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CALIBRATING MACROPRUDENTIAL POLICY

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Abstract: This paper contributes in a quantitative manner to the debate on macroprudential policy in three ways. First, it illustrates how macroprudential surveillance could have been better undertaken with a highly stable crisis-prediction model for 14 OECD countries estimated over 1980-1997. Second, in terms of macroprudential regulation, it uses the related estimates to calibrate the increase in capital and liquidity needed to reduce average crisis probabilities to a desired level, as is being discussed in Basel. We show that an international consensus on regulatory changes will generate "winners" and "losers" in terms of capital and liquidity adjustments, and we suggest that raising capital and liquidity standards by 3.7 percentage points across the board will reduce the annual average probability of a financial crisis to around 1%. Finally, we show that countercyclical macroprudential policy is best calibrated on house prices and current accounts rather than GDP and credit, as are widely recommended at present. Credit growth, for example, has neither a direct nor an indirect statistical impact on crisis risk. Our results have important implications for the next generation of international banking regulations.

Keywords: Macroprudential policy, bank regulation, early warning models of banking crises

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Introduction

A large number of central banks and regulators now generate "Financial Stability Reports" (Cihak 2006) in pursuit of macroprudential surveillance, which can be defined as monitoring of conjunctural and structural trends in financial markets so as to give warning of the approach of financial instability However, such surveillance, which is largely qualitative and judgemental, failed to forecast the subprime crisis of 2007-8 (Davis and Karim 2008b), suggesting a need for further development of macroprudential tools. Meanwhile, an emerging consensus, particularly following the subprime crisis, is that there is a need to complement microprudential bank regulation, concerned with firm-level stability, with macroprudential regulation, which promotes systemic stability. The latter considers both the overall tightness of regulatory policies and whether they should vary over the cycle. However, for the most part issues are discussed without any methodical evaluation of their effects on crisis probabilities, concurrent costs or differential impacts across countries. Furthermore, there appears to be uncritical acceptance of a need for capital buffers which vary procyclically to offset risks arising from patterns of GDP and credit growth.

In this context, the contribution of this paper is threefold. Firstly, we show that macroprudential surveillance could have been better undertaken with a crisis prediction model estimated on data available in 1998 which could have been used to forecast crisis probabilities directly or on a recursive basis from that time onwards. The estimation shows that bank capital adequacy, liquidity, the current account deficit and changes in house prices are the principal factors distinguishing periods of banking crises in OECD countries, with the first two indicating the weakness of defences against the ravages induced by the second two variables. We contend that our results would have been (and remain) usable as an early warning device for macroprudential surveillance, highlighting the nonlinear combination of these variables which is threatening for financial stability. Such a model would have given strong warnings of the approach of the subprime crisis.

Our second contribution addresses macroprudential regulation and uses the model to explicitly quantify the regulatory changes to capital and liquidity that would be required in each OECD economy over time in order to ensure systemic stability. We show that an international consensus on regulatory changes will generate "winners" and "losers" in terms of capital and liquidity adjustments, given a certain degree of crisis-risk-aversion of regulators. Overall, our results suggest an internationally uniform surcharge of 3.7 percentage point on capital and liquidity levels observed over 1998 – 2008 would have ensured that average banking crisis risk in the OECD would have been restricted to around 1 per cent.

Third, we address the issue of using macroprudential regulation to counteract bank procyclicality. It is widely suggested that regulators should follow the Spanish example and provision against credit growth in order to reduce such procyclicality. Our model shows that crises are not driven directly by GDP or credit growth. Furthermore, credit growth does not Granger-cause house prices in a manner that could make it a useful measure of risk by proxy. Rather our results suggest that if procyclical risks accumulate, this must be occurring at a micro (individual bank) level as credit quality deteriorates, perhaps reflecting trends in asset prices and current accounts. Accordingly, macroprudential rules should be set as international benchmarks using these indicators, to be adjusted by domestic regulators who are privy to bank specific behaviour[2]. Illustrating this, we show that procyclicality arising from an increase in house price growth of 5 percentage points suggests that countries such as the UK and US should have increased their capital and liquidity buffers by 4.4 percentage point and 2.7 percentage points respectively in 2008.

The paper is structured as follows. In Section 1, we estimate a model of crisis determination for 14 OECD countries over 1980-1997, and show that the sub-prime crisis was predictable using the original estimate, if right hand side variables namely bank capital adequacy, liquidity, the current account deficit and changes in house prices were accurately forecast. Then the specification is estimated recursively each year from 1997 to 2007 to derive one year ahead crisis probabilities over 1998-2008, showing it to be a useful tool for macroprudential surveillance. Section 2 presents our investigation into calibration of macroprudential regulation. Inverting the rolling estimates, we derive the changes in capital adequacy and liquidity ratios that would be needed to return crisis probabilities to desired levels. We go on to assess what implications these patterns have for individual countries, in terms of levels of target variables and changes in regulatory parameters. Section 3 addresses the possibility of agreement on countercyclical regulatory policies, showing the capital and liquidity changes needed to offset shifts in house prices and illustrating statistically that credit growth is not a useful alternative basis for calibration of countercyclical capital regulations. Section 4 concludes. In an Appendix we consider the range of proposals for macroprudential regulation which form a background to our work, from both the official sector and academia.

1 An early warning system for crisis prediction in macroprudential surveillance

Extensive work has been undertaken over the past 10-15 years to derive models to predict banking or currency crises. In general these Early Warming Systems (EWS) adopt one of three methodologies, namely multivariate logit, signal extraction or binary recursive tree analysis (for surveys see Davis and Karim 2008a and b). Most work to date has been based on global samples of crises, most of which took place in Emerging Market economies of Latin America, Asia and the transition economies. Accordingly, such work has tended to be restricted to variables which are available for the full range of countries, from the IMF's "International Financial Statistics" or World Bank "World Development Indicators" databases.

A typical study is Demirguc-Kunt and Detragiache (2005), who developed a parametric EWS for banking crises for 94 countries featuring 77 crises over 1980-2002 using a multinomial logit model with macroeconomic, financial and structural variables as inputs. Their results suggest that crises occurred in periods of low GDP growth, high interest rates and high inflation, as well as large fiscal deficits. On the monetary side, they found the ratio of broad money to foreign exchange reserves and the credit to the private sector/GDP ratio, as well as lagged credit growth to be significant. Institutionally, countries with low GDP per capita are more prone to crises, as are those with deposit insurance.

As shown in Davis and Karim (2008b), EWS models with such traditional variables could not predict the subprime crisis for the UK or US. The implications are that there may be

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[2] In relation to this point we note the distinction between the use of risk weighted and un-weighted capital where according to Brunnermeier et al (2009) unweighted capital is appropriate for calibrating macroprudential policy since risk weightings are balance sheet specific parameters. Accordingly, our estimation focuses on un-weighted capital adjustments.

distinct crisis determinants in OECD countries from those in Emerging Market Economies or that significant variables had been excluded from previous analyses. Such a surmise was investigated by Barrell et al (2010), again using a multivariate logit but also employing variables that are simply not available for most countries outside the OECD, namely house price growth, bank capital adequacy and bank broad liquidity.

Our approach in the current paper is again to derive a distinctive logit based probability model for OECD countries, starting from the range of variables chosen by Demirguc Kunt and Detragiache (2005) as well as Barrell et al (2010), with the addition of the current account and the replacement of banks' broad liquidity by narrow liquidity. We exclude only GDP per capita Credit/GDP and deposit insurance from the list of variables used by Demirguc Kunt and Detragiache (2005), since countries in the OECD sample have similar GDP per capita and credit/GDP, whilst deposit insurance systems have been universally established. The dataset 1980-1997 encompasses all banking crises since 1980 in the Demirguc Kunt and Detragiache (2005) dataset[3]. There was a period from 1999-2006 with no banking crises in the 14 OECD countries in our sample. Our country choice is dictated by the availability of the regulatory data in the OECD banking sector database. We choose 1980-1997 rather than a more recent period such as 1980-2008 to show that the model could have been estimated at that early date and used for practical macroprudential surveillance. We choose to estimate only up to 1997 also in order to assess whether the recent crisis should have come as a surprise and whether crisis determination is unstable over time.

Table 1: Crisis onset dates 1980 1997

Crisis	Date
Canada	1983
Denmark	1987
Finland	**1991**
France	1994,
Italy	1990
Japan	**1991**
Norway	**1990**
Sweden	**1991**
UK	1984, 1991, 1995
US	**1988,**

Note: bold indicates systemic banking crisis. The chosen dates are based on the crisis definitions by the World Bank (Caprio and Klingebiel 2003) for borderline-systemic and systemic crises in 1980-2002.

The variables for crisis prediction in studies such as Demirguc Kunt and Detragiache (2005) have been extensively discussed elsewhere, whilst the additional variables we use have only recently entered the literature. These are two banking sector "robustness" variables: unweighted capital adequacy (LEV)[4] and narrow liquidity/assets (NLIQ), and two real economy "vulnerability" variables: residential real estate prices (RHPG) and the

[3] They date the Japanese crisis at 1991whilst Laeven and Valencia (2007) date it at 1998.

[4] As Brunnermeier et al (2009) note, risk weighting may be important for evaluation problems faced by individual banks, but may not be relevant for system wide properties as risk is endogenous within the financial system when a crisis occurs.

current account/GDP (CBR)[5]. Reinhart and Rogoff (2009) highlighted a common set of factors associated with OECD banking crises over the past 30 years, including the current account and asset prices, but did not quantify these effects econometrically. Our paper complements their work by providing ex ante quantitative estimates of the impact of these variables on crisis probabilities.

