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Calibrating the Level of Capital: The Way We See It

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CALIBRATING THE LEVEL OF CAPITAL:

THE WAY WE SEE IT

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Executive Summary

This paper aims primarily to propose a framework for estimating the optimal levels of capital at banks with broad perspectives, elaborating factors such as liquidity and macroeconomic conditions. First, we attempt to reorganize the variety of policy proposals for enhancing financial sector regulation. In light of the broad perspective of the prudential policy framework, we discuss the role of bank capital in enhancing banking-sector resilience.

Second, with our perspective in mind, we lay out an early warning system (EWS) to predict a financial crisis where the role of capital and liquidity are explicitly captured. In the EWS, the estimation results confirm two-fold evidence: (i) capital and liquidity are imperfect substitutes for each other against the probability of crisis. And, on top of the liquidity on the asset side of the banks' balance sheet, (ii) liability-side liquidity has a statistically significant predictive power for a potential financial crisis a few years ahead.

Then, we apply the EWS as a component of a cost-benefit analysis (CBA) to gauge the benefit from raising capital and liquidity requirements, as more stringent regulations are expected to reduce the probability of financial crisis. On the other hand, financial-sector regulations should come along with certain costs. To quantify the cost, we employ some existing macroeconomic models to estimate the cost of raising capital and liquidity requirements. Combining the EWS (for benefit calculation) with the macroeconomic models (for cost calculation), we provide a full-fledged CBA framework that can determine the optimal levels of capital that strike the right balance between the costs and benefits of the financial-sector regulation.

The main results indicate that the optimal level of bank capital would considerably vary depending on the level of liquidity indicators both on the asset and liability sides of banks' balance sheets as well as macroeconomic conditions, typically represented by housing market inflation. Finally, the CBA framework suggests that banks could stand in a better shape with a counter-cyclical capital buffer to be well-prepared for a prospective distress.

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1. Introduction

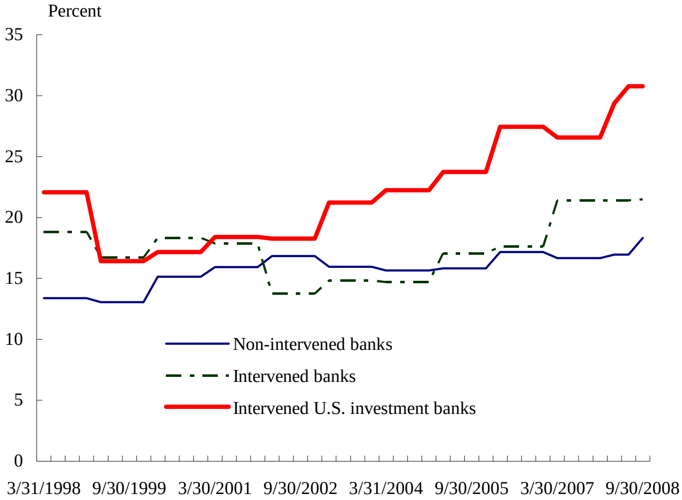
1.1. Capital requirement as a (macro) prudential policy tool

This paper attempts to prepare a framework to assess the optimal level of capital in banks. A straightforward way to set the agenda is to predetermine a single question to address: 'What level of capital would a banking sector need to weather a (typically) severe distress?' While the question may sound sensible in light of this paper's primary purpose, we suggest that calibration of the target level of capital could better be coordinated more closely with other regulatory issues and tools that have been discussed in the preceding efforts to develop new frameworks of macro-prudential policy. With this lead-off idea in mind, as the preamble, we aim first at casting the issues revolving around capital requirements in a broader perspective of (macro-) prudential policy. In line with our view, some preceding works, such as the Turner Review Conference Discussion paper, encourage assessing "cumulative impacts" of the various new tools, including the policy proposal to raise the capital requirement, on the table in the policy arena to develop a comprehensive macro-prudential policy framework. This paper may, in part, echo the call by the Turner Review Conference that taking into account the various tools and issues revolving prudential policies together, rather than dealing with each of them separately, would better calibrate the optimal level of capital in banks. At the outset, we discuss how we would underpin "the way we see it" as follows:

Undoubtedly, raising the level of capital (and its extra buffer) would result in certain costs and benefits, requiring us to strike the right balance. As demonstrated clearly by some previous studies, a notable benefit arising from higher bank capital is, conceivably, the reduced probability that a financial/economic crisis would be triggered in a precipitated manner. This idea, however, may be challenged by a few well-acknowledged facts. For example, most of the intervened banks in the wake of the recent (or ongoing) turmoil had, by and large, higher capital in the run-up to the crisis (Chart 1). This suggests that higher capital *per se* may neither ensure better/safer shape of individual banks, nor more resilience of the banking sector as a whole.

In a similar context, we note several marked examples where levels of capital signaled poorly the resilience of individual banks. Chart 2 shows that a high Tier 1 capital level as of June 2007 had not correctly predicted/identified banks that fared relatively well during the crisis up to its culmination at the Lehman shock. Rather, the level of Tier 1 capital may have (correctly) signaled undue risk-exposures of these banks. Chart 3 indicates that, during the period prior to the BNP Paribas shock, credit default swap (CDS) spreads tended to remain higher for banks with a higher Tier 1 ratio. While we are not to set forth any preconceived interpretations at this point, this observation may suggest that capital may have been recognized by financial markets as a sort of indicators of riskiness rather than resilience: higher capital may, in part or for some occasions, signal a *higher* crisis probability.

Chart 1: Capital/Asset Ratio



Source: GFSR/IMF

These observations reconfirm the questions and challenges that are being tackled by various bodies including the Basel Committee of Bank Supervision (BCBS). Should there be a channel whereby higher capital raises the probability of crisis, wouldn't we need a more mindful and comprehensive approach that could go beyond the scope of the existing de facto "capital-only" approach in calibrating the optimal level of capital? Before moving ahead, we could look into the underlying economics behind the evidence shown in Charts 1-3. To this end, we would suggest three possible interpretations:

(i) Moral hazard: Perhaps the most straightforward interpretation is to detect some sorts of moral hazard having prompted those later-intervened banks to take advantage of the high buffer/capital ratio. Those banks may have felt at (overly) ease or/and safe with the seemingly ample buffer where they incorrectly perceived themselves as being capable of taking extremely high risks in various aspects (including liquidity risks on top of credit risks). As we will discuss later using an illustrative example, even if your car is fully equipped with a very high-quality air-bag, the air-bag should not raise incentives of a driver to drive irresponsibly/imprudently such as drunk-driving or over-speeding.

Chart 2: Changes in Stock Price and Tier 1 Capital Ratio

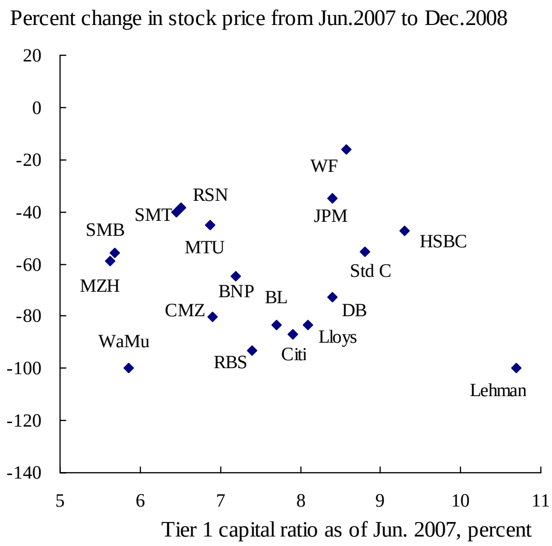
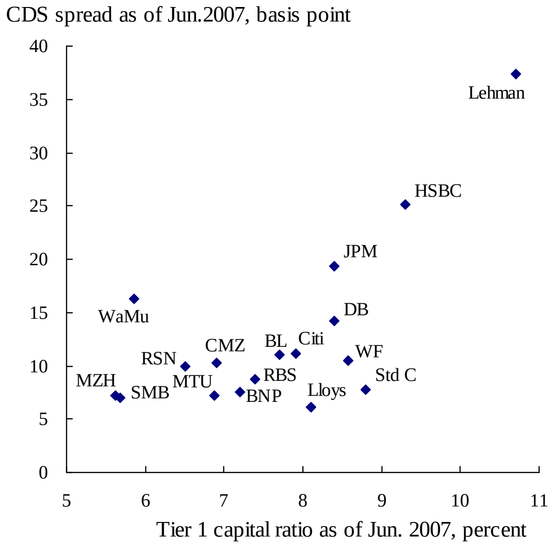


Chart 3: CDS Spread and Tier 1 Capital Ratio



Note: Dates of Tier1 figures might slightly differ due to the limited data availability.
Source: Bloomberg.

(ii) Causality going the other way around: Among the facts that we flagged, for example, Chart 1 may include more profound information than appears at first. If the red-line (indicating the "US intervened banks") is extended to a longer horizon beyond the point in time of the Lehman shock, the line would drops to zero simply because their capital is exhausted then or they do not exist any longer. While the red-line has remained higher than others in the chart, if we look at all of the lines over a sufficiently long horizon, we need to conclude that those intervened banks were, on average, far less profitable with yet inadequate buffers. The upshot of the hypothesis is that for a short horizon, —for example, as in the Madoff's case,[1] — while the banks were going-concerns, they were taking undue risks and that over-risk-taking made them

[1] See for example, http://www.ft.com/indepth/madoff-scandal/.

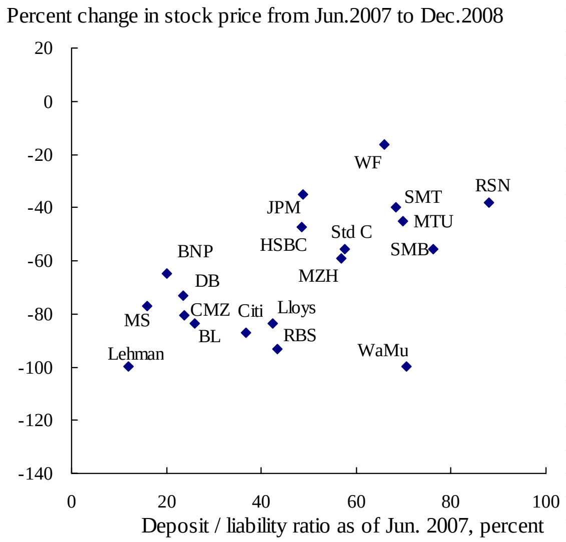
profitable. With such profit, they could accumulate capital and reserves for the short horizon up until a certain point in time when their over-risk-taking turned out unsustainable.

