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Ray Barrell and Dilruba Karim

The Role of Capital, Liquidity and Credit Growth in Financial Crises in Latin America and East Asia

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The Role of Capital, Liquidity and Credit Growth in Financial Crises in Latin America and East Asia

Ray Barrell, Dilruba Karim[1]

Brunel University

We construct a dataset of bank capital adequacy and liquidity to test their relationships to crises in Asia and Latin America. Event studies, logit and ROC estimations suggest these variables are valuable leading indicators of crises. They can be used to improve Early Warning System design although there are trade-offs between model simplicity, which implies less monitoring costs and complexity which may improve accuracy. There are significant differences between the regions so pooling assumptions are unsound. AUCs show that capital and/or liquidity can be used in a parsimonious model without substantial loss in crisis predictive accuracy. We find no direct role for credit growth in either region. Our results have implications for Asian and Latin American financial regulators concerned with the impacts of Basel III on their banking systems.

Keywords: Banking crises, capital, liquidity, early warning systems, logit estimation, ROC curves, Event studies, Asia, Latin America

JEL Classification: C52, E58, G21

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[1] Dilruba Karim (corresponding author): Department of Economics and Finance, Brunel University, Uxbridge. Middlesex, UB8 3PH; ecstddk@brunel.ac.uk. Professor Ray Barrell: Department of Economics and Finance, Brunel University, Uxbridge. Middlesex, UB8 3PH; ecstrjb@brunel.ac.uk. This work is funded under ESRC Grant No. PTA – 053 – 27 – 0002, entitled "An Investigation into the Causes of Banking Crises and Early Warning System Design".

Introduction

Recently, two fundamentals of banking operations have received widespread attention from regulators and markets: capital and liquidity. Aggregated microeconomic inadequacies in these two variables generated systemic financial instability which led to the most costly and globalised crisis since the Great Depression (Claessens et. al., 2010).

Anomalously, few studies have examined the direct impact of capital adequacy and liquidity on banking crisis probabilities[2] and certainly none, to our knowledge, on Latin American and Asian banking systems. Since tighter international standards in these variables are advocated by regulators, there should be a measurable reduction in banking crisis probabilities across regions, including in emerging markets. Without this, stricter capital and liquidity requirements may tax credit provision and cause more disintermediation in some regions compared to others.

The banking crisis literature to date generates different and often conflicting conclusions some of which have been used to underpin policymakers' changes to existing regulations[3]. Invariably such studies rely on diverse ranges of cross-sections, time periods, variables and estimators and yet, alternative models are not routinely compared in any systematic way; factors such as the type of estimator, the informational content of competing indicators and the forecasting value of models all have a bearing on regulators' claims that stricter capital and liquidity standards are necessary to reduce future systemic failures.

This paper addresses some of these deficiencies in the literature by focusing on the role of capital and liquidity specifically in Latin America and Asia. We have painstakingly collected capital adequacy data for a sample of 14 banking systems covering 1980 – 2010. As a preliminary assessment of these new series and "standard" crisis determinants we use an event study approach which identifies variables that behave significantly differently during periods of instability and tranquillity.

Capital and liquidity are then introduced in a logit framework alongside standard banking crisis determinants to see if, as Basel III assumes, healthier capital and liquidity positions reduce crisis probabilities in these regions. We find that capital and liquidity do mitigate crises but only in a pooled sample since the relative importance of each differs between regions: in Latin America both capital and liquidity matter whereas in Asia, crises are associated with banks' liquidity positions.

We also find that capital and liquidity are not the only causes of crises in these economies. Unsurprisingly for these open and emerging markets, the terms of trade, current account positions and the level of banking system development also matter. Specifically, we find that

[2] an exception are Barrell et. al. (2010) who find capital and liquidity to be superior banking crisis predictors in the OECD than macro crisis determinants that were found significant in previous studies such as Demirguc-Kunt and Detragiache (1999, 2005) and Kaminsky and Reinhart (1999). These papers did not test the role of capital and liquidity.

[3] see for example, Barrell et. al., (2010) versus Borio et. al. (2010) or Borio and Drehmann (2009)

Asian crises were preceded by balance of payments problems manifesting as current account and terms of trade deteriorations and capital outflows which compromised banking system liquidity. In Latin America, banking fragility was associated with the inadequate capital adequacy and liquidity positions of banks at a time when rising bank intermediation (domestic credit/ GDP) raised crisis probabilities.

In investigating the roles of capital and liquidity we also address the role of credit. The view that credit growth is a cause of banking crises (and thus requires amelioration via policy responses) underpins the latest international countercyclical buffer proposals under Basel III. However, the evidence that rapid credit growth per se is problematic remains inconclusive even for OECD economies. This also appears to be the case in the context of Latin America and Asia since we do not identify credit growth as a leading crisis indicator in either region.

These results are of interest to international policymakers charged with minimizing future crises. They are especially important for the regions we study, to establish whether the international rules they will be subject to are optimal based on their particular trade-offs between elevated capital and liquidity requirements and the associated output losses. The results also serve as an Early Warning System (EWS) for future crisis risks in these regions.

To identify the best combination of leading indicators, we rank the informational content of our competing model specifications by their Receiver Operating Curve (ROC) characteristics. We use the Area Under the ROC Curve (AUC) to assess the “skill” of our EWSs. This assessment technique for binary event predictors identifies the optimal model in terms of its informational value (noise versus signal).

Our results imply that capital and liquidity outperform many traditionally accepted crisis determinants. In addition, the ROC analysis reveals some variables are suited to predicting idiosyncratic crises. This suggests that global models containing many predictors may add limited value since the identification of distinctive episodes comes at the cost of a higher number of target variables and associated policy errors. A parsimonious model is able to discriminate between crisis and non-crisis episodes almost as well as a more protracted model containing predictors that are inefficient due to these costs.

The rest of the paper is structured as follows. Section 2 reviews the literature on our variables of interest: capital and liquidity. Section 3 describes our data, the event study and logit methodologies and then discusses the ROC curve approach. Section 4 presents our results and Section 5 concludes.

Section 2: Capital, Liquidity and the Asian and Latin American Crises

In this section we review the relationships between capital, liquidity and banking crises. Our remaining variables have been extensively discussed in the extant literature such as Demirguc-Kunt and Detragiache (1998), Davis and Karim (2008), Barrell et.al. (2010) and Davis, Karim and Liadze (2011). We then outline the events of the Asian and Latin American crises before turning to discussions of our data and methodologies in the subsequent section.

2.1 The Role of Capital in Risk Reduction

At its most basic level the rationale for capital buffers is intuitive and not unique to banking firms: by earmarking a portion of funds (capital) to cover deteriorations on the asset side of the balance sheet, a firm can reduce its insolvency rates. However designing practical rules to translate this into optimal capital ratios is not as intuitive for regulators. Since theory suggests capital will be risk reducing only under specific conditions which are not easily executable as regulatory rules, the full benefits may not be observed in practice. As we will discuss, this divergence between theory and reality will affect the empirical relationship between capital and crisis risk.

There are two types of theoretical studies that focus on bank capital, portfolio based approaches and models that focus on the specific relationships between banking firms, depositors and borrowers. Both approaches are reconcilable in that they suggest capital will mitigate banks' systematic risk exposures but by allowing for deliberate risk taking by bank managers they predict limited beneficial effects.

Standard portfolio theory suggests that a portfolio consisting of sufficiently large numbers of uncorrelated asset returns will require no capital buffers due to perfect diversification. In reality bank portfolios will be imperfectly diversified and thus contain enough systematic and idiosyncratic risk to justify the need for capital buffers. Using the terminology of Freixas and Rochet (2008) we can define the regulators' problem. The objective is to set a desired bank solvency probability and then derive the appropriate capital ratio which hinges on the bank's asset exposures and their correlations.

Let q be the probability of solvency so that $(1-q)$ is the failure rate. Each bank will have exposures (x_i) to creditor i and this exposure is subject to a (stochastic) loss per dollar of exposure defined as U_i. Let $\tilde{L}_n$ be the aggregate loss on a portfolio of n assets. The total loss on the portfolio is then given by

$$\sum_{i=1}^{n} x_i \widetilde{U}_i = \tilde{L}_n \qquad (1)$$

To avoid bankruptcy, sufficient capital (K) must be held such that $\tilde{L}_n > K$ does not occur. In terms of regulatory capital ratios (k), this insolvency condition can be re-expressed as

$$\tilde{l}_n = \frac{\tilde{L}_n}{\sum x_i} > \ k = \frac{K}{\sum x_i} \qquad (2)$$

The regulator can now set K such that

$$prob\ (\tilde{l}_n \geq k) = 1 - q \qquad (3)$$

As Gordy (2003) suggests, bank portfolios of consumer loans may be granulated enough to diversify away considerable amounts of idiosyncratic risk but because borrower numbers are finite whilst exposures to different asset classes are not uniform, some residual risk will remain. For example, banks often have concentrated exposures to residential or commercial real estate subjecting them to significant sectoral risks.