The banking sector variables can be seen as crisis defences, rather than causes of crises. Capital buffers banks against losses and shocks. Lower capital not only leaves banks more vulnerable to asset value losses 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 withdrawals by depositors or wholesale funders where these are important. We use narrow liquidity as a percentage of assets as recent experience has shown that broad liquidity is inappropriate as a bank robustness variable since it includes private sector securities, whose illiquidity was an Achilles heel of banks in the sub-prime crisis.

We would argue that crises are typically the result of poor quality lending, often associated with developments in property and especially housing markets and their effects on consumption and on property investment. A boom in real estate prices frequently foreshadows a crisis since in the upturn rising asset prices provide collateral for excessive lending while when prices fall from unsustainable levels, this process goes into reverse, sharply tightening credit conditions, while overextended borrowers in the personal and construction sectors as well as property developers have strong incentives to default. Current account deficits reflect a reduction in national net wealth and 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.[6]

The multinomial logit is the workhorse approach to predicting crises (see for example Hardy and Pararbasioglu (1998), Demirguc Kunt and Detragiache (1998, 2005), and Barrell et al (2010)). There are alternative approaches such as signal extraction (used by Kaminsky and Reinhart (1999) and Borio and Drehmann (2009)) but comparative testing suggests them to be statistically inferior, see Davis and Karim (2008a). 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 dependent variable Y_{it} is a zero-one dummy which is one at the onset of a banking crisis, and zero elsewhere, based on the sample of crises shown in Table 1. Then we have the equation:

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

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

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[5] Variable Definitions: LEV: Ratio of (non-risk weighted) capital and reserves for all banks to end of year total assets as shown by the balance sheet; NLIQ: Ratio of the sum of banks' claims on general government and the central bank, over total assets comprising foreign assets, claims on general government, central bank and private sector.; RHPG: Annual percentage change in real residential property prices; CBR: Current account balance as % of GDP.

[6] 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.

The log likelihood function is:

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

Coefficients show the direction of the effect of a variable on crisis probabilities, although its magnitude is conditional on values of other explanatory variables at time t.

We adopted the general to specific approach, which starts by including all the "traditional" crisis determinants as well as our four extra variables. The steps used to obtain the chosen model are shown in Table 2. From a policy perspective, noteworthy exclusions[7] from the equation include credit growth, GDP growth, M2/reserves and real interest rates. These "traditional" variables were eliminated via a rigorous testing-down procedure which confirms they are less sensitive crisis predictors in OECD countries than asset price booms, lax bank regulation and accompanying current account imbalances..

Table 2: General to specific estimation (data sample 1980-1997)

Step	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LEV(-1)	-0.339 (1.7)	-0.339 (1.8)	-0.348 (1.9)	-0.347 (1.9)	-0.417 (2.9)	-0.345 (2.7)	-0.384 (3.2)
NLIQ(-1)	-0.106 (1.8)	-0.106 (1.9)	-0.108 (2.0)	-0.113 (2.2)	-0.126 (2.7)	-0.104 (2.5)	-0.105 (2.6)
RHPG(-3)	0.091 (1.9)	0.091 (1.9)	0.089 (1.9)	0.095 (2.4)	0.09 (2.4)	0.086 (2.3)	0.081 (2.1)
CBR(-2)	-0.434 (2.3)	-0.434 (2.3)	-0.441 (2.4)	-0.438 (2.4)	-0.418 (2.3)	-0.3 (1.9)	-0.333 (2.2)
DCG(-1)	-0.101 (1.5)	-0.101 (1.6)	-0.1 (1.6)	-0.1 (1.5)	-0.108 (1.7)	-0.053 (1.0)	
YG(-1))	0.277 (1.5)	0.277 (1.5)	0.274 (1.4)	0.279 (1.5)	0.29 (1.5)		
RIR(-1)	-0.054 (0.3)	-0.055 (0.6)	-0.055 (0.6)	-0.06 (0.7)			
BB(-1)	0.022 (0.2)	0.02 (0.2)	0.023 (0.2)				
M2RES(-1)	-1.51E-05 (0.2)	-1.52E-05 (0.2)					
INFL(-1)	-0.0012 (0.1)						

Variable Definitions: LEV: leverage (capital adequacy); NLIQ: narrow liquidity; RHPG: real house price growth; CBR: current account balance; DCG: real domestic credit growth; YG: real GDP growth; RIR: real interest rate; BB: budget balance; M2RES: ratio of M2 money to international reserves; INFL: inflation.
z statistics in parentheses.

We tested the most general equation (i.e. (1) in Table 2) to see whether longer lags applied to credit or GDP growth. We repeated the estimation with second, third and fourth lags. For credit growth the first lag was most significant, whereas for GDP growth it was the second

[7] Our result for the 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. See also the discussion in Section 3.

lag that was the most significant albeit with a ‘t’ statistic of only 1.3. We found that GDP was also not significant after testing down with the second lag also.

The model is summarised in Table 3A. Its in-sample predictive performance shown in Table 3B is strong, and it calls 9 out of 12 crises if we use the sample average occurrence of 0.057 as a cut off, missing only those in Denmark in 1987, Italy in 1990 and the UK in 1995. There are 55 false crisis calls, with half of these adjacent to actual crises. Overall it has Type II errors of 28% and Type I errors of 25%[8]. This compares well with Demirgüc-Kunt and Detragiache (2005) for their most preferred equation which 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. Hence our work stands up well in comparison.

Table 3A: Logit estimation results (1980-1997)

Variable	Coefficient	z-Statistic	Prob.
LEV (-1)	-0.3839	-3.1540	0.0016
NLIQ(-1)	-0.1046	-2.6070	0.0091
RHPG(-3)	0.0813	2.0934	0.0363
CBR(-2)	-0.3327	-2.1502	0.0315

Table 3B: In sample performance

	Estimated Equation		
	Dep=0	Dep=1	Total
P(Dep=1)< 0.057	143	3	146
P(Dep=1)> 0.057	55	9	64
Total	198	12	210
Correct	143	9	152
% Correct	72	75	72
% Incorrect	28	25	28

We should note that property price growth and current account deficits alone do not make a crisis inevitable since banking systems with sufficient capital and liquidity can absorb the losses without failures. The most toxic combination appears to be the unwinding of a boom characterised by overvalued asset prices and external imbalances, *accompanied* by a weak banking system. Macroprudential policy cannot easily directly address macroeconomic imbalances but rather can ensure that the banking system is robust and not vulnerable in the downturn[9]. Capital and liquidity requirements could be increased to strengthen defences against the problems associated with macroeconomic imbalances bad lending as indicated by asset price booms and current accounts[10].

The corresponding implied forecast crisis probabilities are shown in Table 4, using in-sample probabilities of 0.057 as a cut-off. Laeven and Valencia (2007) and Borio and Drehmann (2009) suggest that there were systemic crises in the UK and the US in 2007 and in the UK, the US, France, Germany, the Netherlands and Belgium in 2008. The model predicts the subprime crisis in the UK and US, and flags several problems for some time in advance, as well as calling Belgium and France. It also predicts instability in Spain, which should be seen in the context of the asset price and lending booms in that country. The model calls a banking crisis in Japan in 1998, close to the peak of the second phase of the

[8] Based on the cut-off probability threshold of 0.057.

[9] Arguably a good example was the Spanish banking system in the sub-prime crisis which underwent a great deal of turbulence but did not suffer a crisis per se in 2008. However, despite provisioning, losses by local savings banks were so extensive that large scale restructuring was required in 2010.

[10] Monetary policy may also “lean into the wind” to address macroeconomic imbalances (Wadhwani 2008)

crisis there, and crises are also called during house price bubbles in Denmark and the Netherlands in 2000 and 2002-4 respectively, as well as the stress associated with the rescue of Commerzbank in Germany in 2002, although none of these are noted as crises in our source datasets.

Table 4: Out of sample probabilities from 1980-1997 model

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
BG	0.005	0.004	0.003	0.004	0.009	0.005	0.007	0.014	0.025	0.048	**0.070**
CN	0.032	0.054	0.056	0.033	0.018	0.022	0.026	0.037	0.030	0.036	0.042
DK	0.015	0.041	**0.060**	0.046	0.048	0.029	0.043	0.030	0.042	0.030	**0.113**
FN	0.004	0.006	0.011	0.007	0.000	0.000	0.000	0.004	0.002	0.007	0.008
FR	0.025	0.018	0.012	0.014	0.040	0.028	0.032	0.053	**0.100**	**0.193**	**0.218**
GE	0.026	0.027	0.029	0.045	**0.058**	0.031	0.016	0.020	0.007	0.007	0.007
IT	0.001	0.002	0.002	0.009	0.017	0.020	0.026	0.039	0.034	0.054	0.019
JP	**0.071**	0.025	0.009	0.010	0.007	0.007	0.003	0.002	0.001	0.001	0.002
NL	0.020	0.018	0.050	0.049	**0.157**	**0.141**	**0.079**	0.028	0.017	0.019	0.007
NW	0.011	0.006	0.039	0.016	0.001	0.001	0.006	0.003	0.002	0.001	0.001
SD	0.019	0.016	0.034	0.048	0.039	**0.058**	0.017	0.006	0.009	0.011	0.008
SP	0.005	0.006	0.010	0.028	0.043	0.044	0.047	**0.096**	**0.266**	**0.516**	**0.580**
UK	0.049	**0.060**	**0.088**	**0.173**	**0.203**	**0.201**	**0.115**	**0.207**	**0.282**	**0.277**	**0.254**
US	0.025	0.032	0.044	**0.074**	**0.081**	**0.067**	**0.103**	**0.064**	**0.075**	**0.097**	**0.125**

Note1: cut off threshold is 0.05714; bold indicate values greater then or equal to the threshold Note 2 BG:Belgium, CN:Canada, DK:Denmark, FN:Finland, FR:France, GE:Germany, IT:Italy, JP:Japan; NL:Neths, NW:Norway, SD:Sweden, SP:Spain

However, while the exercise shown in Table 4 is of interest, a more realistic approach in macroprudential surveillance would be to take on board new data as it comes available to obtain the most accurate model of crises at each point in time. Accordingly we repeatedly re-estimated the baseline model presented in Table 3A to obtain a series of rolling crisis probabilities shown in Table 5. For example, to compute the one-year-ahead crisis probability in 1998, we estimate the model using data for the period 1980 – 1997. This process is repeated until the entire estimation period 1980 – 2007 is consumed. In each case, the in-sample average crisis probability is used as a cut-off threshold to distinguish between crisis and non-crisis calls. Appendix 2 shows the recursive coefficients over the rolling sample period are remarkably stable.