(iii) Regulatory arbitrage: While the title of the third view may more or less be a misnomer, we could acknowledge that there may have been some flaws in the existing regulatory framework. In line with this view, some regulator could argue in retrospect that the over-emphasis on the capital/asset ratio (e.g., Tier 1 or whatnot) in the regulatory framework may have ill-incentivized those later-intervened banks to take every action to find loopholes in the financial regulations, maintaining their capital ratio. They may have (incorrectly) recognized that as long as they are maintaining Tier 1 capital at a certain (seemingly) adequately high level, they would not be interrupted by regulators even if they are taking undue risk exposures, such as various off-balance sheet vehicles (e.g., SIVs and conduits, notably).

Bearing these possible interpretations in mind, we may need to pursue missing indicators, on top of the risk-weighted capital ratio, that would further ensure the resilience of the banking system while an increase in those indicators should not result in fueling the risk-taking incentives (which are not fully captured by risk-weighting of bank asset; e.g., liquidity risk) of individual banks. This task/assignment would certainly require further work and research down the road. The linchpin of the argument is, when we pick an indicator aimed at enhancing the resilience of a banking sector, we need to make sure that banks are appropriately incentivized. Otherwise, banking sectors around the globe may end up with undue amount of capital as a result of the new regulations (if inadequately designed). This basic idea would call for a fresh look at some other indicators that are expected to rein in undue risk-taking of banks. In this spirit, the new BCBS's proposals to impose restrictions on new indicators regarding (i) liquidity and (ii) leverage would proceed in this direction toward a tighter control over banks' risk-appetite in broader spectrums.

To proceed further in line with various ongoing efforts to pursue a better regulatory framework, here we underscore the stark repercussion of the recent financial crisis, particularly, in the wake of the Lehman shock. As has been pointed out by a number of market participants with hands-on experience during the crisis, market liquidity rapidly evaporated. Ensuring liquidity in financial markets, notably in short-term funding venues, would be pivotal for banks to ward off distress and to prevent an incipient turmoil from evolving into a greater rout. This lesson prompted the BCBS to call for the liquidity regulation measures (e.g., the net stable funding ratio). We could proceed further in this direction to pursue an effective indicator that can better predict stability in terms of fund-raising or resilience against market liquidity risk. To this end, for example, we would suggest focusing on banks' liability structure in addition to the scrutiny on the asset side of the balance sheets. Chart 4 highlights the fact that banks that had held more stable funding structure, or more specifically, depended on less wholesale funding (proxied by the deposit/liability ratio as of June 2007) tended to fare relatively well through the crisis period. Compared to Chart 1 and 2, Chart 4 suggests that the deposit/liability ratio can outperform the Tier 1 capital ratio in terms of the predictability of a bank's vulnerability at a time of distress.[2] On top of the calibration of the target level of capital (and other regulatory initiatives such as targeting leverage and asset-side liquidity), we may need to proceed in tandem with this type of liability structure monitoring/regulation, possibly by imposing a certain maximum level on some vulnerable wholesale funding relative to a bank's size.

Chart 4: Changes in Stock Price and Deposit/Liability Ratio



Source: Bloomberg.

Against all these background arguments, we would suggest the "three-arrow approach" to better (re)cast the tools and issues being discussed in the broad perspective of the macro-prudential policy. For illustrative purposes, we rely on a familiar (but disapproving) example: a car accident.

Arrow I, Buffer/Resilience: We would welcome every car to be equipped with a high

[2] A similar fact-finding, underscoring the importance of the stable funding structure, is pointed out by Ratnovski and Huang (2009) as well as a variety of non-academic articles.

quality air-bag because this is expected to mitigate the damage of a car accident. An air-bag is an analogy for the first arrow, i.e., the buffer/resilience of a banking system.

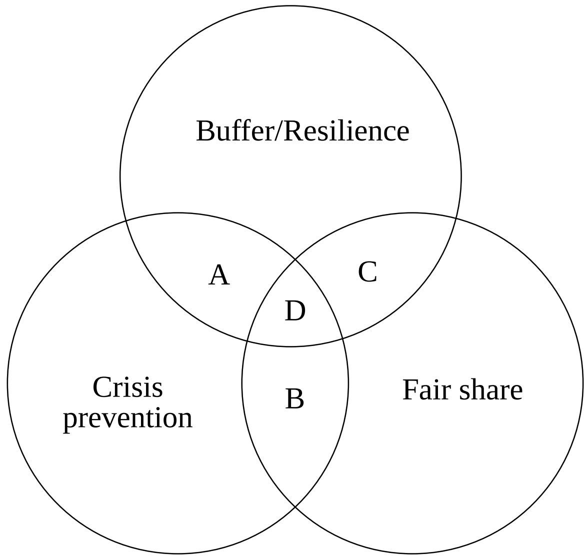
Arrow II, Crisis prevention/Risk-appetite control: Yet, the law prohibits, rather than encourages, drunk-driving even if your car is fully equipped with a high-quality air-bag. Although you may feel safe with the air-bag, such over-reliance is wrong and should be restricted. In this sense, given that this type of risk-appetite control is not adequately taken into account, the calls for a higher buffer/air-bag, stressing that "the larger the buffer is, the safer the banking system (or your car) would be," could be a prima facie fact/proposal.

Arrow III, Fair share: The final issue is; once a car accident unfortunately took place, who should pay the cost of the accident? The cost needs to be borne by the unlawful driver who is responsible for the accident. It should fall neither on the casualties nor the general public (tax-payers). On the other hand, the *fair share* idea would not necessarily advocate that the cost should be borne by a single or a few bank(s) that is/are outright responsible for the crisis. As is widely applied in automobile insurance industry, if you are identified as a risky driver, then your premium rises even if you are not involved in a car accident today. The idea could be, in principle, applicable to how we set out the design of the surcharges on systematically important banks/institutions. In line with the basic idea, non-car drivers need not bear any premiums. This would call for a well-designed "within-sector burden-sharing" to forestall any spill-over of a crisis to anywhere outside the financial sector.

1.2. Digression: Regulatory capital vs. economic capital

Before moving ahead, we briefly clarify how the calibration of the optimal capital level so-far discussed could be encapsulated conceptually into the existing BIS regulatory framework (Basel II). The currently ongoing debate/analysis, including the UK Financial Service Agency's CBA (Barrel et al. 2009) and ours to be set out here in this paper as well, aims at determining the optimal level of capital that could maximize the resilience of the banking sector. In light of the fundamental purpose of the exercise, principally, the *capital* discussed here could point to the economic capital or the target level of capital, as discussed in the second pillar of Basel II, rather than the regulatory capital or the minimum required level (i.e., the first pillar).

Chart 5: Macro-Prudential Policy: The Way We See It



Tools and issues in the regions

Region A: Capital buffer, liquidity/leverage regulations,
Dynamic provisioning/through-the-cycle (TTC) minimum capital requirement

Region B: Surcharges on systematically important institutions/too-big-to-fail,
Restrictions on compensation/claw-back

Region C: Contingent capital (Gone concern), resolution fund

Region D: Contingent capital (Going concern)

Nonetheless, we stress that it would be a matter of choice for policymakers, rather than the stringent outcome of any analysis, whether to set the target above a certain optimal level calculated using econometric models. We need to acknowledge that, if we can point-estimate the optimal level of capital that maximizes the banking sector's resilience, requiring banks to hold any buffer beyond that optimal level would be, by construction, overly costly and thus we are not striking the right balance. In contrast, a macro-stress test that we will discuss later could handle this distinction between the target level and minimum level more clearly, although we need to set the minimum level in an *ad-hoc* manner. Bearing in mind this possible distinction between the two notions regarding the capital levels, we can proceed further to discuss how we can calibrate the optimal level of capital. We will return to this issue later to discuss the possible implementation of the assessments delivered in this paper.

2. Estimating the Optimal Capital Level: A Cost-Benefit Analysis

2.1. The role of capital and liquidity in crisis prediction models

Essentially, the argument that we have outlined so far, conceptually represented by Chart 5, would echo the call in the Turner Review Conference paper[3] for assessing the *cumulative* impact of the items in the new reform agenda, rather than dealing with each of them separately, including the proposal to raise the target/minimum capital level. More specifically, it is neither warranted nor should we have any preconceived idea that the marginal cost and benefit from raising various regulatory standards (e.g., capital, liquidity and etc.) could be linearly additive. Rather, all the individual regulations could interact with each other and any of them may have side-effects that would influence banks' behaviors and alter the marginal net-benefit arising from other regulations. Technically speaking, we would suggest estimating the marginal net-benefit from one regulatory item by means of not only its partial derivative but by the total derivatives, taking into account all other factors (to the extent that it is possible/manageable) to pursue a well-designed macro-prudential policy framework as a whole.

To illustrate our idea, we could use the example raised above, the deposit/liability ratio as one additional factor/indicator to the capital level that could represent the "liability-side liquidity risk." The indicator could be replaced by, for example, the liquidity coverage ratio (LCR) and others, which are being discussed in the BCBS policy agenda. What factor would effectively change the net-marginal benefit and would reduce the crisis probability (or probability of default in the case dealing with individual banks) is a question that requires further empirical analysis and we will tackle this question later in this paper. In fact, our empirical analysis detected a few indicators and/or regulatory standards, including the liability-side-liquidity, which could interact with capital ratio. But for the moment, for illustrative purpose, we take up only one additional indicator, dubbing it "liquidity" simply.

Chart 6 exemplifies a three-dimensional structure where the inversed crisis probability (or the resilience of the banking sector), which could be interpreted as the "benefit" from stricter regulations, is a monotonically increasing function with diminishing marginal returns with respect to both inputs (i.e., "capital" and "liquidity" in this example). The example clearly indicates that, ceteris paribus, raising capital would

[3] Chapter 4 in the Turner Review Conference Discussion Paper, UK-FSA, 2009.

provide a benefit by enhancing the resilience of the banking sector. In other word, the benefit arising from higher capital at a certain given level of liquidity is monotonically increasing (Chart 7). The upward sloping blue curve in Chart 7 contrasts sharply with the real world observation, for example, highlighted by Chart 1: A higher capital (or its buffer) cannot necessarily point to higher resilience/benefit. The observation could be reconciled by the illustrations in Chart 6. We can suppose a bank (or a banking sector in country *X*) located on point *P* in the chart. If the bank moves as indicated by the arrow, the bank is not ascending the mountain as depicted by Chart 6a (i.e., enhancing its resilience) but, in fact, descending (i.e., the crisis probability is rising). This bank would appear, from the viewpoint of capital, to be improving its resilience, but from the other point of view — liquidity risk — their resilience is being undermined. We would reiterate that, essentially, capital (buffer) could, at the maximum, capture only one aspect of the resilience of the bank/banking sector rather than the entire shape of the mountain.