To ensure (3) is satisfied, two conditions must hold: a minimum level of diversification and only one common systematic risk factor across all assets. For internationally diversified portfolios the common factor necessarily becomes the global business cycle. Since Basel II and III rely on these assumptions, capital ratios will only mitigate crises by protecting against systematic risk arising from global business cycle downturns (Blundell-Wignall and Atkinson, 2010); domestic macroeconomic shocks are not accommodated so capital ratios may often be biased downwards. This has implications for the empirical link between capital and crisis risk. In countries where the roots of crises lay in common external events, capital is more likely to exert its desired effect; the effect of capital on crisis probability should be negative and significant. In cases where crises were caused by local (or even regional) factors, the portfolio approach suggests the empirical relationship may not hold because corresponding buffers against were not priced in.

In Diamond and Rajan (2000) capital becomes important when uncertainty over asset prices is introduced. Under certainty, depositors can verify assets values so any attempt by the banker to squeeze rents from depositors leads to bank runs. This commitment device ensures banks always refund depositors fully so pure deposit financing is optimal.

In uncertain environments, depositors who observe a decline in asset prices are unable to verify true values and run on the bank due to sequential service constraints. This could occur due to market forces (systematic risk), idiosyncratic risk or opportunistic behaviour by banks (deliberate imperfect diversification). To avoid failure, banks prefer partial finance with a softer claim, "capital", since this allows them to renegotiate with capital providers and refund deposits fully when asset prices fall, thus avoiding bank runs. Hence theoretically, capital protects against both risk types.

In practice however, capital ratios independent of asset risk will generate moral hazard since banks will reshuffle their portfolios to accept higher risk (Kim and Santomero, 1988; Mausser and Rosen, 2007). Even under risk contingent capital rules, banks may imperfectly diversify, decreasing the size of the portfolio but concentrating risk[4] via asset substitution. Moreover,

[4] This allocative inefficiency is possible if local shocks damage returns; as discussed previously the reliance on a common global business cycle implies correct weights will then not obtain in practice.

once limited liability (deposit insurance) exists, Rochet (1992) shows that risk based capital rules cannot eliminate moral hazard. Hence whilst capital theoretically reduces crisis risk, in practice this effect will be subject to the practices of the banking system and the institutional framework it operates under. Hence the expected negative relationship between capital adequacy and crisis probability may not always hold empirically.

2.2 Liquidity Risk and Banking Crises

Liquidity is important for bank stability from two perspectives: the funding side and the market's assessment of banks asset quality. The two channels are strongly linked in that deteriorations of asset prices can compromise a bank's ability to raise funds in the market. At the same time, acceptance of this liquidity risk is an inherent part of banks' activities as qualitative asset transformers in the process of providing liquidity insurance to depositors.

In the seminal papers of Bryant (1980) and Diamond and Dybvig (1983), banks are modelled as liquidity insurance providers. Assuming depositors are risk-averse, banks are risk neutral and in the face of potential liquidity shocks, the Pareto-optimal allocation of endowment occurs when depositors allocate funds to banks under a fractional reserve system. This outcome dominates autarky and bond market allocations but results in an inherently unstable situation since banks must invest in illiquid projects whilst maintaining solvency under the assumption that in aggregate, withdrawals will satisfy a known probability (the likelihood of a liquidity shock). However, if a patient depositor anticipates other depositors will withdraw, she is also forced (in the absence of liquidity shocks) to withdraw, since early liquidation of illiquid projects means banks' asset values are less than its liabilities.

Withdrawal of funds due to a lack of co-ordination amongst depositors leads to an inefficient allocation via bank runs which are associated with systemic banking crises (Demirguc-Kunt and Detragiache, 1998) and strongly dependent on expectations. This latter channel creates the possibility of contagion when lenders observe a run on one bank and update their beliefs about the liquidity position of another (potentially "sound") bank, which they then subject to a run.

Whilst policymakers attempt to mitigate contagious crises through the provision of deposit insurance, the increasing reliance of banks on short-term wholesale funding means liquidity risk remains systemically pernicious. In this context, endogeneity becomes important both from the perspective of asset prices and also herding amongst systemically important institutions.

Huang and Ratnovski s (2010) show that wholesale lenders rely on noisy public signals of banks' quality which they may disregard or enact upon to withdraw funding. In the latter case, monitoring is inadequate and early bank liquidation is sub-optimal. Withdrawals of wholesale financing may illicit fire sales whereby deleveraging results in rapid depreciation of asset prices. In turn, credit is further rationed (Acharya and Viswanathan, 2011) and liquidity risk propagates systemically via the markets (Perotti and Suarez, 2009).

In summary, the crisis risk reducing roles of capital and liquidity are developed in the theoretical literature. Empirically this association has been confirmed for OECD economies over the last 30 years (Barrell et. al., 2010) but requires testing for Asian and Latin American banking systems. We discuss the data and methodologies we use to do this in the next section.

Section 3: Data, the Event Study and Logit Methodologies and the ROC Curve Approach

3.1 Data

Our data covers the years 1980 – 2010 for eight Latin American and six Asian economies: Argentina, Brazil, Chile, Mexico, Panama, Peru, Uruguay, Venezuela, Indonesia, Korea, Malaysia, Philippines, Singapore and Thailand. Whilst this country selection is dictated by data availability, it covers the major crisis incidents in both regions.

Our main variables of interest, capital and liquidity, have not been widely used as EWS inputs most probably due to lack of data. Of the two, capital poses the greatest problem since even for developed countries there is a lack of internationally comparable reporting prior to 1980. Barrell et. al. (2010) utilised capital adequacy ratios obtained for OECD countries but even OECD data coverage limited the sample to 14 countries for the post-1980 years. Outside the OECD, country coverage is much worse; for emerging market economies especially, international financial institutions such as the IMF or World Bank do not list capital adequacy data consistently before 1998[5].

In order to examine the role of capital in emerging market crises, we were required to construct a dataset for regulatory capital. Whilst regulators may not have appreciated the importance of capital ratio data during the 1980s, the banking industry itself understood the central role capital plays in bank health and thus continually surveyed this variable. We exploit this fact by utilising an industry publication, "The Banker" which has an international focus. The Banker has annually surveyed the top 1000 banks in the world since 1989 and the top 500 global banks from 1980 – 1989. We use the Bank of International Settlements (BIS) Regulatory Capital Ratios reported by the Banker to construct our regulatory capital variable[6].

The BIS Capital Ratio is a comparable measure across banks that were required to calculate capital adequacy according to BIS rules. However coverage may be an issue because not all banks in our emerging market countries will have entered the top 1000 global bank list.

[5] Capital ratios start to be systematically reported by the IMF in their Global Financial Stability Reports from 1998 onwards, possibly in response the Asian and Latin American crises which would have highlighted the lack of available data for analysis.

[6] The Banker data is not available electronically for our sample of interest and hence manual transcription of the BIS ratios was required.

Nevertheless, it is reasonable to assume that where a bank did enter the list, it would have been systemically important (in the "too-big-to-fail" sense) and thus its capital ratio would be correlated with the health of the financial system. Hence although our capital data may not contain all the variance associated with a particular banking system, it should be broadly representative of its capital soundness. Full details of the bank coverage for each country are given in the data appendix[7].

From 1998 onwards, we revert to the IMF's Global Financial Stability Reports to obtain capital adequacy ratios for the entire banking system. Like The Banker, these data are risk weighted according to BIS regulatory requirements. The final variable we construct can be described as:

$$Capital\ charge = EA\ x\ RW\ x\ GCR \tag{4}$$

where EA = amount of exposure; RW = risk weight of exposure and GCR = general capital requirement.

In comparison to capital ratios, liquidity data is easier to obtain although it also needs to be constructed. We use the Barrell et. al. (2010) definition of liquidity

$$Liquidity\ Ratio = \frac{cash + reserves + claims\ \ on\,(central\ bank + government)}{total\ assets} \tag{5}$$

which we construct from the IMF's International Financial Statistics database. This is a narrow liquidity definition because of the exclusion of claims on the private sector. During the Asian crises, capital flight would have reduced the marketability of corporate securities, rendering them illiquid. Hence a narrow liquidity measure is more representative of the liquidity position of banks during crises.