Table 5: Out of sample rolling probabilities

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
BG	0.005	0.003	0.003	0.003	0.006	0.003	0.003	0.008	0.014	0.027	0.033
CN	0.032	0.052	**0.051**	0.026	0.011	0.012	0.014	0.019	0.013	0.015	0.023
DK	0.015	0.038	**0.055**	0.034	0.032	0.015	0.021	0.012	0.016	0.007	**0.044**
FN	0.004	0.005	0.008	0.004	0.000	0.000	0.000	0.001	0.000	0.001	0.002
FR	0.025	0.016	0.010	0.011	0.029	0.018	0.019	0.033	**0.066**	**0.137**	**0.153**
GE	0.026	0.025	0.026	0.041	**0.054**	0.024	0.010	0.012	0.003	0.003	0.002
IT	0.001	0.002	0.002	0.007	0.013	0.013	0.016	0.025	0.018	0.030	0.013
JP	**0.071**	0.023	0.007	0.007	0.005	0.005	0.002	0.001	0.000	0.000	0.001
NL	0.020	0.016	0.042	0.036	**0.122**	**0.096**	**0.047**	0.011	0.005	0.005	0.002
NW	0.011	0.005	0.034	0.010	0.000	0.000	0.001	0.001	0.000	0.000	0.000
SD	0.019	0.014	0.028	0.036	0.025	0.032	0.006	0.001	0.002	0.002	0.002
SP	0.005	0.005	0.008	0.024	0.036	0.034	0.033	**0.062**	**0.217**	**0.493**	**0.675**
UK	0.049	**0.057**	**0.079**	**0.157**	**0.176**	**0.152**	**0.077**	**0.134**	**0.199**	**0.197**	**0.251**
US	0.025	0.029	0.038	**0.062**	**0.064**	**0.046**	**0.070**	0.039	**0.045**	**0.052**	**0.109**
Prob threshold	0.057	0.054	0.050	0.048	0.045	0.043	0.041	0.039	0.037	0.036	0.040

Note1: figures in bold exceed the cut-off threshold Note 2 Note 2 BG:Belgium, CN:Canada, DK:Denmark, FN:Finland, FR:France, GE:Germany, IT:Italy, JP:Japan; NL:Neths, NW:Norway, SD:Sweden, SP:Spain

This exercise simulates the procedures that could have been available to policy makers undertaking macroprudential surveillance working in real time. These forecast crisis probabilities could have been used to determine the ex-ante regulatory tightening that would have been necessary to prevent the sub-prime crisis. Even if policy makers in the US, UK and France had decided to estimate our model one year prior to the sub-prime crisis, they would have had time to enact regulatory changes that may have prevented the crisis from materialising.

We do not intend to imply that other forms of macroprudential analysis are not useful, or that a model such as ours should be used as a sole diagnostic. We consider that both quantitative approaches such as the above and qualitative methods such as are included in "Financial Stability Reports" have a role to play. Nevertheless, we believe that models such as ours can play an important role in policy calibration exercises, also in providing a reality check against suggestions that "this time it's different": In the next section we use this model to quantify the regulatory changes that would have been necessary to reduce crisis probabilities.

3 Using the model to calibrate macroprudential regulation

Having shown the usefulness of our model for macroprudential surveillance, we now go on to show its usefulness in macroprudential regulation. We can invert the model to give the settings of regulatory instruments to give a desired level of crisis probabilities. Although it is impossible to reduce the probability of a crisis to zero, it is feasible using our estimates to analyse how changing minimum capital and liquidity requirements could keep the probability of a crisis below certain threshold values. The appropriate level of liquidity and capital adequacy is subject to intensive discussion, as shown in Appendix 1.

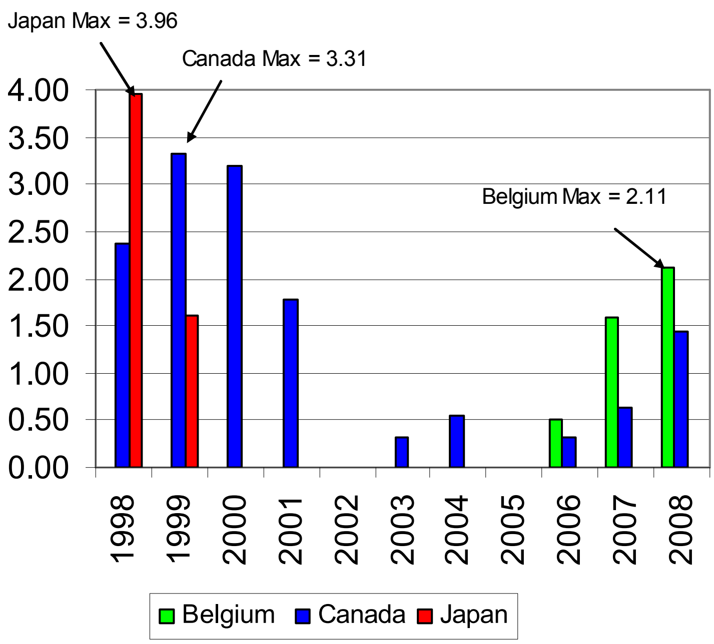
There are a number of alternative definitions of "acceptable" crisis probabilities. Our in-sample crisis probability up to 2008 is 0.055, similar to that of 0.057 in the basic 1980-1997 sample, implying a crisis every 16 observations (or almost one a year in 14 countries), while our subjectively imposed criteria are respectively 0.03 which translates to one crisis every 33 observations (one crisis every 2 ½ years) and our second subjective threshold is more stringent: 0.01 which translates to one crisis every 100 observations[11]. Obviously to bring crisis probabilities in line with the latter definitions will require greater changes to liquidity and capital adequacy levels. We calculated the required regulatory adjustment to leverage and narrow liquidity to obtain a consistent maximum level of risk in each year and for each country using the rolling model constructed for Table 5 above. These give the necessary adjustments required to offset risks to financial stability generated by both the current changes in the macro variables and also the current levels of the regulatory variables. The results are explained and summarised in Appendix 3 and Appendix 4

The distribution of combined capital and liquidity changes for Belgium, Canada and Japan are given as examples in Chart 1. The probabilities in Table 5 show that projected crisis probabilities for Belgium between 1998 and 2005 were below the international benchmark of 0.01, and thus in Chart 1 regulatory adjustments are only visible for 2006 onwards. Crisis probabilities in Canada and Japan exceeded 0.01 at the beginning of the forecast

[11] The rationale for including the in-sample probability is that it represents the historic benchmark crisis rate which is not biased by policy makers' preferences. The subjective criterion however, allows the policy maker to use a more (or less) stringent level of acceptable crisis likelihood.

period and so these countries would have required greater capital buffers to achieve a target probability of 1 per cent.

Chart 1: Percentage Point Combined Capital and Liquidity Adjustment for 0.01 Country Specific Risk in Each Year



In order to start to calibrate a standard for each country, the maximum of the distributions (as shown in Chart 1) were identified. This value represents the largest adjustment each country would have had to make to ensure the crisis probability did not exceed 1% over the 1997-2008 period. The year-by-year maxima across all countries are given in Appendix 4 for the three probability thresholds. There is no evidence that a simple cyclical adjustment to the regulatory instruments is required, but there is evidence that required adjustments generally increased in the run up to the sub-prime episode reflecting housing booms and increased current account deficits experienced by many countries.

The international benchmark we suggest is the average of all the country maxima across all years in the 1997 to 2008 period, which is summarised in Table 6. According to this, the international requirement should be that both capital and liquidity in each country should be topped up equally by 3.7 percentage points, or if preferred, countries can add 4.59 percentage points to their capital alone or 19.83 percentage points to their existing liquidity levels. If we take the average of the maximum as a standard some countries will have a crisis probability in excess of 1 per cent whilst others will have a probability below the target. As the logit function is not linear it is probably the case that the average probability will marginally exceed 1 per cent. Nevertheless this method represents a good starting point for an international calibration exercise. Based on Appendix 3 and 4, we note the significant variance between required capital and liquidity standards across countries and time; for example the capital adjustment for 1% crisis probability ranges from zero in Finland to 5.3 percentage points in the UK. Although the focus of policy discussions has been on procyclicality, our results suggest that such country differences have to be reconciled as part of the process of international reform.