Chart 6a: A logit function

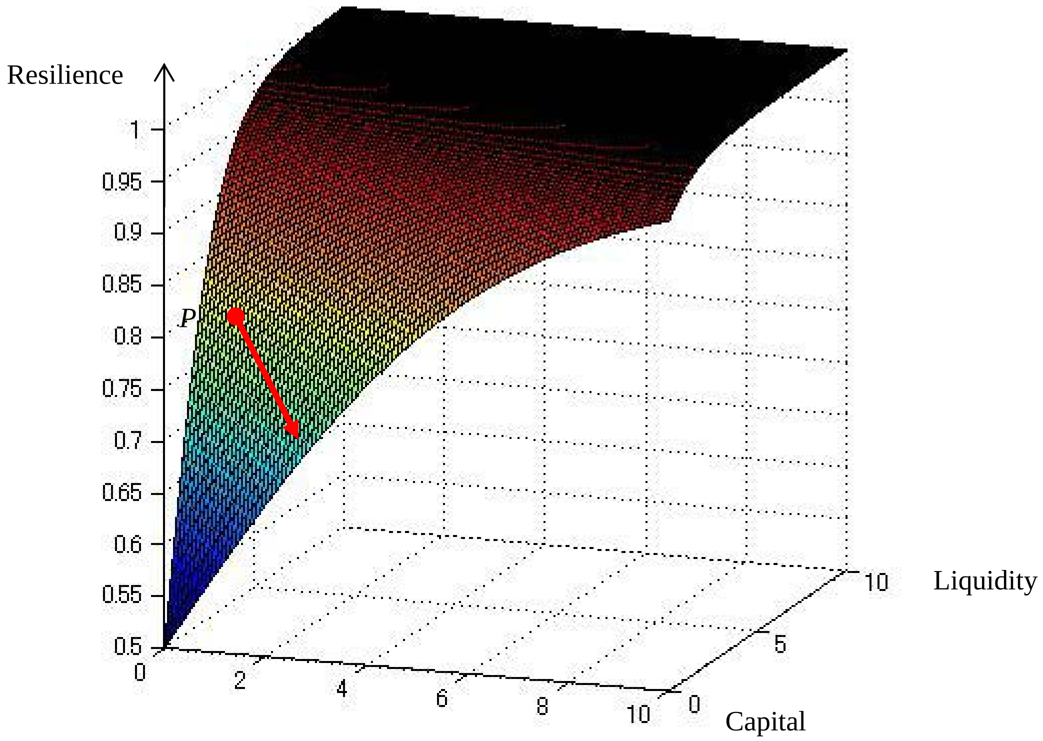


Chart 6b: Contours

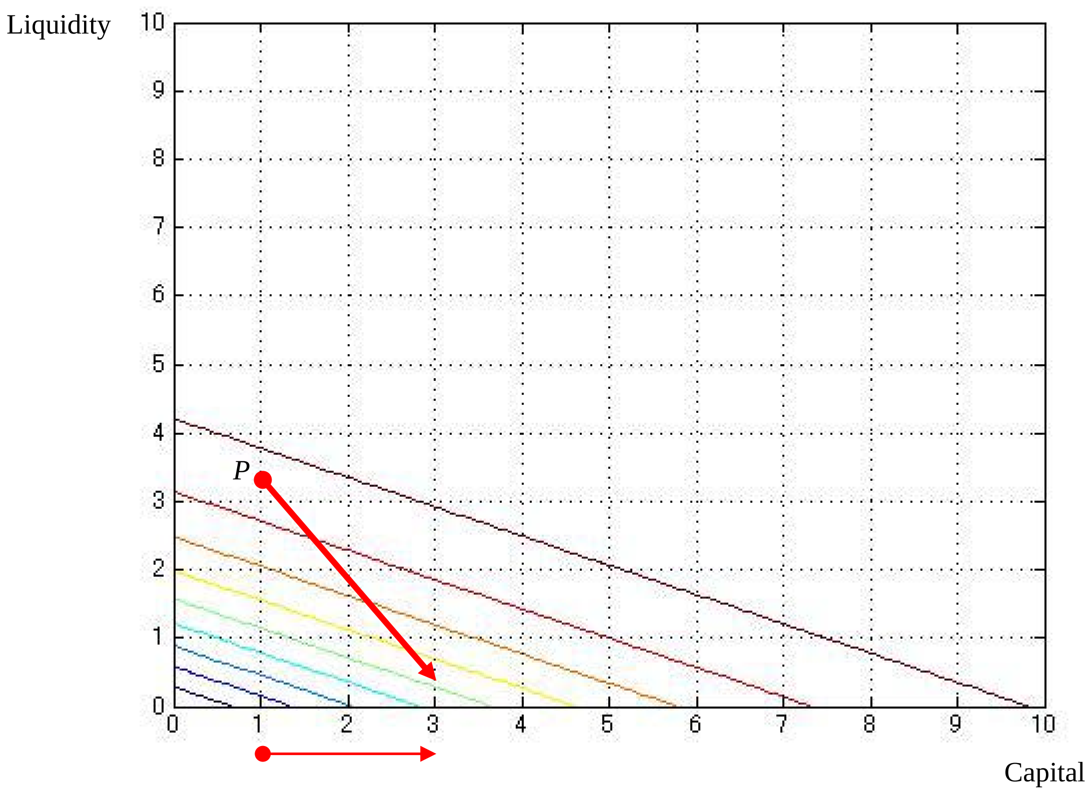
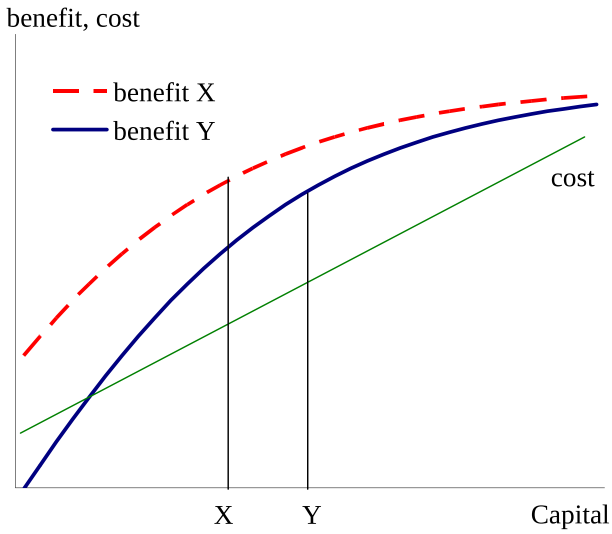


Chart 6 and the plain-vanilla probit/logit models in some early works (e.g., Barrel et al. 2009) essentially postulate that the optimal capital level needs to be determined, or simply depends on, a given level of liquidity a priori. As Chart 7 illustrates, the optimal level of capital would move to and fro subject to the given level of liquidity (and any other explanatory variable/factor) that the banking sector holds at a certain point in time. To clarify the idea, given the three-dimensional shape in Chart 6a, the blue line in Chart 7 corresponds to the case for banks holding low liquidity. We can compare this "illiquid case" with the red dashed-line that represents banks with more liquidity. The red dashed-line remains higher with a flatter slope than the blue line and as a result, the optimal level required for the illiquid banks should be higher. The optimal level of capital could be evaluated/determined at the long-run average level of liquidity, but such an average level could vary across countries even in one-size-fits-all cross-country models. We would stress that any "linear-in-factor" binary state models[4], (standard logit/probit models are archetypal) by construction, can only specify the optimal level of capital if and only if all the other conditions are held somehow at certain constant levels. If the other factors that affect the banking sector resilience are disregarded, the specified capital level could easily be misaligned as illustrated in Chart 6. Then, perhaps, rather than assuming other factors (typically exemplified by liquidity) held at certain ad-hoc constant levels, should we not evaluate the liquidity level as well as the capital simultaneously? On these grounds, to effectively calibrate the capital levels, we propose considering all the possible factors at once, extending the plain-vanilla binary state models, rather than fully abandoning them.

[4] Just to make it clear, we note that standard probit/logit model is in fact non-linear against the probability to explain (i.e., the dependent variable). The non-linearity that we are focusing on is the relationship among explanatory variables.

Chart 7: Uni-Dimensional Cost-Benefit Analysis



Note: Curve Y denotes a banking sector with higher vulnerability.

To move ahead, taking multi-dimensional views over the banking sector resilience (i.e., the shape of the mountain in Chart 6a) would call for a more in-depth investigation concerning how to measure the net-benefit of the macro-prudential regulation reforms, taking the *cumulative* impact into account. As Chart 6b illustrates, the logit formation assumed in some precursors (e.g., Barrell et al. 2009) has linear contours (elevation map or "indifference curves"). More intuitively, the standard probit/logit formation, while it may appear reasonable to capture the crisis probability that spans from zero to one, assumes *perfect substitutability* between capital and liquidity for a bank or a banking sector. This assumption is more restrictive than it appears and could be challenged both conceptually and empirically. Conceptually, the problem is that a bank's optimal choice would never fall within the confines of the isoquant lines but always on the edges. If the marginal cost for a bank to raise capital is infinitesimally higher than that to raise liquidity, the bank's optimal choice in terms of capital is not to hold any capital. Likewise, the bank would choose not to hold any liquidity if the marginal cost of raising liquidity is slightly higher than that of capital. From regulatory viewpoint, the probit/logit formation encourages banks to hold either of the two, rather than to strike the right balance between capital and liquidity[5]. This policy implication derived from

[5] The third hypothesis, denoted as (iii), included in section 1.1 may point to this interpretation. In light of the probit/logit model's prediction and given the lower cost of capital, banks may have been incentivized to raise capital only, disregarding other elements (e.g., exposure to liquidity risk, exchange rate risk, etc) that can potentially shore up the resilience. Admittedly, if this was the case, the incentives were misaligned.

the standard probit/logit models clearly goes against the direction in which the BCBS and other policy bodies are proceeding to raise both capital and liquidity requirements. Empirically, in line with the conceptual issue raised above, no bank that is fully illiquid or with zero capital has remained as a going-concern for a long period of time. Ultimately, this would need to be confirmed by further study, but our view is that assuming perfect substitutability between the two would be highly debatable in light of the banking sector monitoring experience up to this point.

2.2. A nonlinear-in-factor binary state model for early warning exercise

To tackle the challenge, we would suggest assuming a slightly more flexible and plausible — both conceptually and empirically — functional form as depicted in Chart 8 where we allow some imperfect substitutability between capital and other factors (e.g., liquidity). As a sneak peek of the full results of the entire analysis to be unveiled later at the end of Section 2, taking a certain degree of substitutability into account here in the crisis prediction model, the ultimate outcome could identify the optimal schedule (or combinations) of capital and liquidity (with some others as well) for the banking sector. Given the relative cost between capital and liquidity, the model can ascertain the unique bliss point that determines the levels of capital *and* liquidity that maximize the banking sector resilience (or minimize the probability of crisis/default). We will discuss this in greater details later.