The remaining variables that enter our EWS are the more traditional set of determinants (see Demirguc-Kunt and Detragiache, 1998; Davis and Karim, 2008): domestic credit/ GDP, exchange rate, real GDP growth, terms of trade, inflation, budget balance/ GDP, real domestic credit growth, GDP per capita, current account balance/ GDP and M2/ foreign exchange reserves. These data were obtained from the IMF and World Bank.

Our dependent variable is constructed as a binary series such that a value of one represents the occurrence of a systemic crisis whilst a value of zero indicates no crisis has taken place.

To date our crises, we rely on Demirguc-Kunt and Detragiache (2005) where a systemic crisis is recorded if one or more of the following conditions pertain in a given year: non-performing loans/ total banking system assets exceeded 10%, or public bailout costs

[7] For Panama, The Banker provides no data. For this country we relied on IMF Global Financial Stability Reports and IMF Country Reports.

exceeded 2% of GDP, or systemic crisis caused large scale bank nationalisation, or extensive bank runs were visible and if not, emergency government intervention occurred.

Based on these criteria, our dependent variable contains 23 systemic crisis episodes; 14 of which occurred in Latin America and 9 in Asia. A concentration of crises occurs in the early 1980s (predominantly in Latin America), the early to mid 1990s (Latin America) and the late 1990s (Asia). Only 2 crises occur after 1998 (Argentina and Uruguay) and none occur after 2002.

Once a crisis ensues it will impact on the explanatory variables either directly or due to associated policy responses. To remove this endogeneity we use the crisis onset only (see Barrell et. al., 2010). In addition, each explanatory variable in the logit model is lagged to further address this issue. The distribution of crises is shown in Table 1.

Table 1: Systemic Crises Based on Demirguc-Kunt and Detragiache (2005) Dating

	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
ARG	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0
BRA	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
CHI	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEX	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
PAN	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PER	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
URU	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
VEN	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
IND	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
KOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
MEX	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
PHI	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
SIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
THA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Note: Data shown up to 2003 only; there are no crises after 2002. ARG=Argentina; BRA=Brazil; CHI=Chile; MEX=Mexico; PAN=Panama; PER=Peru; URU=Uruguay; VEN=Venezuela; IND=Indonesia; KOR=Korea; MEX=Mexico; PHI=Philippines; SIN=Singapore; THA=Thailand

3.2 The Event Study Approach

Event studies were initially used to establish whether share prices generated abnormal returns following a pre-defined event (Fama et.al., 1969). The event methodology lent itself to crisis investigation and has subsequently been used by Eichengreen et. al. (1995), Frankel and Rose (1996) and Aziz et. al. (2000) for currency crises and Manasse et. al. (2003) for sovereign debt crises. There have been relatively few event studies on banking crises, Gourinchas and Obstfeld (2012) being a recent exception[8].

An event study is a univariate graphical approach which tracks how a variable behaves around the time of an event (crisis). This behaviour can then be compared to non-tranquil times to see if the crisis is associated with significantly aberrant behaviour, in which case the variable may be an informative crisis predictor. In this sense, the approach is not dissimilar to the signal extraction approach used to underpin the Basel II rules on capital and therefore, suffers from a lack of variable interactions. Nevertheless, as a first approach event studies are informative because unlike signal extraction (which is non-parametric), confidence intervals can be used to judge significant abnormality of the variable.

Assuming the vent occurs at time t, an "event window" can be defined as the temporal space: $\{t-3, \dots t, \dots t+3\}$. This three year pre and post crisis window is similar to Manasse et. al. (2003) and Hemming et. al. (2003), although five years can be used (Gourinchas and Obstfeld, 2012). Then for county i and variable X, the behaviour of X_{it} conditional on the temporal distance from t can be computed: $(X_{it}|\{t-3, \dots t, \dots t+3\})$. This behaviour can then be compared against the reference behaviour of X_{it} outside the event window: $(X_{it}|\{t-n, \dots t-4, t+4, \dots t+n\})$. Confidence intervals are used to establish whether the behaviour of X_{it} during crises is significantly different from tranquil periods.

3.3 The Logit Approach

Demirguc-Kunt and Detragiache (1998) first used the multivariate logit estimator to relate the probabilities of systemic banking crises to a vector of explanatory variables. The banking crisis dependent variable, a binary banking crisis dummy, is defined in terms of observable stresses to a country's banking system, e.g. ratio of non-performing loans to total banking system assets exceeds 10%.[9] Demirguc-Kunt and Detragiache (2005) updated the banking crises list to include more years, and more crises. We use the same dependent variable in our current work.

We use the cumulative logistic distribution which relates the probability that the dummy for crises takes a value of one to the logit of the vector of n explanatory variables:

$$\Pr\mathrm{ob}(Y_{it} = 1) = F(\beta X_{it}) = \frac{e^{\beta' X_{it}}}{1 + e^{\beta' X_{it}}} \tag{6}$$

[8] Kaminsky and Reinhart (1999) used event studies to examine banking crises in conjunction with currency crises (the so called "twin crises"). Other approaches test the difference in bank share returns around crises.

[9] Their actual criteria are: the proportion of non-performing loans to total banking system assets exceeded 10%, or the public bailout cost exceeded 2% of GDP, or systemic crisis caused large scale bank nationalisation, or extensive bank runs were visible and if not, emergency government intervention was visible.

where Y_{it} is the banking crisis dummy for country i at time t, β is the vector of coefficients, X_{it} is the vector of explanatory variables and $F(\beta X_{it})$ is the cumulative logistic distribution. The log likelihood function which is used to obtain actual parameter estimates is given by:

$$Log_e\ L = \sum_{i=1}^{n}\sum_{t=1}^{T}\left[\left(Y_{it}\log_e F\left(\beta' X_{it}\right)\right) + \left(1 - Y_{it}\right)\log_e\left(1 - F\left(\beta' X_{it}\right)\right)\right] \tag{7}$$

Although the signs on the coefficients are easily interpreted as representing an increasing or decreasing effect on crisis probability, the marginal values are not as intuitive to interpret. Equation (2) shows the coefficients on X_{it} are not constant marginal effects of the variable on banking crisis probability since the variable's effect is conditional on the values of all other explanatory variables at time t. Rather, the coefficient $ß_i$ represents the effect of X_i when all other variables are held at their sample means. The logistic EWS has the benefit of being easily replicable by policy makers concerned with potential systemic risk in their countries.

Unlike many extant studies which use contemporaneous independent variables (e.g. Demirguc-Kunt and Detragiache, 1998; 2005), we lag all independent variables so as to obtain a valid EWS (see Barrell et. al, 2010). We also test down from a general equation with all variables included to the simplest equation with all remaining significant variables. At each stage of the testing down procedure we assess the loss of predictive ability of the resulting model using a ROC analysis (see Section 3.4).

3.4 ROC Curves

Receiver operating characteristic (ROC) curves test the "skill" of binary classifiers and hence can be used to discriminate between competing models. In the context of logit estimators, probabilistic forecasts can be classified for accuracy against a continuum of thresholds. This generates a true positive rate and true negative rate for each threshold and correspondingly a false positive and false negative rate. In the terminology of ROC analysis, the two variables of interest are: sensitivity (true positive rate) and 1 – specificity (i.e. 1 – the true negative rate, which is equal to the false negative rate). Sensitivity is plotted on the y-axes and 1 – specificity on the x- axes, as shown in Figure 1.

The true positive and false negative rates encapsulate the correspondence between probabilistic forecasts and actual binary events and generate a two dimensional co-ordinate in the ROC space. In turn, the mapping between these co-ordinates and the thresholds (or decision criterion), define the ROC curve. Hence ROC curves are closely associated with the "power" of a binary predictor[10].

[10] In practice, the ROC curve is rarely "smooth" as drawn in Figure 1 since the relationship between the true positive and false negative rates to the threshold is not necessarily monotonic over the range of thresholds.

ROC curves have been widely used in medical research and are considered to be the most comprehensive measure of diagnostic accuracy available[11]. This is because they impound all combinations of sensitivity and specificity that the diagnostic test can provide as the decision criterion varies (Metz, 2006). Since false positive and false negative errors have very different costs in clinical terms, evaluating a predictor based solely on true positive rates can be inefficient. Similarly, in the context of early warning systems for crisis prediction, these two errors will have different social consequences; an EWS that has a high level of sensitivity at the cost of high false negative rates may lead to "tail events" being missed with commensurate economic costs.