Having derived the international benchmark, we can examine the distribution of the new requirements across countries. We have already computed the country-specific adjustments required for limiting their individual crisis probabilities to 0.01 and we also know the top-up to capital and liquidity required by international rules. The difference between the two thus represents the overshoot or shortfall in regulatory targets for each country. These values are presented in Table 6 where columns 1 (capital and liquidity) and 2 (capital only) give the maxima of the country-specific adjustments required to maintain the probability of a crisis at 0.01.

Table 6: Country Specific Regulatory Adjustments versus International Benchmarks

Column	1	2	3	4
	Additions to country specific levels of liquidity and leverage to reduce all prob. to 0.01 or below*		Under or overshoot	
			(column 1 - 3.7)	**(column 2 - 4.59)**
Top Panel	lev+nliq	lev alone	lev and nliq	lev
Belgium	2.11	2.56	-1.59	-2.03
Canada	3.31	4.15	-0.39	-0.44
Denmark	3.35	4.15	-0.35	-0.44
Finland	0.00	0.00	-3.70	-4.59
France	5.08	6.25	1.38	1.66
Germany	3.12	3.79	-0.58	-0.80
Italy	1.74	2.14	-1.96	-2.45
Japan	3.96	5.19	0.26	0.60
Neths	4.72	5.80	1.02	1.21
Norway	2.34	2.87	-1.36	-1.72
Sweden	2.38	2.90	-1.32	-1.69
Spain	9.32	11.48	5.62	6.89
UK	6.08	7.63	2.38	3.04
US	4.35	5.34	0.65	0.75
Mean (International Benchmark)	**3.70**	**4.59**		
SD	2.24	2.77		

** country specific adjustments are the maxima from Appendix 3.*

The averages of columns 1 and 2 could constitute the international benchmarks. The difference between this average and the country-specific adjustment thus represents the extent to which countries must "top-up" their buffers as shown in columns 3 and 4. For example, to maintain the probability of a crisis at 0.01 the UK would have to raise existing banking system capital and liquidity by 6.08 percentage points each. However the international benchmark only requires them to raise standards by 3.7 percentage points. Thus the country specific adjustment warranted in the UK overshoots the international target by 2.38 percentage points. Conversely, Sweden needs only raise capital and liquidity by 2.38 percentage points according to its idiosyncratic risk yet the international standard would require it to hold an additional 1.32 percentage points on capital and liquidity. Unless they have reasons to hold capital above the international minimum, countries such as Sweden would "lose" if they signed up to international agreements as they would be required to hold more costly capital even though their contribution to OECD risk might be relatively small[12]. If the international agreement is seen as a way of 'tying the hands' of the largest actor then there is a case for raising the regulatory level of capital and liquidity together by 4.35 percentage points which reduce probabilities everywhere and brings it down to 1% in the US over both the sample average and in 2008.

In sum, our results suggest capital and liquidity should be raised by at least 3.7 percentage points, and better by 4.25 percentage points. This could be worked out either on a country specific, global average or worst case basis. Of course maxima should not be set in stone and if the situation is objectively worse than in 2008, then capital should reflect it. Rules may also need to be modified to accommodate procyclicality which we discuss in the next section, firstly in the context of property prices and current account deficits and secondly in the context of provisioning against credit and GDP growth.

3 Countercyclical macroprudential regulation

Calculating fixed minima and guides to maxima is only part of a redesign of the macro prudential policy architecture. Restraining lending in upturns and ensuring banks have sufficient buffers to buoy lending capacity in downturns may also be important. The combination of the subprime crisis and the experience of Spain with such buffers have made this issue core to the current policy debate, as discussed in Appendix 1.

In this context, the key question is what variables can be used to guide the cyclical adjustment of capital and liquidity standards. Our results above imply that a simple rule based on GDP or credit growth, as recommended by many official and academic commentators, is not appropriate. Our work suggests rather that the appropriate adjustment for procyclicality requires the country to calculate the trade-off between house prices, current account balances and regulatory variables over time. Since there is nonlinearity in a logit equation, there is not a simple rule that can be derived. Nevertheless, we can show examples of countercyclical policy by illustrating how it should adapt to higher house price growth or current account imbalances. Note that in each case the calibration is to a lag of the variable and not its current value, in line with the equation specification in Table 3A

Table 7 offers a possible illustration, showing how much tighter regulation must be with 5 percentage points higher house price growth with the same lag as in the equation i.e. three years. The calibration uses the marginal effects of higher house prices in the model from Tables 2 and 3 and we assume equal adjustments to leverage and liquidity. It can be seen that the regulatory adjustment is positive, as would be expected, with higher lagged house price growth, but the relationship is not one-to-one – it depends also on the other regulatory and non regulatory variables in the model. A given growth rate of house prices is more threatening to financial stability when there is also low capital and liquidity as well as a current account deficit. Compare for example 2006 in the UK and 2008 in Spain that have the same lagged house price growth but very different regulatory prescriptions because the other variables in Spain are more adverse. It is clear that macroprudential rules for dealing with procyclicality can only be fully expressed in terms of the full equation and the probabilities it generates.

[12] To place the above analysis in the context of the sub-prime episode, we repeat the calculations specifically for 2008, see Appendix 5.

Table 7: Change in regulation required for retaining sample mean probability (0.0555) with 5 percentage point higher house price growth*

	France		Spain		UK		US	
	Regulatory adjustment	Actual RHPG (-3)	Regulatory adjustment	Actual RHPG (-3)	Regulatory adjustment	Actual RHPG (-3)	Regulatory adjustment	Actual RHPG (-3)
1998	0.0	-3.2	0.0	-0.1	0.6	-2.5	0.0	0.8
1999	0.0	1.3	0.0	-1.7	1.0	0.2	0.0	1.5
2000	0.0	0.8	0.0	0.0	1.9	6.2	0.4	1.8
2001	0.0	1.7	0.0	3.8	3.5	8.9	1.5	4.2
2002	0.1	7.5	0.3	5.3	3.8	9.5	1.7	3.1
2003	0.0	6.2	0.4	4.7	3.8	13.7	1.2	4.0
2004	0.0	6.1	0.5	6.1	2.5	6.1	2.2	5.4
2005	0.7	7.2	2.1	12.5	3.9	14.3	1.1	4.9
2006	2.2	10.0	4.6	14.1	4.8	13.9	1.5	4.3
2007	3.7	13.4	6.8	13.4	4.7	10.1	2.1	6.7
2008	4.0	13.6	7.3	10.2	4.4	3.0	2.7	8.4

* *Based on the 1980 – 1997 model outlined in Table 2 and assuming equal adjustments to leverage and liquidity.*

Policy makers are keen to have simple dynamic provisioning against credit booms, as is clear from BIS (2010). These suggestions stem from the observation that rapid credit growth precedes banking crises during a phase when collateral values are high and credit risk is improperly evaluated. Demirguc-Kunt and Detragiache (1998, 2005), Demirguc-Kunt, Detragiache and Gupta (2006) and Borio, Furfine and Lowe (2001) amongst others find credit growth to be a leading indicator of a banking crisis:. However we argue that such estimations are incomplete because:

(1) capital adequacy, liquidity, property prices and current account deficits were often not tested alongside credit growth which means that coefficients on the latter may have suffered from omitted variable bias;
(2) many such studies relied on samples based on a mixture of developed and developing economies with very different banking and financial system characteristics and thus different vulnerabilities to crises. Davis, Karim and Liadze (2010) show the pooling assumption of previous studies is invalid, since banking crisis determinants differ by region even within the group of Emerging Market economies

Moreover, besides our own estimates, other papers equally do not find conclusive evidence for the role of credit growth in generating financial instability. Mendoza and Terrones (2008) found that credit booms often link to banking crises in emerging market economies but less often in OECD countries. In a study based on the Euro area and the US, Kaufmann and Valderrama (2007) note that "The mutually reinforcing effects of lending and asset prices contributing to the build-up of financial imbalances during boom periods is not confirmed in our model" for the Euro area although reinforcement occurs to an extent in the US market based banking system. Boyd et al (2001) investigate the behaviour of credit/ GDP ratios in 22 economies that experienced a single banking crisis and find unusual credit growth in only 6 of them whilst in 10 economies rapid credit growth was not followed by a crisis.

As a consequence of our results which suggest house prices are more significant than credit growth and the ambiguous role of credit in the literature, we went on to test for relationships between real residential property prices and real domestic credit. We investigate whether there are stable effects of credit on property prices which could justify a credit-based rule by proxy, even if it is not among the key predictors of crises itself. We tested by looking for Granger causality around any cointegrating relationships we found between credit and property price growth, or Granger causality in the first differences if cointegrating relationships are absent

Table 8 presents the results of tests for cointegrating relationships which show that a long-run relation exists between credit levels and property price indices in Denmark, Finland, France, Sweden and Italy[13]. For these countries we go on to test an error correction specification for the presence of Granger causality, whilst for the remaining countries the absence of a cointegrating relationship means we can test for Granger causalities in the first differences.

Table 8: Cointegrating Relations

Data Sample: 1980 - 2008	Ho: Unit Root Exists	
	1% (ADF stat = 2.66)	5% (ADF stat = 1.95)
Denmark		-1.951
Finland		-2.056
France	-2.743	
Italy	-4.119	
Sweden	-2.608	

Blank fields indicate non-significance at that level

Where a cointegrating vector exists, a Granger causality test requires that we investigate whether the dynamic time series properties of house prices influence the dynamic properties of credit and vice versa in a regression that also includes the cointegrating vector with an error correction coefficient. The incidence of such effects implies causality exists in the presence of a stable long-run relationship between credit and property. The top two rows of Table 9 presents the dynamic specifications for the countries that are significant in Table 8, namely Denmark, Finland, France, Italy and Sweden. We use one lag[14].