In line with the idea outlined above, we estimated the "nonlinear-in-factor" probit models, which include (i)banks' capital ratio (*LEV*), (ii)banks' asset-side liquidity ratio (L_1), (iii)banks' liability-side liquidity ratio (L_2), (iv) real estate price inflation (*RHP*), (v) acceleration of *RHP* ($DRHP_t$) and (vi) current account balance (CA_t) as explanatory variables, to predict a financial crisis using the (broadly) same data-set as the one used in Barrel et al. (2009). We applied the crisis prediction model to the 13 economies, aiming at estimating the probability of a crisis. To estimate the model, we take the dependent variable, — binary banking crisis dummy (one for crisis years and zero otherwise) —, from the IMF Financial Crisis Episodes Database and the World Bank Database for Banking Crises (Table 1). The data appendix will elaborate this unique data-set.

Table1: Crisis Years Specified by Laeven and Valencia (2008)

Country	Year
Belgium	None
Canada	1983
Denmark	1987
Finland	1991
France	1994
Germany	None
Italy	1990
Japan	1991
Netherlands	None
Norway	1987, 1990
Spain	None
Sweden	1991
United Kingdom	1984, 1991, 1995, 2007
United States	1988, 2007

Note: U.K. is not included in our estimation owing to the limited data availability of the explanatory variables.

As a primer, we note that one of the most commonly used approaches to predict a binary-state could be a logit or probit model where the probability of either of the two states to materialize (i.e., a financial crisis in this case) usefully spans from zero to one. Normally, in these binary-state models, the probability depends on each explanatory variable linearly (inside the probit/logit function). As discussed in the previous section, assuming linear formation like the plain-vanilla probit/logit models would give rise to some difficulties both in terms of the concept/interpretation and empirics, particularly, in the case here in which the models are applied to estimate the cumulative impacts of the regulatory tools in reducing the crisis probability. Intuitively, linear-probit/logit models require a bank to make a take-it-or-leave-it choice between capital and liquidity because of the perfect substitution imposed by its linear form. To avoid this overly restrictive assumption, we employ a slightly more flexible (and sensible) form, a non-linear probit/logit with a few cross-terms to allow imperfect substitutability between capital and the two measures of liquidity indicators (L_1 and L_2).[6]

The estimated benchmark specification of the nonlinear-in-factor probit models can be expressed as

[6] A quite similar specification (i.e., including a cross-term of capital and the liability-side liquidity) is employed in Ratnovski and Huang (2009) to identify the more resilient banks in major OECD countries. They analyze panel data of individual banks and reported that the cross-term is broadly statistically significant to assess banks' resilience/vulnerability.

$$\Pr_t = \Phi\left\{LEV_t \times \left(\alpha_1 L_{1,t} + \alpha_2 L_{2,t}\right) + \beta_i Z_{i,t}\right\},$$

where LEV_t, L_{1t} and L_{2t} denote capital-to-asset ratio, "asset-side" liquidity and "liability-side" liquidity ratios, respectively. Z_t represents a vector of macroeconomic variables including (i) real estate price inflation (RHP_t), (ii) acceleration of *RHP* ($DRHP_t$) and (iii) current account balance (CA_t). Φ denotes a cumulative normal distribution function typically used in the standard probit models. Accordingly, Pr_t denotes the probability for a financial crisis to materialize.

The estimation results are included in Table 2. We took a general-to-specific approach to finally choose the most preferred specification (spec 9 in Table 2). All coefficients in spec 9 have the expected signs, and are statistically significant at the 5 percent level. We would stress that the estimation results confirm, in particular, the moderately imperfect substitutability between capital and liquidity for each other.

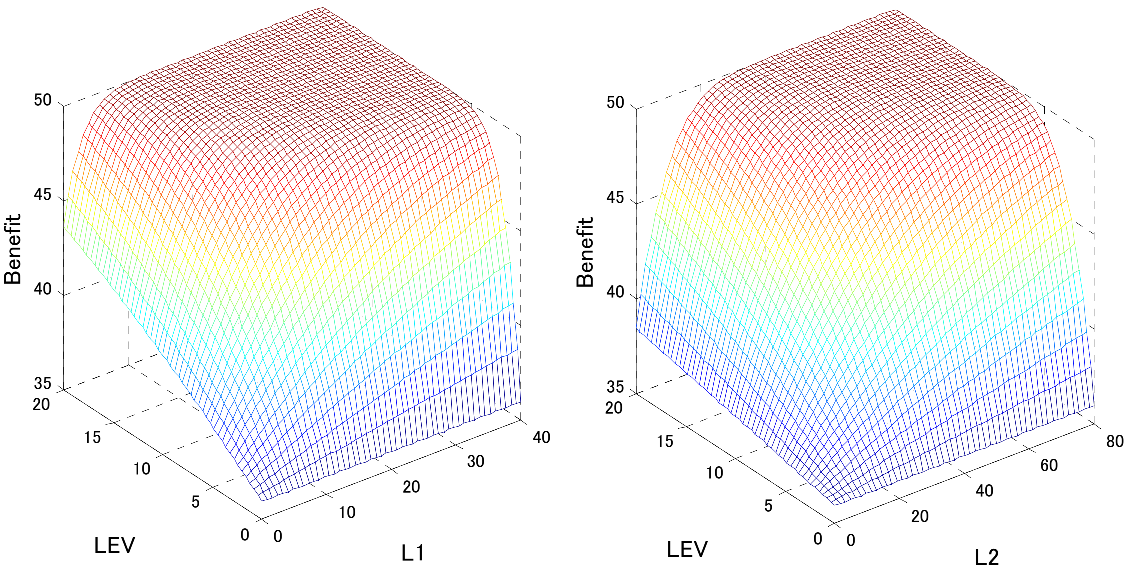
Based on the most preferred specification 9 in Table 2, the estimation result indicates that the coefficient on the capital ratio (*LEV*) would point to somewhere around 65.5 if the L_1 and L_2 are held at a relatively elevated level of 50 percent for each. It means that 0.1 percent point increase in capital ratio has the magnitude of 6.55, which would be translated into the reduction of the probability of crisis via the probit transformation. In contrast, if the liquidity remains relatively low at 10 percent, the coefficient on the capital ratio would decrease to 13.1. The mutually dependent effects between capital and liquidity clearly posit that banks can enjoy their resilience when both capital and liquidities are high. We re-emphasize that, while this nonlinear form may appear overly restrictive, this non-linear-in-factor function is far more flexible and realistic than the plain-vanilla probit/logit models where banks are always assumed to choose between zero liquidity or zero capital rather than in-between. Taking the (imperfect) substitution effects into account, the model could provide useful information to assess the cumulative impacts of the multiple regulatory standards comprehensively.

Regarding the rest of the explanatory variables and some other econometric issues, a few remarks are in order: Including the real estate price inflation (n.b., represented by the housing price inflation in some countries) would be straightforward following a few early works (e.g., Barrell et al. 2009) and may not require much explanation. Rather, you may ask why some other financial variables, such as interest rates, *ROA* and others, are not included in the model. In fact a variety of specifications have been tried and our conclusion at this point in time is that including *RHP* tends to disperse predictive power of other financial variables, effectively replacing them. One interpretation is that *RHP* may contain the largest information set than others, as you could acknowledge, for example, that when housing markets are booming, quite frequently interest rates would remain low as the backdrop of those asset market bubbles. In a related vein, another point that we would like to highlight is that, on top of the real estate price inflation, their acceleration (i.e. second derivative of the asset prices) tends to have significant predictive power in the run-up to crisis. This finding may worth a few comments. During the run-up period to a financial crisis, a phase when the momentum in the real estate market is waning, despite the still rising price levels, would point to a higher crisis risk. The negative sign of the estimated coefficient on *DRHP* shows that decelerating asset prices are indicative. The interpretation of including the current account balance could be more straightforward. In the past, it was repeatedly pointed out that a banking crisis tended to coincide with a currency crisis, and these were well acknowledged as the "twin crises." Given that a large current account deficit can frequently precede a currency crisis, the *CA* term can also predict a banking crisis. If we take a closer look at the recent global financial crisis that unfolded in 2007, the *CA* term may be interpreted as a factor that represents the global imbalance or misalignment of global capital flows among the U.S. and a number of emerging market economies. A relatively minor point that may prompt you to ask relevant questions is that the choice of lag length of each explanatory variable (e.g. *LEV*(-i), L_2(k) in Table 2). We would stress that the probit model applied here provides only a pure reduced form estimates like VARs and the length of lags cannot be interpreted with any economic reasoning or micro-foundations. The lag lengths are chosen simply because the model with the chosen length outperformed other choices. Despite the acknowledgement that the estimates are purely reduced-form ones, nonetheless, if we would try to interpret the difference in the choice of the lag length, it may worthwhile considering that the inadequacy of capital may undermine the resilience of banks over time while the liquidity shortage could precipitate a default in a short period of time. The argument may remind us of how the Lehman shock was precipitated. It was triggered not because of undercapitalization (Chart 1), but because of the liquidity shortage or the incapability to roll-over finances in short-term funding venues, in particular, the repo market. We could elaborate the acuteness of each shortage, comparing the observation of capital inadequacy and liquidity shortage as we move on to accumulate experiences in the real economy.

To wrap up this section, we would need to re-emphasize that our method is, like any other early warning exercise (EWEs) having applied in its long history, essentially, a post-mortem on past crises. While we included lagged variables in the model to predict a few-year-ahead crisis as the dependent variable, we note that the estimation is retrospective, using all the data looking back from the present. We need to bear in mind that the results could be useful to crystallize discussion on backdrops of the past crises rather than how future ones would unfold.