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

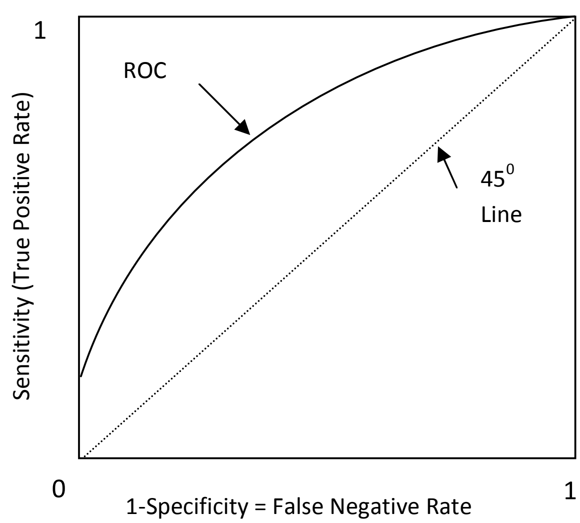


Figure 1: Receiver Operating Characteristic Curves

To separate out preferences from the decision making process, an alternative but related "global" measure of model skill can be used to select between competing models: the Area Under the Curve (AUC). This evaluates a model over all possible thresholds and thus avoids the ranking of models at particular thresholds. An AUC of 0.5 is equivalent to a "naïve" estimator that replicates a random coin toss (corresponding to the 45^0 line) so an AUC above

[11] For a recent example of ROC curve usage in the context of crises, see Schularick and Taylor (2012).

0.5 implies the model adds value in terms of both the ability to call crises correctly and low false negative rates.

Table 2: Area Under the Curve (AUC) and Model Skill	
AUC = 0.5	No discrimination (equivalent to coin toss)
0.7 ≤ AUC < 0.8	Acceptable discrimination
0.8 ≤ AUC < 0.9	Excellent discrimination
AUC ≥ 0.9	Outstanding discrimination (not possible in logit frameworks)

Source: Hosmer and Lemeshow, (2000)

Table 2 indicates discrimination performance in terms of the AUC. Hosmer and Lemeshow (2000) indicate that an AUC ≥ 0.9 is highly improbable for logit models since this level of discrimination would require complete separation of the crisis and non-crisis event, implying that the logit coefficients could not be estimated. Hence for our EWS approach we would accept models with AUCs ≥ 0.7. The AUCs for our competing models are given in the general to specific results.

Section 4: Results

In this section we initially present the results from our event study analysis which at a graphical level identifies the variables that showed significant deviance around crises. We then present our empirical results from the general to specific approach in a logit framework. Conclusions from this approach, which is standard in the extant literature, are then discussed in the light of our ROC curve results. This reveals that there may be a trade-off between an EWS model's simplicity (and thus its usefulness as a policy tool) and predictive accuracy since an increase in the latter may come at the cost of increased monitoring. Recognition of this trade-off will improve future EWS design.

4.1 Event Study Results

Panels 1 to 6 below show the event studies for each of our variables in the cases of pooled samples and then split samples. Each graph compares the variable behaviour in the abnormal period (bold line) against its average behaviour in tranquil periods (dashed grey line). The vertical line at time t indicates the crisis event. We use 95% confidence intervals (dotted lines) to assess significant deviations: if the bold line containing the crisis episodes moves outside the confidence interval, the respective variable behaves significantly different during the event window.

Capital Adequacy (panel 1): The capital adequacy results for our pooled sample reveal banks' capital buffers were significantly and abnormally low prior to crises. Indeed, for the entire 3 year pre-crisis window, capital positions were worse than the non-crisis mean (9.23%) but this deterioration became significant during the crisis when capital adequacy fell to 7.3%, below the regulatory minimum of 8%, during the actual crises.

The regional results reveal the source of this capital inadequacy: for Latin American banks, the average tranquil level of capital stood at 10.1%, above the regulatory minimum. However crises in these economies were characterised by sudden declines in buffers a year before crisis when the level dropped to 7.78%. This suggests that asset write-offs were problematic at this time and since capital levels 3 years before crisis stood at only 8.8%, banks would have been vulnerable to the deteriorations in asset quality.

In the context of Asia, the tranquil period average level of capital stood at 8.08%, effectively at the regulatory floor. Nevertheless, the reductions in capital observed from 2 years prior to crises (down to 6.8%) were not significantly different from this regulatory minimum, suggesting that at this stage, Asian banks could accommodate rising non-performing loans. However within a year of crisis onset, this situation reversed; the capital level of 5.72% one year afterwards is significantly below the non-crisis mean and suggests that buffers were no longer able to accommodate the depth of the Asian crises.

The results suggest that a lack of capital adequacy was a pre-crisis problem in Latin America as opposed to Asia. We would thus expect that if our capital variable was to act as an early warning indicator, it would be relevant to Latin American crises.

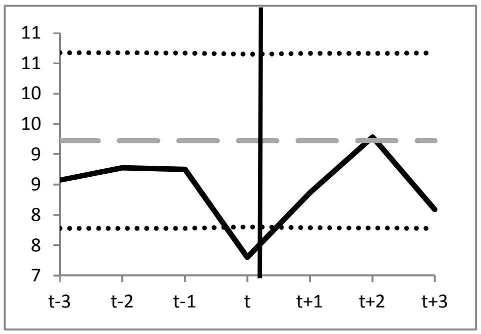
Liquidity (panel 1): The pooled sample results which track banks' liquidity positions show a dramatic deterioration of liquid assets 3 years prior to crises. The tranquil period average liquidity ratio was 26% yet liquidity remained significantly below this level during the entire pre-crisis window. The worst deterioration occurred one year before crises began when liquidity stood at 16.7%.

A regional analysis shows Asia to be the main source of this vulnerability. In Latin America, banks held 28% of their assets in liquid form on average. This level started to decline significantly 3 years prior to crises so that by the pre-crisis year the ratio stood at 19.8%. However in the immediate run-up to crisis, Latin American banks appear to have shored up their liquidity positions such that at crisis commencement their liquidity ratios were not significantly different from their pre-crisis levels. This upward trend continued; within 1 year of crisis onset the liquidity ratio of 33% actually stood above its tranquil period average.

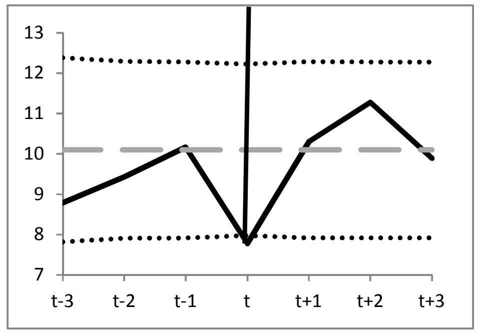
PANEL 1:

CAPITAL ADEQUACY (%)

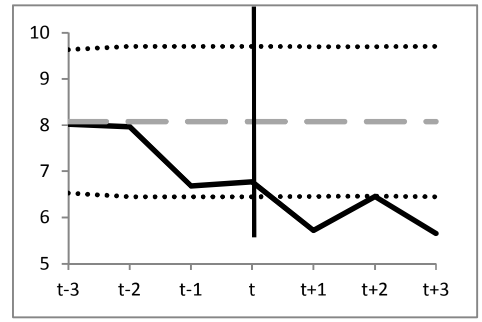
POOLED



LATIN AMERICA

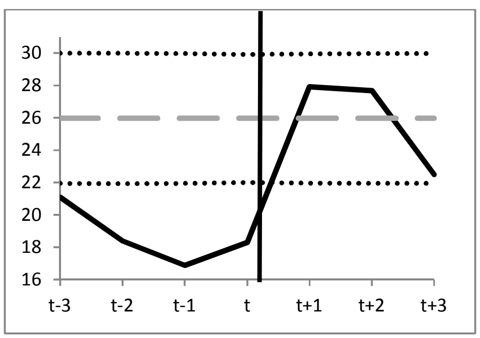


ASIA

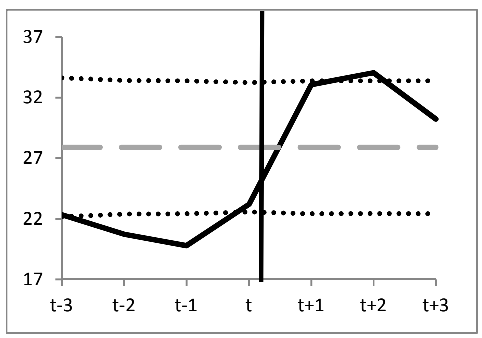


LIQUIDITY (%)

