital adequacy of the banking system (LEV) has a significant negative effect, as does banks' narrow net liquidity/assets (NLIQ) ratio. In other words tighter regulation will reduce the risk of banking crises. Meanwhile, rapid house price growth (RHPG) lagged three years has a significant positive effect, with a preceding asset price boom boosting the probability of a crisis. The lag was initially chosen by including first to fourth lags and retaining only that which was significant. Rapid house price growth is often associated with rapid lending growth and lowering of standards in loan evaluation, and may lead to defaults within a few years, especially if the property price increase is reversed.

The model is able to detect 13 of the 20 crises in the sample, although there are a large number of "false alarms", namely 115. The outcome is well in line with standards established in the existing literature, where for example Demirguc Kunt and Detragiache (2005) for their most preferred equation had a type II error of 32% and a type I error of 39%, with an overall success rate of 69% at a threshold of 0.05. Our corresponding results at 0.0555 threshold quoted here are for a type II error of 33% and a type I error of 35%, with an overall success rate of 67%. As shown in the paper, the specification can be improved markedly by including the current account/GDP ratio, however.

Table A3: Logit estimation results with narrow liquidity ratio

	Basic equation, 1980-2008		Memo: Barrell et al (2010a), estimated 1980-2006*	
Variable	**Coefficient**	**z-Statistic**	**Coefficient**	**z-Statistic**
LEV(-1)	-0.322	-3.9	-0.333	-2.9
NLIQ(-1)	-0.127	-3.7	-0.118	-3.6
RHPG(-3)	0.095	2.7	0.113	2.8

* Estimated with broad liquidity measure at the same lag.

Table A4: In sample model performance based on correct calls

	Dep=0	Dep=1	Total
P(Dep=1)<=C	229	7	236
P(Dep=1)>C	115	13	128
Total	344	20	364
Correct	229	13	242
% Correct	66.57	65.00	66.48
% Incorrect	33.43	35.00	33.52

APPENDIX 4: NEST WITH THIRD LAG OF GDP GROWTH

Table A5: Nested logit

Step	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LEV(-1)	-0.271 (2.4)	-0.272 (2.4)	-0.28 (2.7)	-0.294 (3.0)	-0.285 (3.0)	-0.274 (3.0)	-0.34 (-4.1)
NLIQ(-1)	-0.11 (2.7)	-0.108 (2.9)	-0.109 (2.9)	-0.108 (2.9)	-0.113 (3.1)	-0.107 (3.2)	-0.11 (-3.3)
RHPG(-3)	0.111 (2.8)	0.11 (2.9)	0.111 (2.9)	0.109 (2.9)	0.101 (2.8)	0.101 (2.8)	0.08 (2.4)
CBR(-2)	-0.216 (2.3)	-0.218 (2.4)	-0.222 (2.5)	-0.225 (2.6)	-0.217 (2.6)	-0.225 (2.7)	-0.24 (-2.8)
DCG(-1)	-0.02 (0.4)	-0.02 (0.5)	-0.02 (0.5)				
YG(-3)	-0.226 (1.4)	-0.229 (1.4)	-0.232 (1.4)	-0.248 (1.6)	-0.224 (1.5)	-0.213 (1.4)	
BB(-1)	-0.0079 (0.1)						
M2RES(-1)	-8.23E-06 (0.2)	-7.34E-06 (0.8)					
INFL(-1)	-0.108 (0.7)	-0.111 (0.7)	-0.111 (0.7)	-0.112 (0.7)			
RIR(-1)	0.0731 (0.8)	0.076 (0.8)	0.076 (0.8)	0.079 (0.8)	0.023 (0.4)		

APPENDIX 5: Nest with an exogenous probability of a crisis

Our presumption has been that we should not include, and this has been common but not universal in the literature. Its exclusion does require that there is no exogenous probability of a crisis and that we have not omitted any relevant variables. These propositions are testable in the same way as leverage and liquidity are testable. If we include a constant in general model including the current balance it is not significant at first pass – see general model below. It is the least significant variable at the fifth pass through leaving only income growth and credit growth and would have been dropped at this stage – see second regression below. It is no different from any of the other variables in that its presence represents a testable hypothesis, and hence we do not need to maintain it in the current balance paper. However if we keep it in until our penultimate regression – see third regression below – it is the least significant variable, and we should drop it – see fourth regression below. Hence our result is robust to the inclusion of a constant. It should not be there.

General model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.854	1.339	-1.385	0.166
LEV	-0.170	0.162	-1.048	0.295
NLIQ(-1)	-0.114	0.047	-2.432	0.015
RHPG(-3)	0.101	0.037	2.753	0.006
CBR(-2)	-0.184	0.110	-1.667	0.096
DCG(-1)	-0.050	0.053	-0.946	0.344
YG(-1)	0.206	0.159	1.296	0.195
BB(-1)	-0.072	0.088	-0.819	0.413
M2RES(-1)	0.000	0.000	0.024	0.981
INFL(-1)	-0.019	0.159	-0.122	0.903
RIR(-1)	0.066	0.099	0.665	0.506

Stage where a constant should be removed

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.036	1.021	-1.015	0.310
LEV	-0.226	0.151	-1.496	0.135
NLIQ(-1)	-0.097	0.044	-2.224	0.026
RHPG(-3)	0.091	0.033	2.713	0.007
CBR(-2)	-0.236	0.093	-2.535	0.011
DCG(-1)	-0.053	0.050	-1.050	0.294
YG(-1)	0.161	0.151	1.066	0.287

Penultimate regression with a constant added

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.048	0.993	-1.056	0.291
LEV	-0.211	0.148	-1.422	0.155
NLIQ(-1)	-0.085	0.041	-2.082	0.037
RHPG(-3)	0.083	0.033	2.498	0.013
CBR(-2)	-0.210	0.087	-2.418	0.016