Chart 8: Nonlinear-in-Factor Binary State model

Three-dimensional graphics



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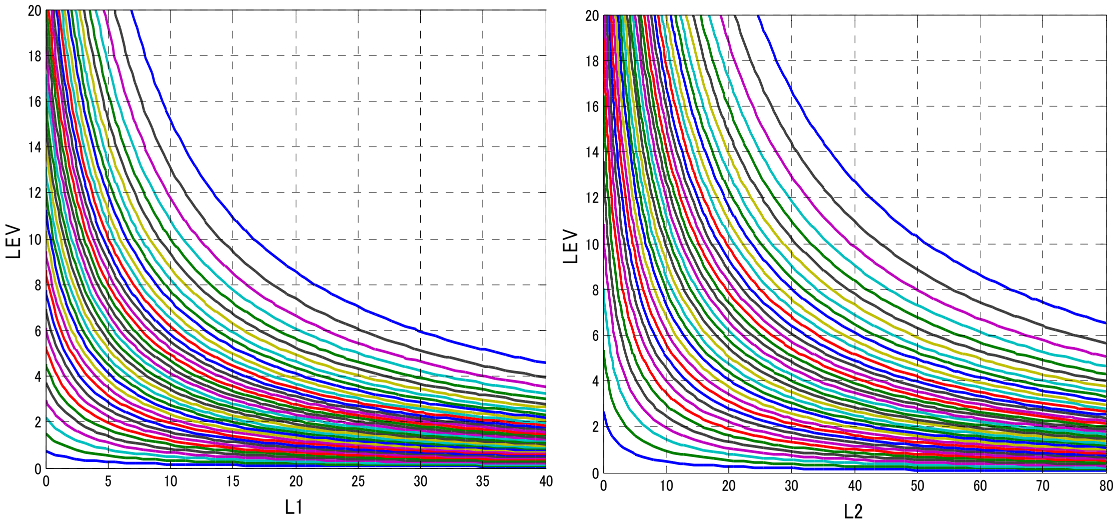


Table 2: Estimation Results

variable \ spec	Nest			Linear-term-only			Nonlinear-term-included		
	1	2	3	4	5	6	7	8	9
LEV(-i)*L1(-j)	2.55	2.33	2.12				-0.94	-1.23	-0.96
	(1.48)	(1.62)	(1.34)				(-2.16)	(-3.31)	(-2.16)
LEV(-i)*L2(-k)	-1.07	-0.62	-0.92				-0.33	-0.22	-0.35
	(-1.40)	(-0.99)	(-1.29)				(-2.06)	(-1.67)	(-2.12)
LEV(-i)	-0.13	-0.23	-0.12	-0.15	-0.13	-0.15			
	(-1.13)	(-2.10)	(-1.06)	(-2.33)	(-2.00)	(-1.89)			
L1(-j)	-0.17	-0.16	-0.14	-0.04	-0.05	-0.04			
	(-1.79)	(-1.98)	(-1.69)	(-1.80)	(-3.96)	(-2.16)			
L2(-k)	0.04	0.03	0.04	-0.01	-0.01	-0.01			
	(1.17)	(0.99)	(1.04)	(-0.87)	(-0.62)	(-0.84)			
RHP(-h)	0.06	0.06	0.04	0.05	0.06	0.04	0.03	0.05	0.05
	(2.82)	(2.99)	(2.32)	(2.74)	(3.53)	(2.79)	(2.22)	(2.88)	(2.75)
DRHP(-h)	-0.04	-0.05		-0.04	-0.05			-0.04	-0.04
	(-2.25)	(-2.61)		(-2.19)	(-3.29)			(-2.36)	(-1.99)
CA(-2)	-0.17		-0.18	-0.16		-0.17	-0.23		-0.22
	(-2.71)		(-2.97)	(-2.86)		(-2.49)	(-4.09)		(-3.95)
i	3	3	3	3	3	3	3	3	3
j	1	1	1	1	1	1	1	1	1
k	2	2	2	2	2	2	2	2	2
h	2	2	2	2	2	2	2	2	2
S.E. of regression	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.17
Sum squared resid	9.00	9.69	9.52	9.22	9.68	9.79	10.40	10.75	9.67
Log likelihood	-36.16	-40.90	-38.88	-37.37	-42.96	-39.87	-44.17	-53.11	-42.12
Akaike info criterion	0.27	0.30	0.28	0.27	0.30	0.28	0.30	0.35	0.29
Schwarz criterion	0.37	0.38	0.36	0.34	0.35	0.34	0.34	0.40	0.35

Notes: Probit estimation.

Figures in parentheses are *t*-statistics and LEV=unweighted capital ratio, L1=asset-side liquidity ratio, L2=liability-side liquidity ratio, RHP=real estate price inflation, DRHP=first difference of RHP, CA=current account balance/nominal GDP. The real estate price inflation data is provided by BIS.

2.3 The multi-dimensional cost-benefit approach for calibrating capital levels

With the non-linear-in-factor probit model estimation results ready to use, we can extend the existing uni-dimensional cost-benefit approach (Chart 7) to a multi-dimensional version, where we can assess the cumulative impacts of a variety of regulatory standards taken into account at once. An additional advantage over some preceding attempts using linear-probit/logit models is that, our approach can determine the unique sets of the optimal capital together with other regulatory indicators (Chart 9). Essentially, the approach aims at striking the right balance comparing the benefits and costs arising from the regulations. In quantifying the benefits, the basic idea is to consider that the benefit could be represented as the forestalled loss by averting a financial crisis because of the more stringent capital and liquidity regulations. More specifically, we quantify the benefit of the new regulations as the reduction of the probability of financial crisis multiplied by the expected loss arising from a one-off financial crisis:

$$\text{Benefit} = \Delta\text{Prob(crisis)} \times \text{expected loss from a financial crisis} \quad (1)$$

Using the probability of crisis estimated by the model presented in the previous section as a part of equation (1), it is straightforward for us to quantify the marginal effect/benefit from raising capital and/or liquidity requirement by each one unit.

Quantifying the "expected loss" — the scarring effect — if a financial crisis (unfortunately) were to take place is a difficult challenge but there are some early works that tackled this question. Among others, one of the most widely acknowledged works addressing this issue could be Reinhart and Rogoff (2009). Reinhart and Rogoff (2009) examined the past crisis experiences over the long history thoroughly[7] and provided useful "summary statistics." Their work notes that, on average, the peak-to-trough decline of real GDP would be 9.3 percent and the downturn could be protracted for 1.9 years. There are various other estimates that attempted to quantify the scarring effects of financial crisis and given the range of those estimates, picking a single number is not an easy task. One difficulty that complicates the quantification is that in many cases, some or a large portion of the initial loss, particularly, the public money injection to bailout the troubled banks, would later be redeemed over time as the financial sector and the economy recover subsequently. Bearing these difficulties in mind, we need to pick a point estimate of this scarring effect to proceed, relying on some judgmental calibration: Our best estimate at present is 9.5-10 percent of GDP in light of the early works in the academic literature and the past (and the ongoing) recession experiences in the Japanese economy. For the moment, we will use this number to yield the result from the augmented cost benefit analysis, but we fully acknowledge that this estimate could be improved in future research down the road.[8]

The "benefit surface" yielded by equation (1) looks like a smooth hill with an upward slope along with the horizontal axes away from the origin (the lower-left panel in Chart 9). Subtracting the "cost plane" from the benefit surface would result in a net-benefit surface that looks like a mountain with a unique bliss point (the lower-right panel in Chart 9). While the charts are presented in the three-dimensional space for illustrative

[7] Reinhart and Rogoff (2009) examined the episodes over the past 200 years while they also note that they focused on the experience since the World War II.

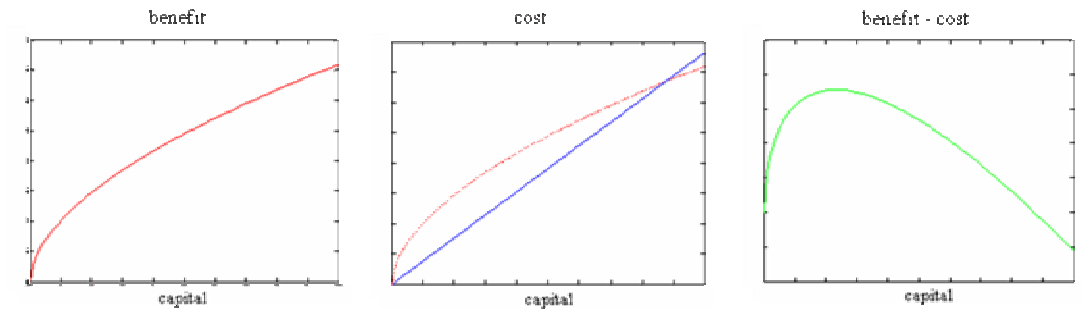
[8] In a similar context, you could argue that the depth and the length of a crisis may depend on pre-crisis levels of capital and some other factors. This view also requires further research. At this point time, we leave this as an open question as well.

purposes, in the actual calculation, our augmented CBA takes more than three dimensions as it includes at least two types/notions of liquidities on top of capital. In this context, as we will discuss later in greater detail, the optimal schedule of capital and liquidities varies depending on the levels of other explanatory variables included in the crisis prediction model. For example, when the real estate markets are booming, the probability of crisis tends to be higher and so is the marginal benefit of raising capital. As a result, the bliss point moves away from the origin along the horizontal axis, which means that banks need to hold more capital and liquidities at a peak of the housing/real estate market boom. We will revisit this issue in a later section where we discuss the counter-cyclical capital buffer.

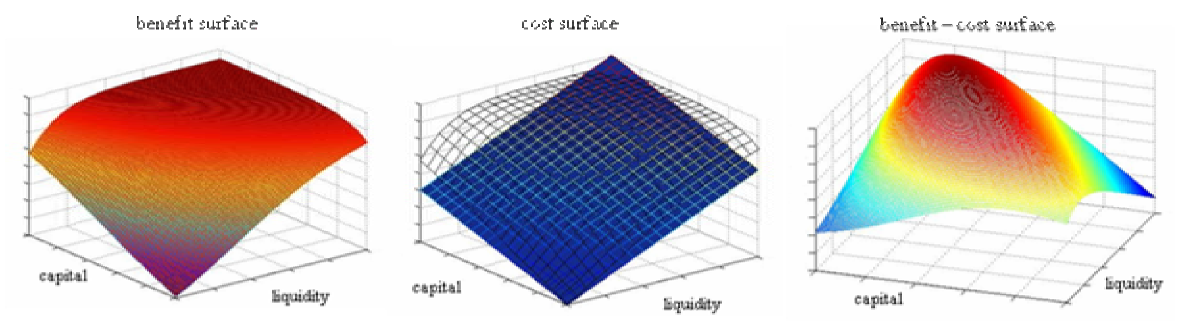
To yield the final results, we need to quantify the cost of capital and liquidities. The next section discusses how these costs could be measured in terms of macroeconomic welfare loss.

Chart 9: Augmented CBA: Synthesis

Uni-dimensional CBA (early work)



Multi-dimensional CBA (our proposal)



2.4 Measuring the cost of more stringent regulations

Requiring extra capital for banks would give rise to *de facto* taxation or surcharges on them. In line with this view, the "cost of capital" has been broadly studied both theoretically and empirically in long strands of the literature. For example, Barrell et al. (2009) employed the UK-specific macroeconomic model (NiGEM[9]) to estimate the cost of raising capital. In our work, we apply Van den Heuvel's (2008) model where the welfare loss arising from a higher capital requirement can be explicitly measured. The model is easy to calibrate to the Japanese economy, and the key formula looks straightforward. The basic idea proposed by Van den Heuvel (2008) is that raising regulatory capital forces banks to abandon less costly funding measures, such as deposit and whole sale funding (e.g., repos and CPs). In line with this basic idea, the welfare loss increases as the wedge between the cost of equity fund-raising and other alternative less costly financing widens. Bearing this economic interpretations in mind, we can introduce Van den Heuvel's formula to calculate the macroeconomic cost of capital,

$$\Delta C = D \times (R^E - R^D) \times (1-\gamma)^{-1} \times \Delta\gamma,$$

where C and D denote consumption and deposits and thus the loss is measured in terms of consumption reduction (while it can easily be translated into a GDP loss). $R^E - R^D$ represents the spread between the return on subordinated debt and deposits, which should broadly capture the wedge in the cost of fund-raising for banks across the two vehicles. γ stands for the capital-to-asset ratio. This γ can be replaced by *LEV* if we stick to our notation used in the previous sections. With this formula in place, we stress that in Japan, cost of capital tends to be high compared to other countries given the fact that the size of customer deposits relative to the households' asset is overwhelmingly dominant. More precisely, in the context of the formula, the deposit-to-consumption ratio falls somewhere around 250 percent. Comparing with the relatively easy calculation for D/C, measuring the return on equities or subordinated debt to yield a single number is quite difficult as it tends to vary sizably over time and across banks. Our best estimate at this point in time is 3.75 percent, which is the simple average of 40 samples of the recently issued subordinated debts by the three major banks.[10] We note that this number is likely to be underestimated as the other smaller banks (not included in the sample owing to the limited data availability) issue their subordinated debts with higher returns. For the deposit rate, we can comfortably calibrate this number at nearly zero.