Table 9: Granger-Causality outturns for countries where cointegration is present

	ΔLOG(Real Property Price Index(-1)) CAUSES ΔLOG(Real Domestic Credit)	ΔLOG(Real Domestic Credit(-1)) CAUSES ΔLOG(Real Property Price Index)	Pre - 1995	Post - 1995
Denmark	NO	NO	NO	NO
Finland	NO	YES	NO	YES
France	YES	NO	NO	NO
Italy	NO	NO	NO	NO
Sweden	NO	YES	YES	NO

Note: Granger causalities for countries where real domestic credit and property prices show no long-run relationships are presented in Table 10.

[13] For the bivariate cointegrating equations we restrict the coefficient to a unit root.

[14] We also conducted the tests for the second, third and fourth lags but the addition of extra lags did not change the results.

Apart from France, there is no causality from property to credit. With regards to the opposite causality, we find evidence that credit Granger causes property prices in Finland and Sweden. Given that time series effects are present and as a robustness test for where no dynamic relationship exists either way (Denmark and Italy), we test whether the dynamic effects differ according to the sample period, and the regressions were run for pre-1995 and post-1995 subsamples these results are given in the last two columns of Table 9. Results suggest that in Finland, property price increases lead the growth of credit in the post-1995 period while in Sweden the same effect was observed prior to 1995. In the case of France, causality runs from credit to property prices and this effect is not present in the shorter sample periods. For Denmark and Italy the result does not change for split samples.

The results associated with splitting the sample in 1995 may be explained by the financial liberalisation policies adopted in Sweden and Finland. In financially repressed systems, credit rationing would have meant that prospective homeowners would have been restricted in their property transactions; once the restriction was lifted, the sudden increased access to mortgage finance would have put upwards pressure on house prices which may explain the split sample results. Barrell and Davis (2007) give the Swedish liberalisation date as 1985 and Abaid et al (2008) show that although there was also a round of liberalisation in Finland in the mid 1980s, financial liberalisation actually peaked in 1993. Jonung (2008) notes how liberalisation in these economies fundamentally affected credit availability: aggressive competition for market shares by banks caused a lending boom with bank portfolios becoming increasingly concentrated in real estate. This ultimately generated the property price bubbles that appear to underpin our results.

Table 10: Granger Causality outturns for countries with no cointegration

	CREDIT → PROPERTY PRICES: null hypothesis: no granger causality F-stat (probability)				**PROPERTY → CREDIT GROWTH: null hypothesis: no granger causality F-stat (probability)**			
	1 LAG	2 LAGS	3 LAGS	4 LAGS	1 LAG	2 LAG	3 LAGS	4 LAGS
BELGIUM	**4.66 (0.04)**	1.9 (0.17)	1.29 (0.31)	0.7 (0.61)	0.27 (0.6)	0 (1)	0.13 (0.94)	0.17 (0.95)
CANADA	**4.94 (0.04)**	2.74 (0.09)	0.44 (0.73)	1.39 (0.29)	3.14 (0.09)	2.3 (0.12)	0.99 (0.42)	0.68 (0.62)
GERMANY	2.58 (0.12)	1.8 (0.19)	0.51 (0.68)	0.46 (0.77)	2.56 (0.12)	0.99 (0.39)	0.5 (0.69)	1.24 (0.34)
JAPAN	0.98 (0.33)	2.88 (0.08)	1.82 (0.18)	1.78 (0.19)	**6.2 (0.02)**	1.62 (0.22)	0.49 (0.69)	0.28 (0.88)
NETHERLANDS	0.04 (0.84)	0.58 (0.57)	0.39 (0.76)	0.69 (0.61)	**5.13 (0.03)**	1.36 (0.28)	0.32 (0.81)	0.21 (0.93)
SPAIN	0.3 (0.59)	0.11 (0.89)	0.31 (0.82)	0.41 (0.8)	1.28 (0.27)	1.19 (0.32)	0.67 (0.58)	0.5 (0.74)
UK	0.02 (0.88)	0.66 (0.53)	2.08 (0.14)	1.12 (0.38)	**5.36 (0.03)**	**6.12 (0.01)**	2.75 (0.07)	1.66 (0.21)
USA	1.75 (0.2)	0.6 (0.56)	0.68 (0.58)	0.24 (0.91)	0.67 (0.42)	0.67 (0.52)	0.28 (0.84)	0.93 (0.47)
NORWAY	0.02 (0.89)	0 (1)	1.21 (0.34)	1.55 (0.24)	**13.27 (0)**	**8.18 (0)**	**4.48 (0.02)**	**3.43 (0.04)**

Figures in each cell are the F-statistics with the corresponding p –value in brackets; significance of 5% or better is highlighted in bold.

The Granger causality results in first differences for those countries where there is no cointegration are shown in Table 10. Credit growth leads property prices in Belgium and Canada. More commonly property price growth appears to Granger-cause credit growth, and such an effect exists in four economies.

We would expect property prices to lead credit in cases where mortgage credit is relatively easy to access. If perceptions of the fundamental value of house prices shift such that society now believes property is undervalued we may observe increases in property price indices which in turn fuel the demand for credit. In such cases, property may cause credit although this phenomenon should dissipate once imbalances in real estate markets correct themselves. According to our results this appears to be the case in the UK, the Netherlands, Japan and also in Norway, where financial liberalisation and the corresponding property price bubble occurred earlier than in Sweden and Finland (Jonung, 2008).

Our results suggest that it is not the cycle or overall lending per se but bad lending and the consequent vulnerability of the banking system which lead to crises. Hence it is property booms and current account deficits that distinguish booms which require macroprudential policies to counteract them. Provisioning on credit or GDP would risk choking off sustainable booms where supply capacity is moving in line with demand, with adequate fixed investment (including housing investment) and increasing labour supply.

An alternative to use of growth rates of credit or GDP is use of measures of “gaps” vis-à-vis long term sustainable levels. An example is Borio et al (2010) which suggests that the gap between credit/GDP and its trend level is the best indicator of banking crisis risk.[15] However, such an approach also requires adequate knowledge of trends, i.e. “output gaps” and “credit gaps”. But these gaps are not observable and thus allow policymakers to set rules according to their subjective classification of unsustainable credit and GDP growth. We contend that property price growth and current account deficits enter our equation precisely because they do reflect unsustainable demand in the economy and thus they supersede credit and GDP growth as crisis determinants. Accordingly capital provisioning against excess demand should be conditioned on the behaviour of property prices and current accounts following the example shown in Table 7.

4 Conclusions

We have shown that a quantitative estimate of determinants of crises for OECD countries covering the period 1980-1997 can be of major assistance both to macroprudential surveillance and macroprudential regulation. The model indicates that low levels of liquidity and of capital along with recent house price booms and current account imbalances are the major explanatory variables driving crisis probabilities in OECD countries.

For macroprudential surveillance purposes, the model could have been used to evaluate the probability of crises between 1998 and 2008, either on a long-term or a recursive one-step ahead basis, if the independent variables are predicted accurately. Such a tool would have been of major use to macroprudential surveillance, which was unable to predict the subprime crisis (Davis and Karim 2008b) using conventional qualitative judgement, while

[15] They note that property prices also perform well in the signal extraction based calculation, but dismiss it as not available for a sufficient range of countries.

equally the traditional variables used in EWS equations would also have missed the crisis. Using the model estimated only up to 1997, we can "call" the US crisis accurately, as well as those in France, Belgium and the UK.

For macroprudential regulation purposes, the model allows us to calibrate prudential policy to keep crisis probabilities below a chosen threshold. These are a useful input to the debate on macroprudential regulation in that 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. We show what path macroprudential policy could have followed to offset specific macroeconomic risks to banks. A degree of compromise would be needed between countries to ensure that countries could agree on a single macroprudential adjustment, given the needs for extra capital and liquidity over our sample period for a given reduction in crisis probability vary widely.

We show also that countercyclical provisioning rules based on GDP or credit growth are less appropriate than a full calculation of systemic risk based on the current model of house prices, current accounts, leverage and liquidity. Credit is not only excluded from our model – and hence shown to not be a key predictor of banking crises, but also for most countries it does not Granger-cause property prices – suggesting it cannot be justified as an indicator by proxy either.

We conclude by noting that the analysis is incomplete because we do not allow for the costs of regulation since higher capital and liquidity requirements induce banks to raise lending margins, hence adversely affecting the user cost of capital, investment and the capital stock[16]. 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.

[16] See Financial Stability Board (2010) for international estimates of these "costs" of tighter regulation.

Appendix 1 The debate on regulatory responses to financial crises

As background to our work, in this Appendix we first review the ongoing policy debate surrounding bank capital and liquidity requirements before we consider the recent academic contributions that also stress the importance of capital and liquidity. In this context, procyclicality will also be discussed. The current debate is extremely dynamic, as regulators attempt to catch up with deficiencies in the Basel II framework, and so we will restrict our review to the most recent policy discussions.

In the light of the regulatory deficiencies observed during the subprime crisis, the Financial Stability Board had already begun to recognise the need for strengthened international capital and liquidity standards (2009). Based on the objective of creating less procyclical and more systemically stable financial markets, the Basel Committee on Banking Supervision is due to calibrate the new capital requirements during 2010[17]. The quantity and quality of capital for individual banks and banking systems will be re-stipulated in a set of rules that are intended to apply in a similar way across all countries.