POOLED



LATIN AMERICA



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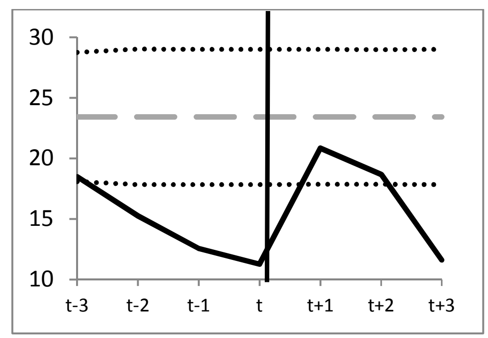
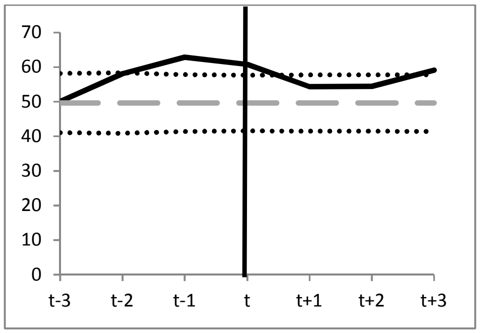


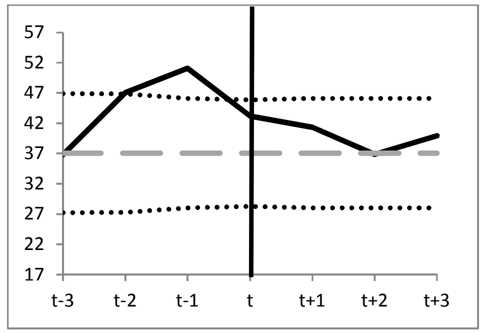
PANEL 2:

DOMESTIC CREDIT/ GDP

POOLED



LATIN AMERICA



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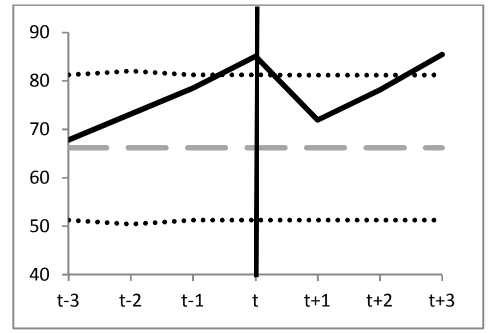
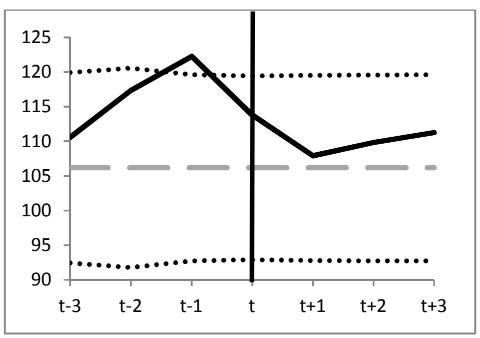
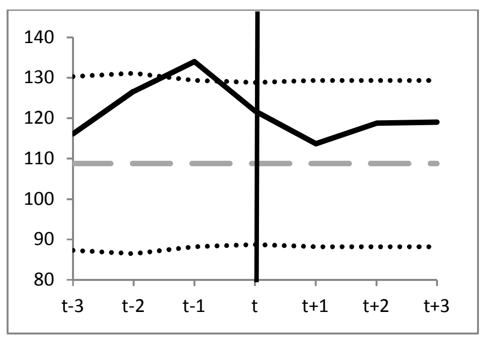


TERMS OF TRADE (2000=100)

POOLED



LATIN AMERICA



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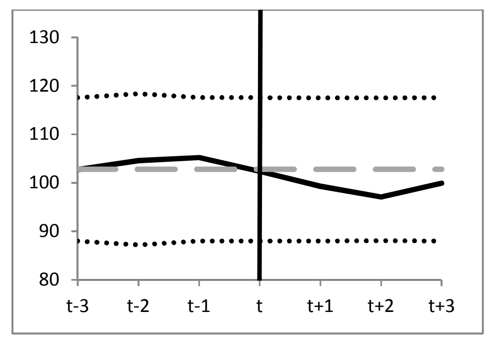
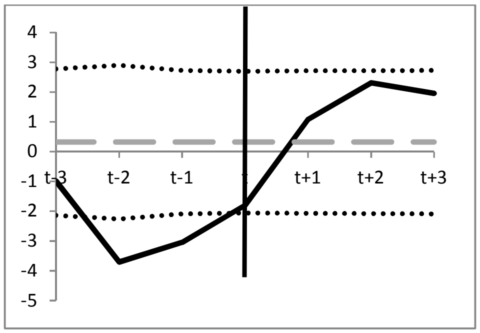


PANEL 3:

CURRENT ACCOUNT (% GDP)

POOLED



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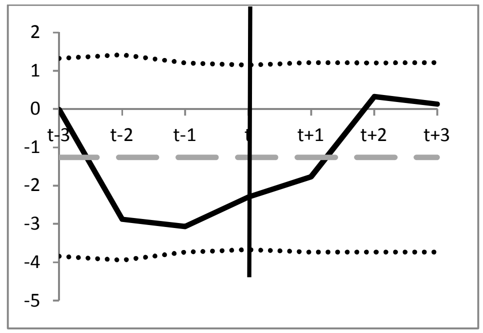

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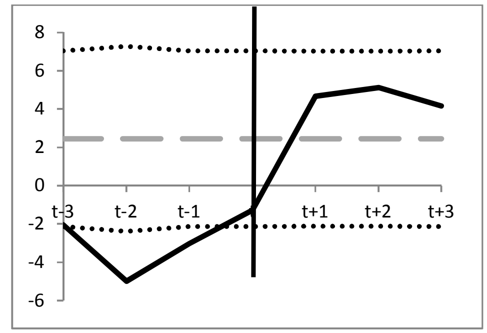
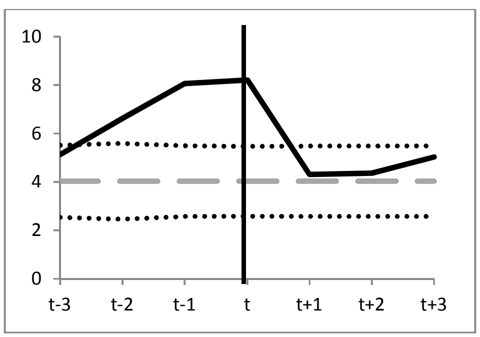
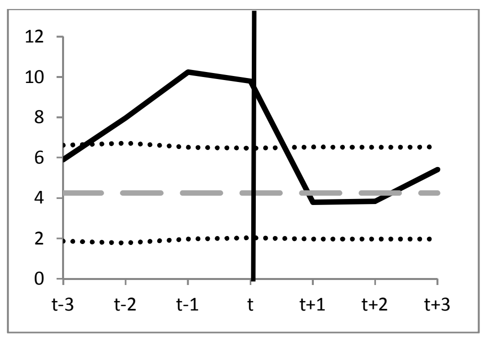


M2/FOREIGN EXCHANGE RESERVES

POOLED



LATIN AMERICA



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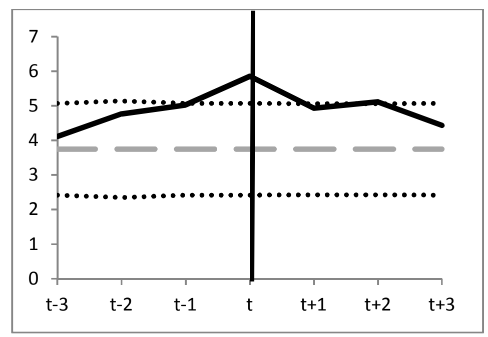
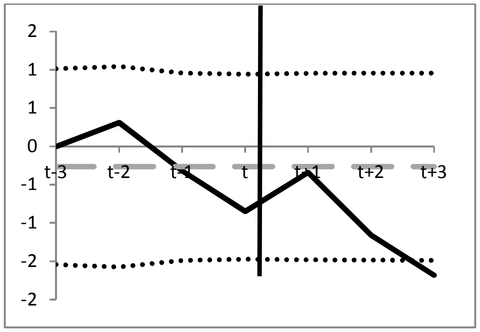