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[9] More precisely, the NiGEM is a multi-country model and Barrell et al. (2009) focused on the UK part of the model.

[10] The 40 samples are collected from the semi-annual reports of the three major banks (the so-called three mega-banks in Japan) as of September 2009.

On the liquidity front, likewise, raising or maintaining a certain level of liquidity would also increase banks' burden via some cost-channels. As discussed in the previous sections where we set out the crisis prediction model, we incorporated two notions of liquidities: the asset-side liquidity (L_1) and the liability-side liquidity (L_2). Accordingly, (marginal) cost of liquidity on asset- and liability-side of the banking sector's balance sheets needs to be measured separately.

Cost of Asset-side Liquidity

Regulation focusing on the asset-side liquidity ratio (denoted as ASLR hereafter) requires banks to maintain a certain prescribed level of liquid assets (at the minimum). The opportunity cost of imposing this regulation can be roughly calculated as the wedge between the average bank lending rates and the average yield on liquid assets (i.e. government bonds, typically) held by banks. In Japan, the average rate of bank loans in the last five years (2005-2009) was approximately 1.9 percent, while the average yield on government bonds held by banks for the same period was 0.8 percent. The wedge between these two returns (approximately one percent) could reasonably proxy the spread of yields between liquid and illiquid assets held in actual portfolio of banks and can be interpreted as the marginal opportunity cost per unit of liquid assets held by banks. We would assume that the opportunity cost paid by banks would, in the long run, be passed on to outside borrowers. Under certain assumptions that we will discuss shortly, we could calculate the long-run (expected) increase in bank lending rates. Before proceeding to the detailed calculation method, we summarize the notations as follows:

A : Total assets

L : Liquid assets required to satisfy ASLR regulation

r : Loan rates

w_a : Wedge between liquid and illiquid assets (i.e., bank loans/mortgages) (w_a = 1 percent or 100 basis points, as derived from the actual data)

Δ_a : Increase in loan rates reflecting the cost of ASLR regulation

Δ_a represents the compensatory increase in bank lending spread that could save the loss arising from the ASLR regulation. We stress that the time horizon we are focusing on here is a sufficiently long period where the economy can reach its new steady state. Bearing this time horizon in mind, we assume that, over the long horizon, banks can restore their pre-regulated ROA level by passing all the additional cost on to borrowers ultimately.[11] More specifically, Δ_a needs to satisfy the following formula for banks to keep their ROA under the new ASLR regulation.

$$r \times A = (r - w_a) \times L + (r + \Delta_a) \times (A - L),$$

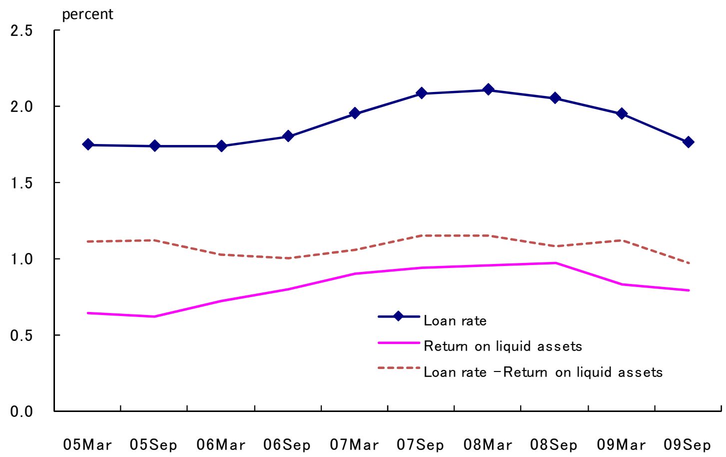
where r, w_a and Δ_a are expressed in percent. The equation could be solved for Δ_a:

$$\Delta_a = \frac{w_a \cdot L}{A - L} = \frac{L_1}{1 - L_1},$$

where $L_1 = L/A$ is the required ratio. We plugged one (percent) for w_a in the equation as discussed.

In principle, an increase in loan rates would rein in economic activities via an elevated cost of funding for firms and households. To translate the cost of holding liquidity in banks into a long-run economic (welfare) loss, we run simulations assuming a higher cost of funding using the Quarterly-Japanese Economic Model (Q-JEM), the Bank of Japan's in-house macroeconomic model.[12] The long-run deviation from the baseline solutions for output (and consumption) in the Q-JEM could be interpreted as the welfare loss resulting from the more costly financial intermediation and the newly imposed liquidity requirement.

Chart10: Cost of Asset-side Liquidity



Source: Bank of Japan

[11] Van den Heuvel's (2008) model stands on a similar assumption in terms of time horizon and the final bearer (i.e., households or borrowers rather than the financial intermediaries) of the social cost of the regulation.
[12] See Ichiue et al. (2009) for the details of the model.

Cost of Liability-side Liquidity

Cost of the regulation being imposed on the liability-side liquidity ratio (denoted as LSLR) could be estimated in a similar way: banks will pass on any cost arising from the LSLR requirement on to borrowers over the long horizon. Under the new regulation, banks are required to maintain a certain level of stable funding (e.g., deposit), by abandoning a corresponding amount of the less costly (but easier to evaporate) wholesale funding. The lower reliance on wholesale funding would give rise to an increase in the overall cost of funding for banks. To estimate the (opportunity) cost resulting from the introduction of the LSLR regulation, we could first look into the spread of the marginal costs of fund-raising via wholesale funding (e.g., repo) and retail funding (e.g., customer deposits). The fund-raising cost via, say, the repo market needs to be cheaper, otherwise banks have no reason to rely on it. As opposed to the basic idea, it may appear that interest rates in short-term funding venues, for example, the 3-month Libor rate, could exceed deposit interest rates. The point that squares the circle is to identify who is paying the funding cost. The interest rates on deposit are the face-value for depositors, but for banks as fund-raisers, they are paying a higher cost to collect deposits. Typically, taking deposits gives rise to various administrative costs. Notably, we could acknowledge the fact that most retail deposit-takers maintain a large network of branches, ATMs and other infrastructures. These “all-inclusive costs” (including non-interest cost) of fund-raising via deposits would naturally be higher than the interest-only cost of wholesale funding. Essentially, banks are enjoying a more stable fund-structure relying on deposits at the cost of giving up less costly wholesale funding.

The question is how we could estimate such non-interest/administrative costs arising from deposit taking. Our tentative approach is to run a simple linear regression with total deposit amounts as the explanatory variable and total costs as dependent variable. The basic idea is to consider that, simply, the more deposits a bank takes, the more (non-interest) costs they need to bear. We take 15 large Japanese banks subject to the Basel “Accord” and prepare the data-set covering the five latest years (2005-2009). The regression coefficient is 0.5 basis point, which could mean that if a bank were to take one hundred yen deposit, it needs to bear 0.5 yen for the administrative cost on top of the deposit interest rate. The sum of the above-estimated add-on cost and the deposit interest rate would, for the moment, be the best proxy for the all-inclusive cost of stable fund-raising. Then, calculating the spread between the all-inclusive cost of deposit and the typical short-term wholesale funding rate, the 3-month Libor rate, would leave a positive number somewhere around 0.6 percent (Chart 11). In a similar fashion to the case of ASLR, this key spread will be used to calculate the expected increase in the lending rate wedge denoted by w_l.

Likewise, we again lay out the notations as follows:

B	:	Total liabilities
D	:	Deposits
y	:	Inter-bank borrowing rate
w_l	:	Wedge between the deposit cost (including non-interest cost) and Libor rate
Δ_l	:	Increase in loan rates as a result of LSLR regulation

In a similar context to the ASLR, Δ_l represents the compensatory increase in the bank lending spread that could save the loss arising from the LSLR regulation. Again, we assume that, over the long horizon, banks can restore their pre-regulated ROA level by passing all the additional costs on to borrowers ultimately. In this case, Δ_l needs to satisfy the following formula for banks to keep their ROA under the new LSLR regulation being introduced.

$$r \times A - y \times B = (\Delta_l + r) \times A - y \times (B - D) - (y + w_l) \times D.$$

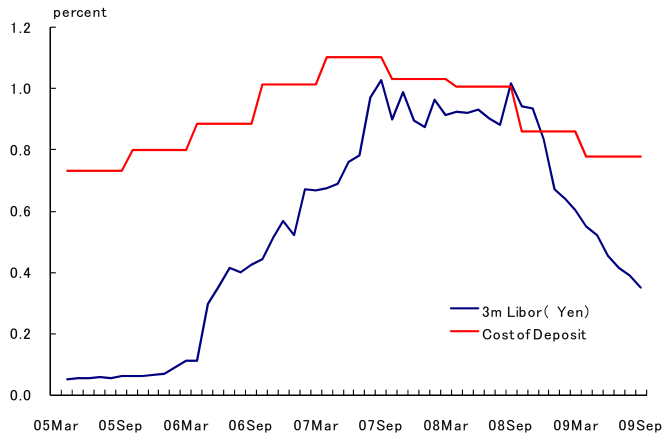
We note that r, y, Δ_l and w_l are expressed in percent. Then, we can solve the above equation for Δ_l:

$$\Delta_l = w_l \times \frac{D}{A} = w_l \times \frac{B}{A} \times L_2,$$

where $L_2 = D/B$ denotes the required ratio. B/A can be easily observed by actual data. The size of the increase in the lending wedge, Δ_l derived from the equation, will be translated into a macroeconomic (welfare) loss in the Q-JEM via the same procedure as discussed in the case of ASLR.

Up until this point, the effects/costs of ASLR and LSLR are independently assessed in this paper. In practice, however, there could be a need to examine the overall cost of liquidity regulations, taking some interactions for each other. In this regard, our tentative analyses using the Q-JEM confirmed that correlations/interactions between the two liquidity regulations are reasonably small, and on this ground we could handle them separately, simply adding them up. Against this backdrop, as illustrated in Chart 9, we have treated the "cost surface" as a bona fide flat plane in contrast to the benefit surface that in fact has a smooth curvature.