The BIS (2009a) consultative framework which emerged out of the FSB (2009) recommendations to G20 leaders was intended to flesh out the regulatory changes before the calibration stage ensued. Specifically, the BIS (2009a) proposals include measures to:

(i) Improve the quality of capital by subjecting common equity to regulatory adjustments. Previously, adjustments excluded the equity component of Tier 1 capital so that high Tier 1 ratios could be reported when actually the common equity fraction (which absorbs losses first) was low. In a similar vein, non-equity instruments can only be included after they have been shown to be loss absorbing in practice (e.g. subordinated instruments which issue discretionary payouts and which are unlikely to be redeemed).

(ii) Improve the quantity of capital, since previously the maximum amount of Tier 2 capital held by a bank was dependent on how much Tier 1 capital had been issued. Moreover, the restriction that Tier 1 capital must exceed Tier 2 capital will be removed but will be replaced by unambiguous minimum Tier 1 requirements. The BIS (2009a) suggests explicit minima be applied to the different grades of capital, common equity, total Tier 1 and total capital.

The FSB (2009) recognised that liquidity risk management should be considered from an ex-ante perspective (redefined liquidity ratios to prevent risk from accumulating) as well as ex-post (ensuring that authorities monitor banks' reliance on liquidity and foreign currency funding markets once liquidity risk is already accepted). Recommendations were made to the Basel Committee on Banking Supervision in order to redefine minimum liquidity standards which could be exceeded by countries at their discretion. Subsequently, BIS (2009b) put forward two new standards aimed to produce internationally consistent liquidity risk supervision as well as a minimum set of monitoring metrics for supervisors. These metrics are designed to cover the needs of individual banks, but they need to be supplemented by an understanding of, and a set of standards regarding, market liquidity as

[17] The Financial Stability Board (2009) suggests that on average this will require large banks to at least double their capital buffers by the end of 2010.

a whole. The need for liquidity is in large part a system wide requirement, and can be evaluated from crisis probability models and these should supplement the individual bank standards below.

The first new standard concerns the Liquidity Coverage Ratio which focuses on whether short term (30 day) funding shocks (which can be bank specific or systemic in source[18]) can be met. The ratio is constructed as the level of high quality liquid assets that covers net cash outflows based on scenarios envisaged by supervisors. In order to ensure the bank has sufficient liquidity up to day 30, and to buy time for the bank to take corrective steps, the ratio should continuously exceed 100% throughout the simulation month. High quality assets are defined as those that remain liquid when markets are stressed, are central bank acceptable and are unpledged as collateral to others.

Longer term liquidity problems are to be addressed via the Net Stable Funding Ratio (NSF) since the maturity-liquidity characteristics of a banks' balance sheet assets and the contingent cash needs arising from off-balance sheet exposures become important. Consequently, scenarios are built using a 1 year horizon with the aim of reducing banks' wholesale funding. To avoid large-scale distress, the bank must ensure the ratio exceeds 100% over the entire simulation period. The benefits of this new supervisory measure are that it caters for off-balance sheet liquidity requirements (which were not built in to previous measures such as "net liquid assets") and that it reduces banks' incentives for regulatory arbitrage whereby assets are funded with securities whose maturity fall just beyond the supervisory horizon[19].

The problem of capital and liquidity adequacy was addressed in a UK context by Barrell et al (2009) who quantified on behalf of the UK regulator the FSA the impact of capital adequacy and liquidity on banking crisis probabilities, and extended the analysis to undertake a cost and benefit evaluation of tighter standards. Barrell, Holland and Karim (2010) extend some of this analysis to international regulation based on the results in the earlier paper.

The procyclicality of the financial system (already apparent with Basel 1), seemed set to worsen with Basel 2 (Goodhart, 2005) which prompted banks to sell assets due to rating downgrades and higher capital charges associated with recessions. In aggregate this worsens borrower solvency further[20] and may spread credit rationing to other markets (Warwick Commission 2009). However recently, in recognition of the procyclical amplification of systemic risks during the sub-prime episode, BIS (2009a) proposed a macroprudential framework that complements the microprudential recommendations highlighted above. A countercyclical capital structure has been suggested so that banks accumulate capital stocks when output gaps are positive enabling them to better absorb losses during recessions. There are also recommendations for more forward looking provisioning so that future expected losses are accommodated in advance. This would

[18] For example, bank specific funding shocks may arise from credit rating downgrades or a partial loss of deposits whereas the termination of unsecured wholesale funding is feasible after systemic risk increases.

[19] Recent discussions have recognized the complexity of these suggestions, and their implementation is likely to be delayed. Complicated rules are not advisable as they are designed to deal with specific problems that may not re-occur and they are difficult to police.

[20] Even lacking such regulation, in trying to make themselves safer, banks may collectively generate systemic risk (for example by selling assets when the price of risk rises).

reduce the impact of sudden increases in non-performing loans on balance sheets during business cycle downturns thereby dampening procyclicality further.

To ensure that regulatory changes actually transmit to reduced procyclicality, the BIS (2009a) advocates the use of longer historic time series to estimate default probabilities, that specific "downturn loss-given-default" estimates should be computed and that the risk functions that are used to map these losses to capital adjustments are revised accordingly. It has been suggested by CEBS (2009) that procyclicality should be addressed by modifying the existing Pillar 2 framework rather than via the introduction of new supervisory mechanisms. Their view is that internal-ratings-based (IRB) banks that assess credit risk using in-house models are more likely to be exposed to procyclical dynamics; banks should therefore focus on two capital components: buffers beyond the minimum regulatory requirement to accommodate business cycle downturns and buffers which are held against extreme events[21].

There have been a number of proposals that suggest capital requirements, either in terms of the regulatory minimum, or extra tranches above that minimum, should vary over time and should depend upon the potential state of the economy. Time varying capital requirements related to lending growth are recommended, alongside the purchase of catastrophe capital insurance by Kashyap et al (2008). Goodhart (2005) suggests that capital requirements related to bank lending should be related to the rate of change of asset prices, while another alternative is to limit individual bank asset growth to a rate consistent with an inflation target (Warwick Commission 2009). In a widely-cited contribution, Brunnermeier et al (2009) recommend that credit growth be used as a guide in countercyclical regulatory policy, with the calibration being on the degree of credit growth considered to be consistent with the long run target for nominal GDP. An adjustment should perhaps be made for assets and liabilities maturity mismatches, thus penalizing the financing of long run assets with short run liabilities[22]. Borio et al (2010) recommend use of the gap between the current credit-to-GDP ratio and its trend level for accumulation of buffers and a loss based indicator for the release of buffers.

In order to evaluate the relative strengths of these suggestions it is useful to look at them in the light of evidence on the factors associated with banking crises in the OECD, and in this paper we suggest that credit growth based rules may be less effective than those based on asset price growth. It is also useful to evaluate these proposals in the light of the recent academic literature which has also examined the impact of liquidity, capital adequacy, property price growth and current account deficits on crises. We next turn to that area first before looking at new empirical results on capital adequacy.

Acharya et al (2009) note that when banks hold risky assets during economic upturns, higher expected profits make these assets more acceptable as collateral. Consequently,

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[21] Although CEBS (2009) focuses on the former capital adjustment, we note that our empirical estimates give an idea of the capital adjustments necessitated by tail events such as OECD crises.

[22] Capital buffers against downturns would be adequately provided if probabilities of default (PDs) are adjusted to incorporate recessions. The adjustment factor would then decrease in size when output gaps are negative (because existing PDs and "recessionary PDs" are now aligned) and increase during expansions. Such adjustments therefore translate into countercyclical provisioning. The FSA (2009) also advocate similar capital adjustments in order to reduce the procyclicality that arises from biased PD estimates.

liquidity provisioning becomes countercyclical[23]; banks hold less than the socially optimal amount of liquidity during booms[24]. Moreover, bank bailouts and unconditional support to healthy banks increases their ex-ante liquidity risk whereas liquidity support conditional on existing liquidity holdings forces them to hold more ex-ante liquidity. The revised FSB (2009) liquidity standards discussed previously may address these findings to an extent.

Diamond and Rajan (2009) discuss structural factors that promote under-provisioning of bank capital. During booms, short-term debt is cheaper than long-term capital and so short-term leverage dominates bank balance sheet compositions. Because the converse occurs during recessions, the authors note that countercyclical regulatory capital adjustments may be hard to implement in practice.

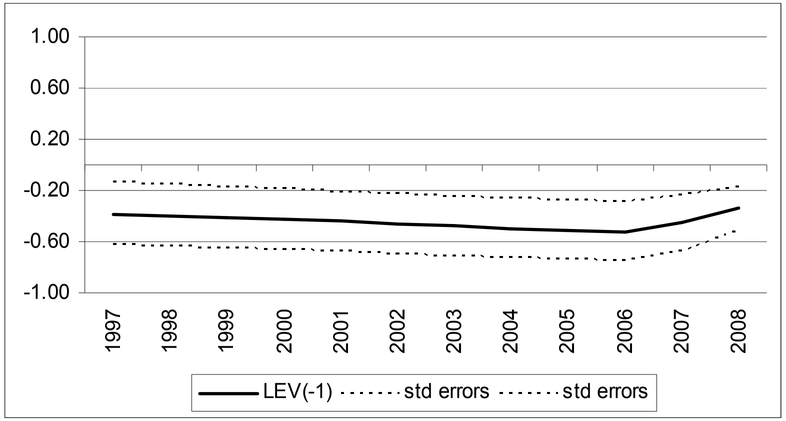
Although the regulatory debate has focused on capital and liquidity as target variables without an explicit framework for setting such standards in relation to systemic risks, the results for property prices and current accounts in this paper mirror recent academic discussions. Reinhart and Reinhart (2008) investigate 181 economies over the period 1980 – 2007 and find that capital account liberalisations have increased the prevalence of current account deficits. Moreover, in high income economies, significant current account deficits marginally increase the probability of a banking crisis occurring (as well as the likelihood of a sovereign debt crisis). In addition Reinhart and Rogoff (2008, 2009) observe that excessive property price growth was a feature of many post-world war II banking crises including Spain, Norway, Finland, Sweden and Japan and was particularly high in the US prior to the sub-prime episode alongside large increases in the current account deficit.