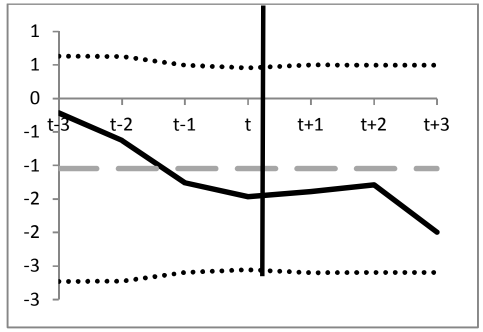
PANEL 4:

BUDGET BALANCE (% GDP)

POOLED



LATIN AMERICA



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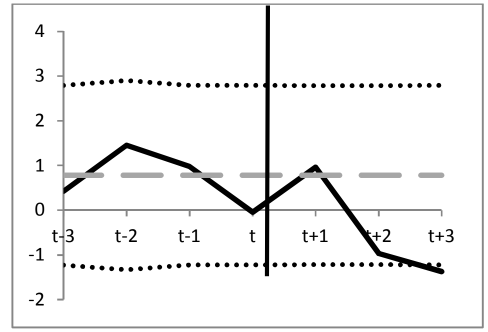
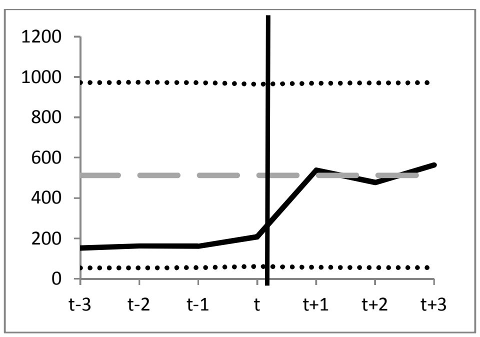
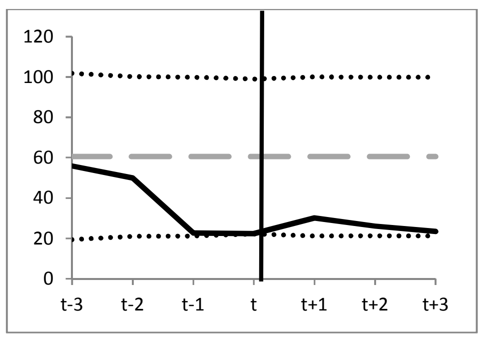


EXCHANGE RATE ($US)

POOLED



LATIN AMERICA



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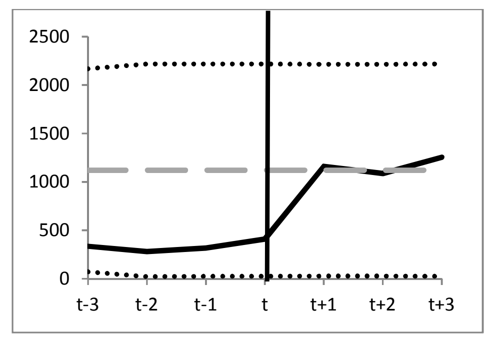
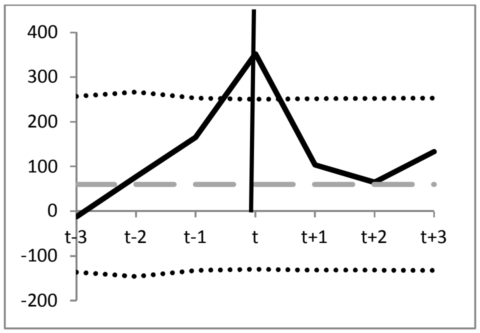


PANEL 5:

INFLATION (%)

POOLED



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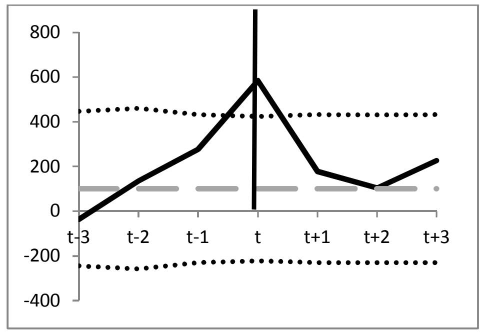

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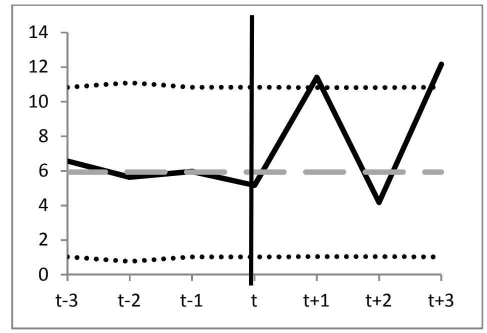
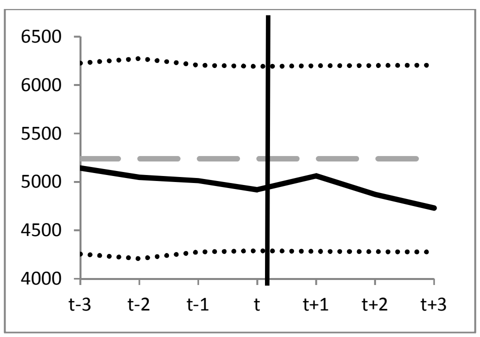
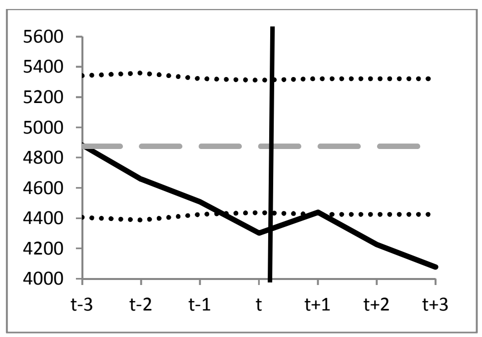


GDP PER CAPITA (CONSTANT 2000 US$)

POOLED



LATIN AMERICA



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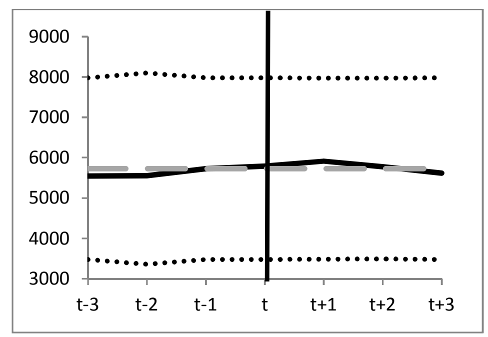
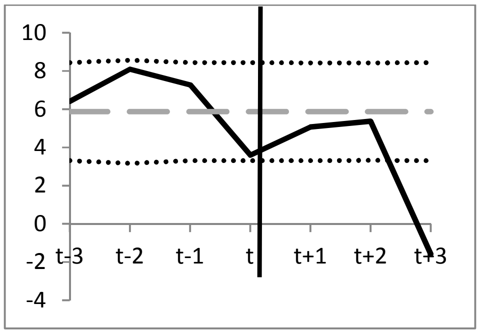


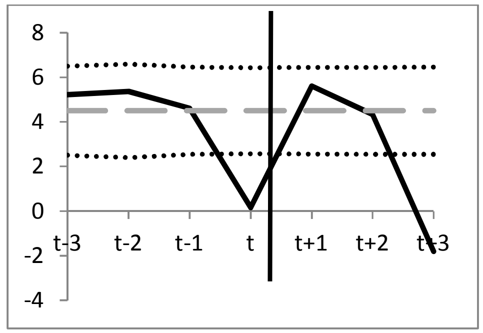
PANEL 6:

GDP GROWTH (%)

POOLED



LATIN AMERICA



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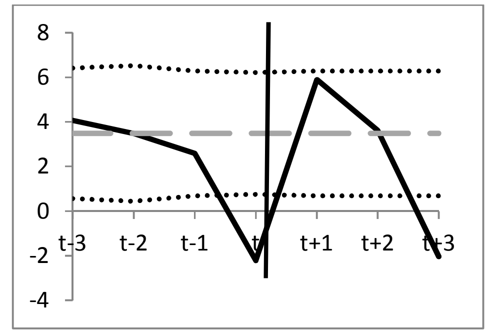


In the case of Asia, the liquidity position of banks was far more critical. Even during non-crisis periods the average liquidity ratio was 23.4%, below the Latin American average of 28%. Moreover in Asia, the decline was more protracted; even 3 years before crisis the starting level of liquidity was only 18% and persistent significant declines thereafter resulted in a ratio of 1.3% at crisis onset.