Chart 11: Cost of Liability-side Liquidity



Sources: Reuters, Bank of Japan.

2.5 Main results: The ready-reckoners and counter-cyclical capital buffer

As briefly mentioned in Section 2.3, the augmented cost-benefit approach introduced in this paper can set out how the optimal combinations of capital and the liquidity indicators vary "through the cycles" depending on the conditions of the real estate markets. Among various possible presentation of the results, a few ready-reckoners included as Table 3 could usefully summarize the main results of the augmented CBA introduced in this paper. We need to bear in mind the usual caveat in most of econometric analyses, in which all the estimates are subject to fairly wide margin of error and need to be interpreted as ballpark figures. With all the caveats in mind, we set forth our approach as a full-fledged method (conceptually, at the minimum) to gauge the cumulative impacts from the various newly proposed regulatory tools in the macro-prudential policy agenda.

To interpret the results, we note that Table 3 indicates, given the levels of L_1 and L_2, the optimal levels of capital-to-asset ratios that strike the right balance between the cost and the benefit from changing capital levels. As a recap, we stress again that the binary-state model introduced in Section 2 allows imperfect substitutability among capital and liquidity and this imperfect substitutability brings complexity into the assessment of the cumulative impact of the variations in each regulatory indicator as illustrated in Table 3. If capital and liquidities were fully interchangeable, a bank with very high L_1 or/and L_2 has no reason to hold capital. This "either one is enough" view contrasts sharply with the numbers in the ready-reckoners. Even if a bank had lots of liquid assets and less easy-to-evaporate (more stable) funding structure, the table suggests that the bank, nonetheless, should hold an adequate level of capital, and this result arises from the imperfect substitutability among capital and liquidity. In a nutshell, neither can fully replace the other.

As already noted and clearly illustrated in Table 3, we would re-emphasize that the optimal capital level varies depending on various conditions, notably, the real estate/housing price inflation. As discussed in Section 1.2, these results showing "variable capital levels" should not be interpreted as opposed to setting a uniform regulatory minimum capital requirement across jurisdictions. The numbers included in Table 3 point to optimal levels rather than the minimum requirement by any standard. One way to translate these numbers into implementation of regulatory policies is to take numbers in the "trough" table as the regulatory minimum levels and require banks to increase their capital (or to set aside the provisions) as the real estate markets start booming. While this suggestion could be conceptually sensible, implementation would raise a number of difficulties and questions.

Among others, it is hard to recognize when the trough of the real estate markets is reached. To catalyze the discussion, we included Chart 12, which indicates the distribution of real housing price inflation in 13 OECD countries over the past three decades. With the distribution as the backdrop, we took one standard deviation as the "peak" and the "trough" (i.e., a 10.5 percent increase and 6 percent decline, respectively) to set out the ready-reckoners. But we could not judge the range of housing market volatility should be accepted to ensure financial stability. That would go beyond the capacity of this work to answer and need to be revisited in future work.

Table 3: Ready-Reckoners: The Optimal Capital Ratios "Through-the-Cycles"

1. At a peak of the cycle: Real estate prices rising (+1σ)

L_2 \ L_1	5	10	20	30	40
10	24.5	17.7	11.4	8.5	6.8
20	19.1	14.7	10.2	7.8	6.4
40	13.3	11.1	8.3	6.7	5.6
60	10.3	8.9	7.1	5.9	5.1
80	8.4	7.5	6.2	5.3	4.6

2. In "calm waters": Real estate prices remaining steady (at the mean of the distribution)

L_2 \ L_1	5	10	20	30	40
10	20.1	14.8	9.7	7.3	5.9
20	15.9	12.4	8.7	6.7	5.5
40	11.3	9.4	7.1	5.8	4.9
60	8.8	7.6	6.1	5.1	4.4
80	7.2	6.4	5.3	4.6	4.0

3. At a trough of the cycle: Real estate prices declining (-1σ)

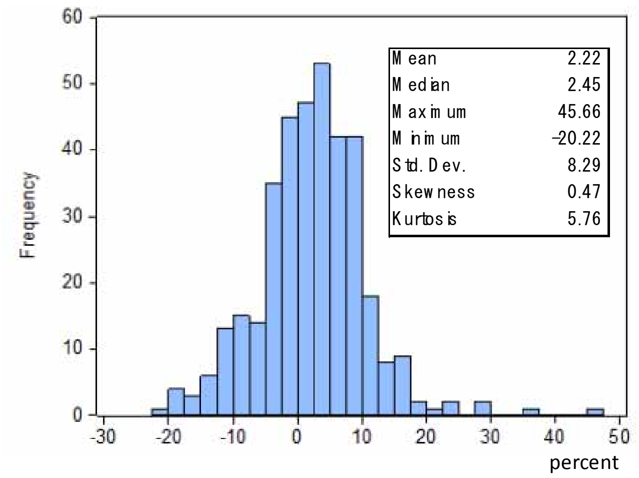
L_2 \ L_1	5	10	20	30	40
10	15.5	11.8	7.9	6.1	4.9
20	12.6	10.0	7.1	5.6	4.6
40	9.1	7.7	5.9	4.8	4.1
60	7.2	6.3	5.1	4.3	3.7
80	6.0	5.4	4.5	3.8	3.4

Note: L_1 and L_2 denote (i) asset-side-liquidity ratio and (ii) deposit/liability ratio, respectively (in percent). The capital ratios in the tables are defined as capital and reserves divided by total asset. See Data Appendix for greater detail.

While this is not our main purpose, using the framework, it is possible to indicate the global optimal "bliss point" where the net benefit is maximized by adjusting both capital and liquidity indicators (Chart 13). We suggest interpreting the results as purely illustrative rather than indicative from any practical viewpoint. If regulations were to be imposed on all the three dimensions (i.e., capital, L_1 and L_2), operations of financial institutions would completely lose flexibility and be left over-restricted. Our view is that we need to bear in mind that restricting one indicator (i.e., capital) would give rise to side-effects through the (imperfect) substitution channel as illustrated in Tables 1 and 3. We need to take into account every factor, to the extent that it is possible, which affects bank's resilience, but this does not necessarily mean that we need to impose restrictions on everything. We would defer further discussion of this point to future work down the road and would like to leave the question open.

Rather than further pursuing the goals in this direction, we would take a fresh look at the basic issue; the level of capital needed for banks, from a completely different aspect in the subsequent section.

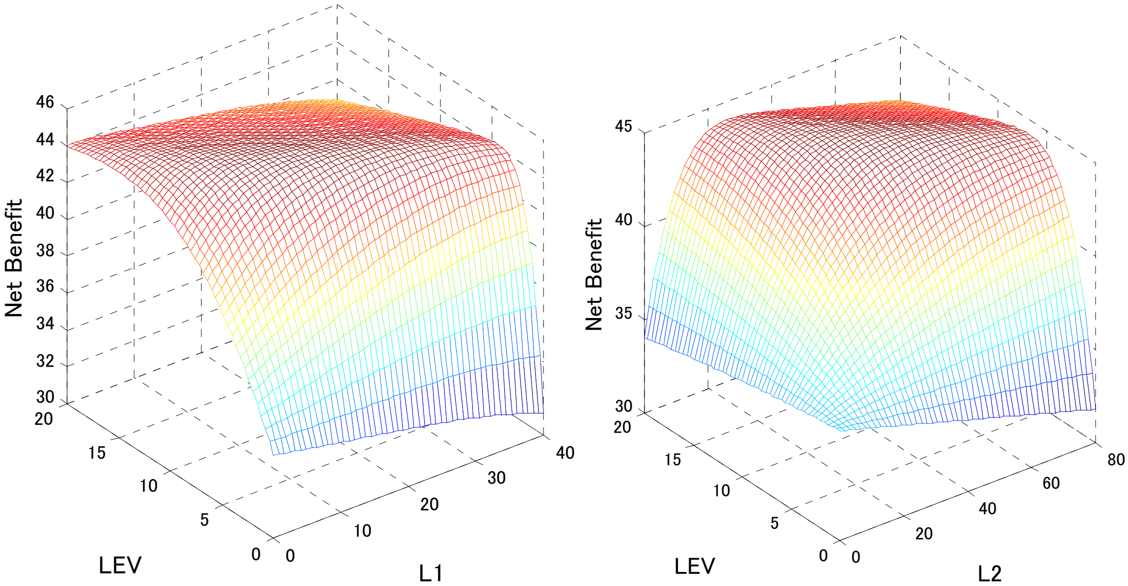
Chart 12: Distribution of Real Estate Prices



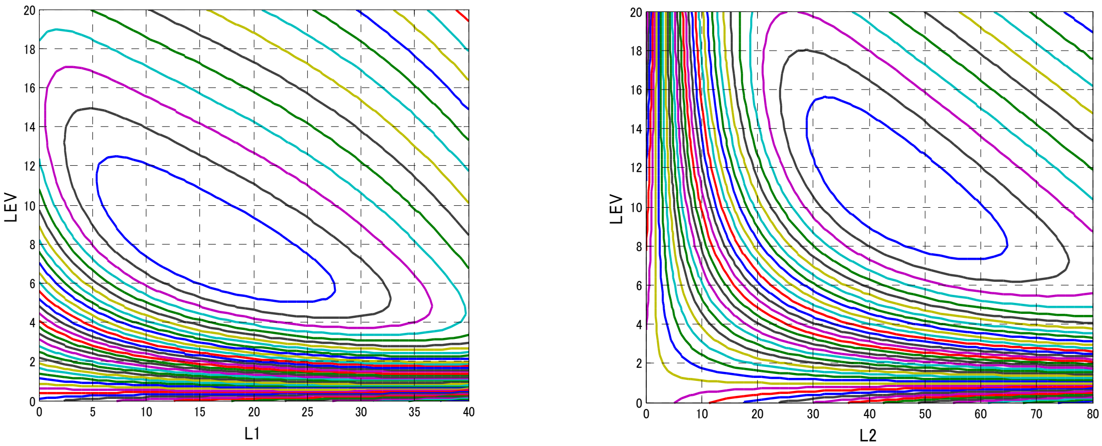
Note: Real estate price data are BIS calculations based on national data, except for Japan. Japan's real estate price data are obtained from the officially published Land Price Index. The price increases are measured in real terms denominated by CPI inflation.