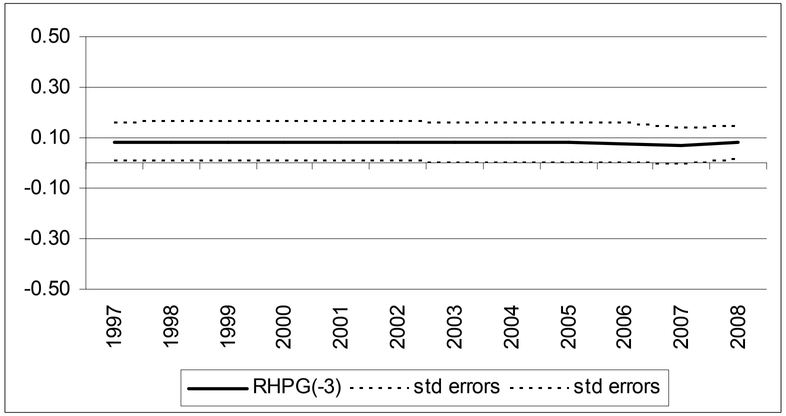
Mulligan et al (2008) note the impact of a property price crash on bank capital. After the collapse, investors will only demand mortgages with higher expected returns and consequently, the supply of capital decreases. Moreover, since the homeowner's loss is restricted to their housing equity, any remaining losses must be absorbed by bank shareholders and their creditors. The latter may include public authorities if creditors include depositors.

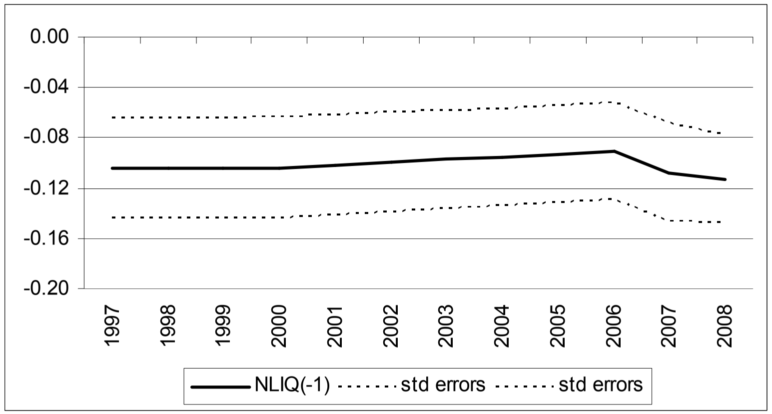
Finally we note that any minimum standards imposed on banks in terms of capital adequacy and liquidity protection would also have to accommodate the insurance sector. The EU Commission (2009) has stressed the importance of a unified set of regulations between the banking, insurance and reinsurance sectors to ensure solvency of this interconnected system and accordingly their Solvency II directive is based on the Basel II framework. The UK Treasury (2008) estimates that by forcing the adequate capitalisation of insurers, for the UK at least the benefits will outweigh the costs of raised capital adequacy. However, these calculations are based on preliminary estimates of the revised minimum standards.

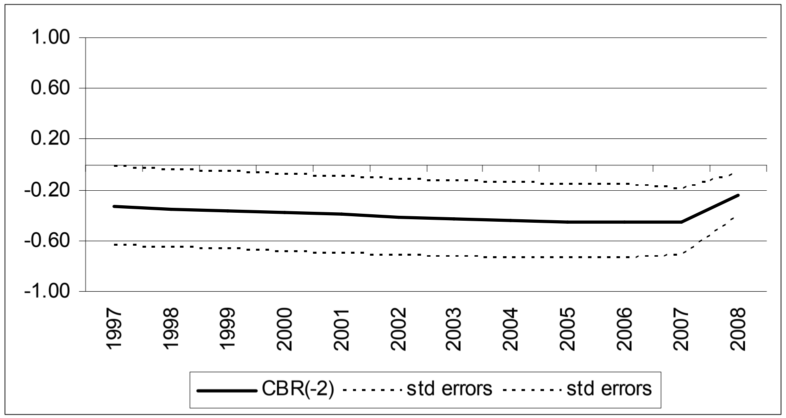
[23] Some banks may hold excess liquidity but this is in anticipation of the impending crises caused by low aggregate liquidity which as these banks know will create profitable opportunities via fire sales of assets.
[24] The authors cite IMF (2008) which noted the deeper haircuts during the post sub-prime period when expected profits were low and risky assets became less pledgeable.

Appendix 2: Recursive coefficients on the rolling estimates (with 2 standard error bands)









Appendix 3: Country by country analysis of required regulatory adjustments

Step 1: Setting the International Benchmark

We need to assume that regulators agree on an internationally acceptable level of systemic risk. In our case, "international" translates to "OECD" and as a benchmark for acceptable risk we can take one of the two subjective crisis probabilities mentioned previously: 0.01 or 0.03. For our demonstration we will focus on prob(crisis) = 0.01.

Translating country-specific risks to internationally agreed systemic risk levels means interpretations of regulatory adjustments are not straightforward. There are at least two alternative options for interpreting "acceptable levels of systemic risk":

- Option 1: this could mean that 0.01% crisis risk is maintained in each country in each year of the forecast horizon, or,
- Option 2: it could also mean that only average risk is maintained at 0.01% across the OECD over the forecast horizon.

Option 1 represents a framework for country specific regulation whereas Option 2 focuses on OECD-wide systemic risk. Existing Basel capital rules apply a common (8%) standard to all countries whilst discretionary top-ups are left for domestic regulators to stipulate. However the fulfilment of Option 1 by all countries does not necessarily mean Option 2 is also satisfied and herein lies the problem of international benchmarks; even if countries restrict crisis probability to 0.01 in every period, if the average of their capital adjustments is used as an international standard the OECD risk may exceed 0.01 in some years. Indeed this is almost certainly likely to be the case given the non-linearity of the logit function: countries that have high levels of instability will be located in the middle of the distribution where marginal impacts of capital and liquidity changes are high, whereas in countries with less instability the marginal effects of capital are much lower.

Thus, applying a common capital top-up requirement to n countries will not generate an (n*0.01) reduction in systemic risk. This point is important because in order to hone in on an international standard we have to focus on maintaining systemic risk at 0.01 *in each country* (Option 1) as a starting point but highlight that it cannot guarantee that OECD systemic risk is restricted to 0.01 in every year.

We are thus concerned with how the "average rule" will impact on countries individually since some will be inherently more unstable than others and will require larger capital or liquidity adjustments. Conversely, countries which are more stable than the OECD average will be penalised when they are required to top-up their capital and liquidity ratios to an agreed figure. In order to measure these impacts we proceed to the second calibration step.

Step 2: Country Specific Adjustments

The 1980 – 1997 logit model is inverted and used with the rolling crisis probabilities (Table 5) to infer the changes in capital and liquidity required to maintain prob (crisis) = 0.01 in each year of the forecast horizon (option 1). We will assume that the adjustment is split equally between capital and liquidity[25].

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[25] We make this simplistic assumption for tractability only; regulatory adjustments based on changes to capital adequacy and liquidity alone are also computed and presented in the Appendix.