These patterns accord with the chronology of Asian crises events where significant capital outflows resulting from a "flight to quality" left banks without access to financing. This may explain the post-crisis relapse in liquidity positions; although they temporarily improved 1 year after crisis onset, by the following year, Asian banks' liquidity ratios again fell significantly below their tranquil period levels. Hence liquidity ratios are a potential leading indicator for Asian crises but are less likely to be so in the case of Latin America.

<u>Domestic Credit/ GDP; M2/Reserves; Current Account/ GDP (Panels 2 and 3):</u> Some variables we examine do not display anomalous behaviour during the pre-crisis windows; although there are deviations from the non-crisis mean in several cases, most of these are not especially significant in terms of the confidence intervals. Exceptions include domestic credit/ GDP, the current account and M2/ reserves.

The rises in domestic credit/ GDP in the pooled sample show credit intermediation expanded above its tranquil period average (49.6%) during all 3 pre-crisis years. This expansion falls outside the upper confidence level 2 years before crisis onset, peaking at 62.9%. The pooled results are attributable to Latin American banks' lending activity where balance sheets expanded; credit/ GDP remained elevated in the run-up to crises rising to 51% compared to a non-crisis average of 37%. In Asia, although the tranquil period mean (66.2%) was higher than Latin America, credit expansion relative to income did not significantly differ in the run up to crises.

In line with the expansion of Latin American banking intermediation, M2/ reserves also increased significantly. Whereas the non-crisis mean level was 4.2%, the pre-crisis level peaked at 10.2%. However this deviation was not persistent; a rapid post-crisis correction meant the M2/ reserves ratio fell below the tranquil average within a year of crisis onset. This correction is not observed for domestic credit/ GDP in Latin America. In Asia, a relatively minor aberration of M2/ reserves is observable close to crisis onset but the correction was rapid.

On the other hand, the current account deficit behaved significantly worse in Asia than in Latin America. This generates the trends observed in the pooled sample where the current account remains well below the tranquil average in all 3 pre-crisis years. Whilst current accounts worsened in Latin America the deviations were not significantly different from the non-crisis mean of -1.26%. In contrast, the deficit was markedly worse in Asia where the tranquil period was associated with a 2.5% surplus. Relative to this baseline, Asia's imbalances rose for all 3 years before crisis onset. These significant deviations caused the deficit to dip to 5% of GDP 2 years before the crises erupted with commensurate effects on the balance of payments.

4.2 Logit Results

Having identified different potential leading crisis indicators for Latin America and Asia using the event study methodology, we next discuss our results for the general to specific logit exercise. The logit results can be used to assess the relative leading indicator qualities of competing variables where the sign on the coefficient indicates whether an in increase in the value of the variable reduces the probability of crisis or not.

Tables 3 to 5 display the testing down procedure for the pooled and separated samples. A priori we make no assumptions abut the relative importance of variables as leading indicators hence we start with all variables and iteratively remove the least significant at each stage. Although we do not assume statistical differences between the two regions, we conduct separate exercises for Latin America and Asia and test whether the results are significantly different.

The pooled sample results (Table 3) show 9 sequential variable deletions culminating in a 3 variable equation. The final specification is the most parsimonious model that can be used to explain systemic banking crises across Latin America and Asia. The variable deletions themselves are of interest since they suggest changes in domestic credit growth, GDP growth, inflation, GDP per capita and M2/forex reserves do not significantly affect crisis probabilities. These results contrast with those of Demirguc-Kunt and Detragiache (1998; 2005) who found these variables to be associated with emerging market crises, albeit contemporaneously[12].

Some of these differences may be attributable to our inclusion of capital and liquidity which remain untested in the extant literature on these regions. The final pooled specification suggests the most important determinants of combined Latin American and Asian crises are: the terms of trade, changes in domestic credit/ GDP and bank capital adequacy. An improvement in the terms of trade and capital soundness of banks reduces the likelihood of systemic bank failures while an increase domestic credit relative to income raises the failure probability.

The event study approach highlighted these variables as indicators of financial instability albeit with different regional importance. Although we have made no assumptions regarding regional differences in crises, and thus their causes, we expect divergences to exist given the

[12] Credit growth was the only variable to be lagged (by two periods) in their specifications.

Table 3: General to Specific Results for Pooled Sample

Regression Number	1	2	3	4	5	6	7	8	9	10
Terms of trade(-1)	-0.013 (0.029)	-0.013 (0.029)	-0.014 (0.024)	-0.015 (0.012)	-0.016 (0.007)	-0.018 (0.001)	-0.019 (0.001)	-0.023 (0)	-0.02 (0)	-0.019 (0)
Δ Domestic Credit/ GDP(-1)	0.049 (0.051)	0.049 (0.051)	0.049 (0.052)	0.049 (0.056)	0.053 (0.031)	0.055 (0.026)	0.053 (0.034)	0.052 (0.03)	0.065 (0.005)	0.069 (0.002)
Capital Adequacy Ratio(-1)	-0.132 (0.041)	-0.132 (0.041)	-0.135 (0.035)	-0.147 (0.02)	-0.142 (0.021)	-0.131 (0.024)	-0.141 (0.019)	-0.153 (0.007)	-0.142 (0.01)	-0.145 (0.006)
Current Account Balance (% of GDP)(-1)	-0.06 (0.261)	-0.06 (0.261)	-0.054 (0.285)	-0.062 (0.2)	-0.06 (0.208)	-0.069 (0.152)	-0.079 (0.09)	-0.081 (0.079)	-0.084 (0.07)	
M2 Money/ Forex Reserves(-1)	0.048 (0.231)	0.048 (0.231)	0.047 (0.247)	0.046 (0.261)	0.049 (0.232)	0.049 (0.232)	0.064 (0.102)	0.072 (0.092)		
Liquidity Ratio(-1)	-0.035 (0.061)	-0.035 (0.061)	-0.035 (0.062)	-0.035 (0.055)	-0.033 (0.063)	-0.034 (0.055)	-0.025 (0.107)			
Budget Balance (% of GDP)(-1)	-0.092 (0.379)	-0.092 (0.379)	-0.103 (0.306)	-0.108 (0.273)	-0.111 (0.259)	-0.11 (0.271)				
Exchange Rate(-1)	0 (0.434)	0 (0.434)	0 (0.427)	0 (0.441)	0 (0.444)					
Inflation(-1)	0 (0.599)	0 (0.599)	0 (0.54)	0 (0.508)						
GDP per Capita(-1)	0 (0.557)	0 (0.557)	0 (0.559)							
ΔGDP(-1)	-0.019 (0.723)	-0.019 (0.723)								
Δ Domestic Credit(-1)	0 (0.984)									
Observations	401	401	401	401	401	401	402	402	402	402

Note: p-values in parentheses

. Table 4: General to Specific Results for Asia

Regression Number	1	2	3	4	5	6	7	8	9	10
Current Account Balance (% of GDP)(-1)	-0.201 (0.131)	-0.211 (0.108)	-0.224 (0.084)	-0.242 (0.062)	-0.207 (0.06)	-0.195 (0.04)	-0.197 (0.036)	-0.199 (0.036)	-0.189 (0.036)	-0.194 (0.012)
Liquidity Ratio(-1)	-0.075 (0.209)	-0.072 (0.214)	-0.088 (0.053)	-0.082 (0.052)	-0.079 (0.054)	-0.064 (0.051)	-0.063 (0.051)	-0.065 (0.038)	-0.071 (0.025)	-0.063 (0.041)
Terms of trade(-1)	-0.019 (0.344)	-0.014 (0.304)	-0.017 (0.157)	-0.019 (0.131)	-0.02 (0.092)	-0.018 (0.081)	-0.016 (0.059)	-0.017 (0.025)	-0.016 (0.026)	-0.021 (0)
GDP per Capita(-1)	0 (0.305)	0 (0.303)	0 (0.189)	0 (0.229)	0 (0.26)	0 (0.343)	0 (0.331)	0 (0.354)	0 (0.331)	
Budget Balance (% of GDP)(-1)	0.337 (0.411)	0.377 (0.338)	0.322 (0.383)	0.305 (0.4)	0.277 (0.44)	0.203 (0.454)	0.179 (0.489)	0.182 (0.484)		
Inflation(-1)	-0.083 (0.548)	-0.084 (0.514)	-0.103 (0.419)	-0.134 (0.27)	-0.109 (0.317)	-0.03 (0.668)	-0.021 (0.731)			
M2 Money/ Forex Reserves(-1)	0.217 (0.297)	0.214 (0.291)	0.224 (0.273)	0.213 (0.286)	0.205 (0.298)	0.063 (0.699)				
Δ Domestic Credit(-1)	0 (0.352)	0 (0.353)	0 (0.284)	0 (0.385)	0 (0.468)					
Δ Domestic Credit/ GDP(-1)	-0.046 (0.506)	-0.046 (0.503)	-0.05 (0.459)	-0.037 (0.584)						
Exchange Rate(-1)	0 (0.543)	0 (0.563)	0 (0.559)							
Capital Adequacy Ratio(-1)	-0.08 (0.74)	-0.097 (0.672)								
ΔGDP(-1)	0.059 (0.745)									
Area Under Curve (AUC)	0.713	0.759	0.837	0.837	0.838	0.829	0.817	0.821	0.808	0.807
Observations	173	173	173	173	173	173	177	178	178	179