Chart 13: Augmented CBA: Cumulative Impacts of Regulatory Tools

Three-dimensional graphics



Contours



3. The Macro-Stress Test Approach: The Optimal Level of "Snapshot" Capital

3.1. Macro-stress test approach: Strength and limits

Admittedly, all else being equal, higher capital would mitigate financial distress. As discussed above, our concern is that this key *ceteris paribus* assumption could easily or even inevitably be violated when the level of required regulatory capital is altered. Nonetheless, it is possible to assume that changing the level of capital requirement does not affect banks' incentive nor their risk-appetite. With this (perhaps debatable) assumption in place, we can estimate the level of capital that a banking sector needs to weather a crisis, using our macro-stress test framework.[13]

With all the usual and unusual caveats in mind, the approach is similar in its primary purpose to a number of precursors such as US-SCAP and the Bank of England's stress test (Bank of England 2009). Essentially, the approach is to estimate the necessary capital buffers for the banking sector as a whole to weather a severe stress, maintaining a certain lower-bound of capital.

Specifically, we take the distribution of 14 internationally active banks' balance sheets as of September-2009, —— a point in time when their Tier 1 capital was at its recent peak— as the status quo. The "stress scenario" given to the testing framework is a sizable and protracted downturn in nominal GDP associated with a considerable decline in asset prices that is comparable to a certain severe size of distress experienced by the Japanese economy. Our test is, by construction, retrospective, with the incentive/risk-appetite of banks left unchanged. On account of these underlying assumptions for the test, the results should not be interpreted as applicable to future crises where banks' incentives and behaviors are likely to be changed. Based on the scenario, the test can estimate the amount of extra capital that a few of the most severely damaged banks should have raised prior to the (virtual/imaginary) crisis to maintain certain floor levels of Tier 1 capital. Then, we can report the level of average capital needed for the banking sector as a whole to weather the crisis without resorting to any emergency actions/policy measures, such as immature/urgent capital raising or government bailouts.

The results of the test are reported in Chart 14, which show the change in the distribution of bank capital over the shock. The "pre-shock" distribution indicates the actual positions of the bank capital as of September 2009, and the "post-shock" plots

[13] See the Appendix for the methodology in greater detail.

illustrate the simulated bank capital conditions as of 42 months later following the onset of the shock.[14] Using the simulation results, we can calculate the extra capital for a few banks that cannot maintain minimum Tier 1 capital at an arbitrary assumed level. The size of the necessary extra capital that needed to be raised in advance would vary depending on the assumed minimum floor, and thus it may be premature to suggest definitive figures based on this macro-stress test only. With all these caveats in place, our sense is that, with 0.1-0.6 percent of additional Tier 1 capital as of September 2009, perhaps none of the internationally active banks would have had to be bailed-out or have been precipitated into other predicaments. The results also suggest that, given the status quo as of September 2009, the Japanese internationally active banks as a whole need to hold 10.5-11.0 percent of Tier 1 capital to weather a severe distress, maintaining their minimum level of the capital at 6-8 percent. We would reiterate that all these results are based on an imaginary scenario rather than what has actually taken place in the recent financial crisis.

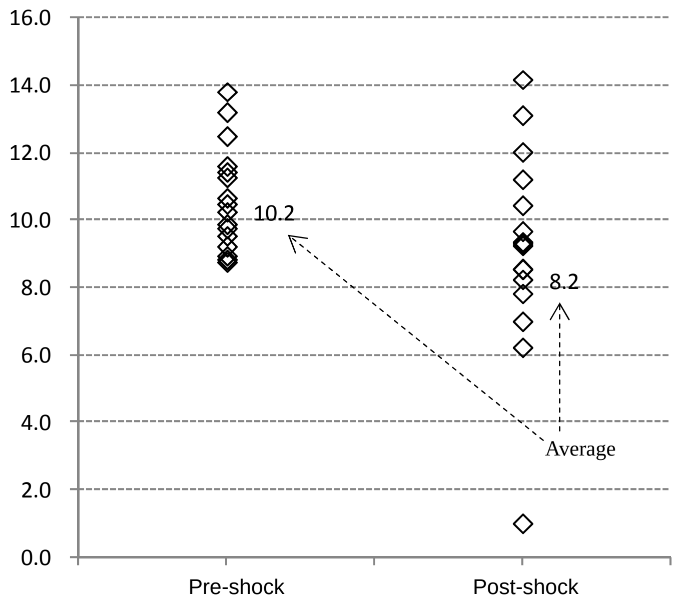
Table 4: Macro-Stress Test Results with Some Precursors

Source	**Description**	**Capital requirement**	
Japanese and Nordic past experiences		8.50%	Tier 1
Bank of England's stress test		9-10%	Core Tier 1
UK-FSA's cost-benefit analysis	TTC minimum	4%	Core Tier 1
	At the peak	6-7%	Core Tier 1
US-SCAP		8.10%	Tier 1
Bank of Japan's macro-stress test		10.5-11.0%	Tier 1

Source: Band of England (2009) and BoJ's calculation.

[14] A few banks look in better shape in the "post-shock" position, as these banks are expected to weather the trough of the stress-scenario earlier than 42 months and to proceed against the head-wind by the end of the simulation period.

Chart 14: Distributions of Bank Capital Ratios



4. Recap and the Way Forward

As a recap, first, we reiterate that both conceptually and practically, two notions, (i) the optimal level of capital that maximizes the banking sector's resilience and (ii) the regulatory minimal capital level, need to be separately discussed. Any cost-benefit type approach (CBA) yields, by construction, the "optimal" levels of capital beyond which any additional buffer turns out to be inefficient. In this regard, we employed two approaches: (i) a CBA to estimate the optimal capital levels and (ii) a macro-stress test to explore the regulatory minimum.

Second, there are notable empirical supports pointing to the fact that the benefit from raising bank capital (or the whole banking sector's capital) could not be determined uniquely but would vary depending on the level of the banks' risk-appetite (which cannot be fully captured by the existing framework of risk weighting of asset) proxied by, for example, the stability of the banks' liability structure and, presumably, other exogenous conditions surrounding the banking sector. This would call for controlling the crisis probability function (e.g., the Barrell et al. 2009 among others) by adding a few more explanatory variables representing those factors where capital and those additional factors are, to some extent or *moderately*, substitutable. Typically, the optimal capital level would need to remain at a relatively high level when the level of banks' risk appetite is being elevated. Accordingly, as the flip-side of the same coin, banks may be able to weather a severe crisis more easily, if their risk-appetite has been reined in at a reasonably moderate level. Our efforts on this front to assess the banking sector resilience from multi-dimensional perspectives are still at an early phase and we would welcome any comments, suggestions and assistance to improve our approach and, ultimately, to develop and share an internationally harmonized and useful framework for capital level calibration and better designed macro-prudential policy tools.

Appendix: A Quick Look at the Macro-Stress Testing Method

The macro-stress test method essentially follows the framework set out in Otani et al. (2009) and its subsequently upgraded version developed by our in-house working team (Bank of Japan 2009). The broad framework itself is still under development, but the latest version is currently up and running to assess the soundness of the Japanese banking system and its results are periodically published in our Financial System Report. Essentially, we apply the same methodology to 14 internationally active banks in Japan assuming a severe stress scenario and a few minimum capital levels. This box outlines the overview of the methodology, the given scenario and possible interpretations of the results.

In the framework, the paramount item is the probabilistic transition matrix of the credit ratings of borrower-firms. Broadly in line with the regulatory standards, a bank's loan portfolio is segmented into five brackets; (i) normal, (ii) attention needed, (iii) special attention needed, (iv) in danger of bankruptcy and (v) bankrupt (including *de facto* bankrupt). Any bank credit falls in one of the five brackets and depending on the bracket, the probability of default would vary. More formally, $P_{ij,t}$ can be defined as the probability of a bank loan classified in the i_{th} bracket at time t-1 to fall in the j_{th} bracket at time t. On top of the unexpected loss arising from bona fide defaults, banks need to set aside loan loss provisions against expected defaults. When the probability of a loan to be downgraded in terms of the credit rating (i.e., re-classification from bracket i to j where $i < j$) is high, banks are required to set aside more provisions. The increases in provisions erode profits and capital, leaving banks under stress. To embody the idea, the elements in the transition matrix $P_{ij,t}$ are regressed on nominal GDP growth and using this link between $P_{ij,t}$ and nominal GDP growth, we can assess the impact of a downturn of the economy (i.e., declines in nominal GDP growth) on the banking sector's capital.

With this method in place, we estimated the size of bank capital eroded under a stress scenario where we assume a protracted downturn in nominal GDP growth. The size of the recession assumed in the stress scenario is comparable to the most severe experience in the past three decades[1]. Separately, we tentatively set the minimum regulatory standard of Tier 1 capital at 6 and 8 percent and identify a few banks that failed to maintain this minimum level under the stress scenario. Despite the severity of the stress, most of the internationally active banks can, in this test, ward off the shock, primarily because of their high capital levels (prior to the onset of the shock) compared to the historical average. We would reiterate that the results of the test need to be interpreted under a number of assumptions, inter alia, their retrospective nature. The transition matrix is constructed using past data and it is not warranted that the matrix would remain stable in a future crisis. Prompted by some other motivations as well, various efforts to improve the method are underway in our bank.

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[1] See Chapter III in the March-2010 issue of the Financial System Report (Bank of Japan 2010) for greater details.

Data Appendix

1. Crisis Year Indicators

As the dependent variable, we used the binary banking crises dummy, which is taken from Laeven and Valencia (2008) data set (Table 1). Their data set is primarily constructed using the IMF Financial Crisis Episodes Database and the World Bank Database for Banking Crises. We note that although crisis years in United Kingdom are identified, the U.K. is not included in our sample owing to the limited data availability of the explanatory variables. For greater details on the crisis year data-set, see Laeven and Valencia (2008).

2. Explanatory variables

Explanatory variables include (i) balance-sheet variables for a banking sector in each country and (ii) macroeconomic variables.

(i) Balance-sheet variables for a banking sector

Balance-sheet variables are basically obtained from OECD Statistics. Any missing observations are supplemented by the IMF International Financial Statistics (IFS) and CEIC database. Macroeconomic variables are obtained from the IMF World Economic Outlook (WEO) and individual country's official statistics.

a) Un-risk-weighted capital ratio (LEV)

$$LEV = \frac{Capital\ and\ resreves}{Total\ assets}$$

b) Asset-side liquidity ratio (L1)

$$L1 = \frac{Cash\ and\ balances\ with\ cetral\ banks + Securities}{Total\ assets}$$

c) Liability-side liquidity ratio (L2)

$$L2 = \frac{Customer\ deposits}{Total\ liability}$$

Definitions of above items in *italic* are based upon those of OECD Statistics.

(ii) Macroeconomic variables

We include macroeconomic variables as shown below. They are chosen as a result of dropping other candidate variables that are insignificant.

a) Real estate price inflation (*RHP*) and its acceleration (*DRHP*)

We used the real estate price data provided by BIS, except for Japan. For Japan, we used the officially published Land Price Index for commercial areas of three large cities, to capture real estate boom and bust most appropriately.

b) Current account balance/nominal GDP (*CA*).

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