		Prob=0.01			Prob=0.03			Prob=0.055		
		Country mean	Country median	Country maximum	Country mean	Country median	Country maximum	Country mean	Country median	Country maximum
Belgium	Both	0.38	0.00	2.11	0.02	0.00	0.18	0.00	0.00	0.00
	lev(-1)	0.45	0.00	2.56	0.02	0.00	0.19	0.00	0.00	0.00
	nliq(-1)	2.26	0.00	10.94	0.06	0.00	0.71	0.00	0.00	0.00
Canada	Both	1.26	0.63	3.31	0.22	0.00	1.19	0.00	0.00	0.00
	lev(-1)	1.57	0.71	4.15	0.27	0.00	1.42	0.00	0.00	0.00
	nliq(-1)	6.51	4.44	15.80	1.06	0.00	5.52	0.00	0.00	0.00
Denmark	Both	1.49	1.30	3.35	0.26	0.00	1.24	0.00	0.00	0.00
	lev(-1)	1.85	1.52	4.15	0.31	0.00	1.56	0.00	0.00	0.00
	nliq(-1)	7.80	7.40	16.35	1.26	0.00	6.10	0.00	0.00	0.00
Finland	Both	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	lev(-1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	nliq(-1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	Both	1.77	1.15	5.08	0.66	0.00	3.14	0.36	0.00	2.00
	lev(-1)	2.13	1.30	6.25	0.79	0.00	3.88	0.43	0.00	2.48
	nliq(-1)	10.24	6.50	29.87	3.96	0.00	18.12	2.15	0.00	11.04
Germany	Both	1.24	1.54	3.12	0.16	0.00	1.17	0.00	0.00	0.00
	lev(-1)	1.57	1.83	3.79	0.20	0.00	1.44	0.00	0.00	0.00
	nliq(-1)	6.37	8.35	16.56	0.85	0.00	6.31	0.00	0.00	0.00
Italy	Both	0.42	0.31	1.74	0.00	0.00	0.00	0.00	0.00	0.00
	lev(-1)	0.54	0.51	2.14	0.00	0.00	0.00	0.00	0.00	0.00
	nliq(-1)	2.60	1.51	12.02	0.00	0.00	0.00	0.00	0.00	0.00
Japan	Both	0.51	0.00	3.96	0.17	0.00	1.85	0.05	0.00	0.54
	lev(-1)	0.65	0.00	5.19	0.21	0.00	2.31	0.06	0.00	0.70
	nliq(-1)	2.43	0.00	19.15	0.78	0.00	8.54	0.22	0.00	2.46
Netherlands	Both	1.71	1.25	4.72	0.61	0.00	2.78	0.24	0.00	1.60
	lev(-1)	2.12	1.74	5.80	0.75	0.00	3.41	0.29	0.00	1.96
	nliq(-1)	9.28	5.81	25.63	3.35	0.00	14.96	1.32	0.00	8.57
Norway	Both	0.21	0.00	2.34	0.02	0.00	0.24	0.00	0.00	0.00
	lev(-1)	0.26	0.00	2.87	0.03	0.00	0.30	0.00	0.00	0.00
	nliq(-1)	1.03	0.00	11.37	0.11	0.00	1.19	0.00	0.00	0.00
Sweden	Both	0.89	0.67	2.38	0.04	0.00	0.35	0.00	0.00	0.00
	lev(-1)	1.09	0.71	2.90	0.05	0.00	0.44	0.00	0.00	0.00
	nliq(-1)	4.62	3.11	12.50	0.23	0.00	1.80	0.00	0.00	0.00
Spain	Both	2.97	2.08	9.32	1.80	0.20	7.48	1.44	0.00	6.35
	lev(-1)	3.57	2.47	11.48	2.17	0.21	9.24	1.73	0.00	7.85
	nliq(-1)	17.63	11.91	50.00	10.85	0.90	39.06	8.70	0.00	33.18
UK	Both	4.28	5.10	6.08	2.47	3.09	4.19	1.44	1.99	3.14
	lev(-1)	5.25	6.03	7.63	3.02	3.80	5.26	1.76	2.44	3.88
	nliq(-1)	23.67	27.69	34.96	13.87	17.39	22.87	8.26	11.30	16.39
US	Both	2.63	2.75	4.35	0.86	0.78	2.48	0.18	0.00	1.33
	lev(-1)	3.27	3.30	5.34	1.06	0.94	3.07	0.22	0.00	1.65
	nliq(-1)	14.31	15.95	22.50	4.84	4.72	12.95	0.97	0.00	6.97
Summary										
Mean	Both	1.41	1.20	3.70	0.52	0.29	1.88	0.27	0.14	1.07
	lev(-1)	1.74	1.44	4.59	0.63	0.35	2.32	0.32	0.17	1.32
	nliq(-1)	7.77	6.62	19.83	2.94	1.64	9.87	1.54	0.81	5.62
SD	Both	1.21	1.41	2.24	0.75	0.83	2.07	0.51	0.53	1.81
	lev(-1)	1.48	1.67	2.77	0.91	1.02	2.57	0.62	0.65	2.24
	nliq(-1)	6.83	7.75	12.34	4.33	4.70	11.06	3.01	3.02	9.52

Appendix 4: Year by year analysis of required regulatory adjustment

	Year means			Year medians			Year maxima		
prob = 0.01	Both	lev(-1)	nliq(-1)	Both	lev(-1)	nliq(-1)	Both	lev(-1)	nliq(-1)
1998	1.3	1.7	6.1	1.2	1.6	5.6	4.0	5.2	19.2
1999	1.2	1.6	5.9	0.9	1.1	4.4	3.5	4.3	16.5
2000	1.6	2.0	7.7	1.9	2.4	9.2	4.1	5.1	20.2
2001	1.6	2.0	8.1	1.7	2.1	9.0	5.5	6.8	27.7
2002	1.8	2.2	9.5	1.7	2.2	9.4	5.5	6.9	29.4
2003	1.4	1.7	8.2	0.8	1.0	5.0	5.1	6.2	28.5
2004	1.1	1.4	6.6	0.7	0.9	3.9	3.6	4.4	21.5
2005	0.1	0.1	0.4	0.0	0.0	0.0	0.9	1.0	5.2
2006	1.5	1.8	9.8	0.4	0.5	2.9	7.8	9.2	50.0
2007	1.7	2.0	11.4	0.3	0.4	2.2	7.4	8.7	49.8
2008	2.2	2.8	11.7	0.9	1.1	4.5	9.3	11.5	48.5
Total mean	**1.4**	**1.7**	**7.8**	**1.0**	**1.2**	**5.1**	**5.2**	**6.3**	**28.8**
SD	**0.5**	**0.7**	**3.1**	**0.6**	**0.8**	**3.0**	**2.4**	**2.8**	**14.8**

	Year means			Year medians			Year maxima		
prob = 0.03	Both	lev(-1)	nliq(-1)	Both	lev(-1)	nliq(-1)	Both	lev(-1)	nliq(-1)
1998	0.2	0.3	1.0	0.0	0.0	0.0	1.8	2.3	8.5
1999	0.2	0.3	1.0	0.0	0.0	0.0	1.3	1.7	6.4
2000	0.4	0.5	2.0	0.0	0.0	0.0	2.0	2.5	9.8
2001	0.5	0.6	2.3	0.0	0.0	0.0	3.4	4.3	17.4
2002	0.6	0.8	3.5	0.0	0.0	0.0	3.6	4.4	19.1
2003	0.5	0.6	2.6	0.0	0.0	0.0	3.1	3.8	17.7
2004	0.3	0.4	1.8	0.0	0.0	0.0	1.7	2.1	10.3
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.8	1.0	5.3	0.0	0.0	0.0	5.9	7.1	38.0
2007	0.9	1.1	6.1	0.0	0.0	0.0	5.7	6.6	38.2
2008	1.3	1.6	6.8	0.0	0.0	0.0	7.5	9.2	39.1
Total mean	**0.5**	**0.6**	**2.9**	**0.0**	**0.0**	**0.0**	**3.3**	**4.0**	**18.6**
SD	**0.4**	**0.5**	**2.2**	**0.0**	**0.0**	**0.0**	**2.3**	**2.7**	**13.9**

	Year means			Year medians			Year maxima		
prob = 0.055	Both	lev(-1)	nliq(-1)	Both	lev(-1)	nliq(-1)	Both	lev(-1)	nliq(-1)
1998	0.0	0.1	0.2	0.0	0.0	0.0	0.5	0.7	2.5
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3
2000	0.1	0.1	0.3	0.0	0.0	0.0	0.8	1.0	3.8
2001	0.2	0.2	0.9	0.0	0.0	0.0	2.2	2.7	11.3
2002	0.3	0.3	1.5	0.0	0.0	0.0	2.4	2.9	12.8
2003	0.2	0.3	1.2	0.0	0.0	0.0	2.0	2.4	11.3
2004	0.1	0.1	0.5	0.0	0.0	0.0	0.6	0.8	3.7
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.5	0.6	3.5	0.0	0.0	0.0	4.9	5.8	31.5
2007	0.6	0.7	4.1	0.0	0.0	0.0	4.6	5.4	31.0
2008	0.9	1.1	4.8	0.0	0.0	0.0	6.3	7.9	33.2
Total mean	**0.3**	**0.3**	**1.5**	**0.0**	**0.0**	**0.0**	**2.2**	**2.7**	**12.8**
SD	**0.3**	**0.4**	**1.8**	**0.0**	**0.0**	**0.0**	**2.2**	**2.6**	**13.0**

Appendix 5: Country Specific Regulatory Adjustments versus International Benchmarks Based on 2008 Data

Column	1	2	3	4
	Additions to country specific levels of liquidity and leverage to reduce 2008 prob. to 0.01 or below *		Under or overshoot	
			(column 1 - 2.23)	(column 2 - 2.77)
Top Panel	lev+liq	lev alone	lev and nliq	lev
Belgium	2.11	2.56	-0.12	-0.21
Canada	1.43	1.75	-0.80	-1.02
Denmark	2.60	3.28	0.37	0.51
Finland	0.00	0.00	-2.23	-2.77
France	5.08	6.25	2.85	3.48
Germany	0.00	0.00	-2.23	-2.77
Italy	0.31	0.51	-1.92	-2.26
Japan	0.00	0.00	-2.23	-2.77
Neths	0.00	0.00	-2.23	-2.77
Norway	0.00	0.00	-2.23	-2.77
Sweden	0.00	0.00	-2.23	-2.77
Spain	9.32	11.48	7.09	8.71
UK	6.08	7.63	3.85	4.86
US	4.35	5.34	2.12	2.57
Mean (Intenational Benchmark)	**2.23**	**2.77**		
SD	2.94	3.62		

* *country specific adjustments are the maxima from Table A.2, Appendix*

Note: In this table we repeat the analysis of Table 6 in the main text except this time we use 2008 data (with appropriate lagged values for the explanatory variables). Although countries such as Denmark held sufficient capital and liquidity over the entire sample period it is clear that during the crisis they should have raised their standards. On the other hand, Canada and Norway for instance actually showed an improvement in their positions in 2008 relative to their average standards. At the same time, risky countries such as the UK, US, France and Spain had developed such degrees of systemic risks in 2008 that their capital and liquidity surcharges increase substantially beyond their period averages. These costs could have been mitigated if adequate provisions had been held in the decade preceding the sub-prime episode and they show the extent to which vulnerabilities had built up in these economies due to inadequate regulations.

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