Note: p-values in parentheses

Table 5: General to Specific Results for Latin America

Regression Number	1	2	3	4	5	6	7	8	9	10
Capital Adequacy Ratio(-1)	-0.136 (0.139)	-0.136 (0.137)	-0.134 (0.139)	-0.124 (0.117)	-0.125 (0.103)	-0.122 (0.11)	-0.117 (0.096)	-0.157 (0.003)	-0.18 (0)	-0.219 (0)
Liquidity Ratio(-1)	-0.032 (0.237)	-0.032 (0.237)	-0.031 (0.237)	-0.027 (0.209)	-0.028 (0.175)	-0.03 (0.156)	-0.033 (0.098)	-0.041 (0.023)	-0.039 (0.026)	-0.047 (0.008)
Δ Domestic Credit/ GDP(-1)	0.056 (0.151)	0.056 (0.151)	0.059 (0.151)	0.057 (0.055)	0.062 (0.034)	0.063 (0.031)	0.07 (0.012)	0.072 (0.011)	0.071 (0.013)	0.062 (0.022)
Exchange Rate(-1)	-0.123 (0.306)	-0.123 (0.306)	-0.127 (0.306)	-0.115 (0.285)	-0.106 (0.296)	-0.102 (0.311)	-0.104 (0.278)	-0.14 (0.118)	-0.136 (0.145)	
ΔGDP(-1)	-0.081 (0.34)	-0.081 (0.34)	-0.083 (0.34)	-0.086 (0.303)	-0.064 (0.382)	-0.048 (0.456)	-0.053 (0.408)	-0.067 (0.281)		
Terms of trade(-1)	-0.011 (0.406)	-0.011 (0.406)	-0.011 (0.406)	-0.009 (0.37)	-0.009 (0.334)	-0.009 (0.341)	-0.006 (0.443)			
M2 Money/ Forex Reserves(-1)	0.037 (0.402)	0.037 (0.402)	0.038 (0.402)	0.039 (0.371)	0.034 (0.426)	0.03 (0.463)				
Current Account Balance (% of GDP)(-1)	-0.036 (0.649)	-0.036 (0.649)	-0.036 (0.649)	-0.045 (0.548)	-0.035 (0.625)					
Budget Balance (% of GDP)(-1)	0.142 (0.617)	0.142 (0.617)	0.146 (0.617)	0.157 (0.576)						
GDP per Capita(-1)	0 (0.773)	0 (0.773)	0 (0.773)							
Inflation(-1)	0 (0.874)	0 (0.875)								
Δ Domestic Credit(-1)	0 (0.996)									
Area Under Curve (AUC)	0.677	0.677	0.678	0.687	0.670	0.659	0.662	0.659	0.648	0.610
Observations	200	200	200	200	200	200	200	200	200	200

Note: p-values in parentheses

variations in banking system activity, institutional and policy frameworks as well as the openness to financial and trade flows. We therefore repeat the general to specific exercise on separate regions. The results show marked differences in crises determinants between Latin America and Asia. These differences are statistically significant: when we test the pooling assumption (under a null of no significant difference between the regions) we obtain an F-statistic of 2.91 versus a critical value of 2.32 (at 1% significance).

Table 4 shows the competing models for the Asian economies. In contrast to the pooled results, elevated domestic credit/ GDP and insufficient capital adequacy do not appear to precede crises. Instead, the current account balance, terms of trade and liquidity ratios are important crisis predictors. These effects appear robust in that the coefficients remain fairly stable through nine rounds of variable deletions.

The results accord with the chronology of the Asian crises: triggered by a reduction in demand for the region's exports, current account imbalances financed by speculative capital inflows and deteriorating bank liquidity positions once these inflows revered. The results are also in line with the event studies which identified significant anomalies in liquidity and current accounts in the pre-crisis window.

Liquidity ratios have become a target variable under Basel III and based on Asia's crisis history, regulation of this variable may be beneficial for regional financial stability. However the absence of capital adequacy from the final specification suggest the more stringent capital rules of Basel III are unlikely to yield the benefits available to OECD economies where capital inadequacy had a more obvious crisis generating role.

In contrast, Table 5 shows unhealthy capital positions are a crisis determinant in Latin America. Moreover, banks in this region held inadequate liquidity provisions at a time when the growth in bank expansion surpassed increases in income as a result of liberalisation policies. The lack of accompanying prudential regulation allowed banks in these regions to operate without adequate capital buffers and diverse sources of funding.

The introduction of capital and liquidity in the Latin America model relegates variables such as domestic credit growth, exchange rates and fiscal balances in terms of their leading indicator properties. Although these variables have connections to individual crises (e.g. Mexico and Argentina) it appears that they cannot explain broad crises classes as well as capital and liquidity. The event study approach also identified anomalies in capital soundness and credit/ GDP in this region although on a univariate basis, liquidity appeared to be less of a concern.

Hence in Latin America, increases in capital soundness and liquidity ratios should reduce the probability of future crises as would a focus on prudential supervision[13]. In this context, Latin America may benefit from the adoption of the Basel III framework.

4.3 ROC Results

So far, the interpretation has been in the context of leading indicators as an input to EWSs. From the perspective of a policy tool, the general to specific approach is useful because it identifies the most succinct sub-set of predictors that can be monitored to warn against financial instability. This reduces costs of monitoring and the chances of unnecessary policy

[13] It is not always been the case that highly regulated banking systems avoided crises in the region; Carstens et. al. (2004) point to the crisis in Peru as an example.

interventions based on a wider set of target variables; any set of target variables that enter the EWS must be scrutinised by the policy maker and are likely to be enacted upon if deviations become significant.

We may however be interested in the informational content of variables that do not survive the general to specific deletion process. Their removal may arise from variable interactions we cannot capture in a linear framework so that their ability to explain idiosyncratic crises is lost when we rank them against more dominant competitors. In such cases, the "skill" of the resulting parsimonious model may be inferior to the extended version containing the deleted variables.

Policy makers with a strong aversion to crises will wish to call as many episodes as possible even at the cost of mistaken signals; for them the cost of a Type I error (failure to call a crisis) is higher than the cost of a Type II error (false alarm). On the other hand, if an extended model contains no additional informational value, the same policy maker may prefer the parsimonious version, assuming costs of monitoring and intervention exist.

Informational value therefore becomes a function of both Type I and II errors whenever there is a cost involved with unnecessary policy intervention. If a deleted variable lowers the Type I error rate without significantly raising the Type II error rate (or vice versa), the more stringent model will be inferior from a forecasting accuracy perspective since this accuracy is a function of both errors.

We view the informational content of our competing models using ROC curves and compare their "skill" using the AUCs. Since we have established differences between crisis determinants in Latin America and Asia, we focus on regional results. Figures 2 and 3 display the ROC curves for competing models for Asia and Latin America respectively.

In both regions, the graphs suggest the parsimonious models are inferior to their competitors when both sensitivity and specificity are taken into account (the more convex the ROC curve, the better the model skill). Thus the trade-off between parsimony and skill becomes important because variable deletions cause losses in predictive accuracy. To shed light on this trade off, we compute the AUC for all models. For ease of reference, these figures are presented at the bottom of the general to specific results in Tables 4 and 5.

The highest AUC for Latin American models is 0.69 while the lowest value is 0.61. Referring to Hosmer and Lemeshow (2000) this implies that the worst model offers limited discrimination between crisis and non-crisis episodes, while the best model borders on acceptable discrimination (see Table 2). The Asian models are always superior in comparison; the highest AUC is 0.84 whilst the minimum occurs at 0.71. Hence the Asian EWSs generate acceptable to excellent discrimination.

In both regions, it is also clear that the parsimonious model does not yield the highest AUC. The Asian model with the highest AUC is regression 5 but compared to the most parsimonious version it contains 5 extra target variables (GDP per capita, budget balance, inflation, M2/reserves and domestic credit growth). The best Latin American model is

Figure 2: ROC Curves for General to Specific Asia Model

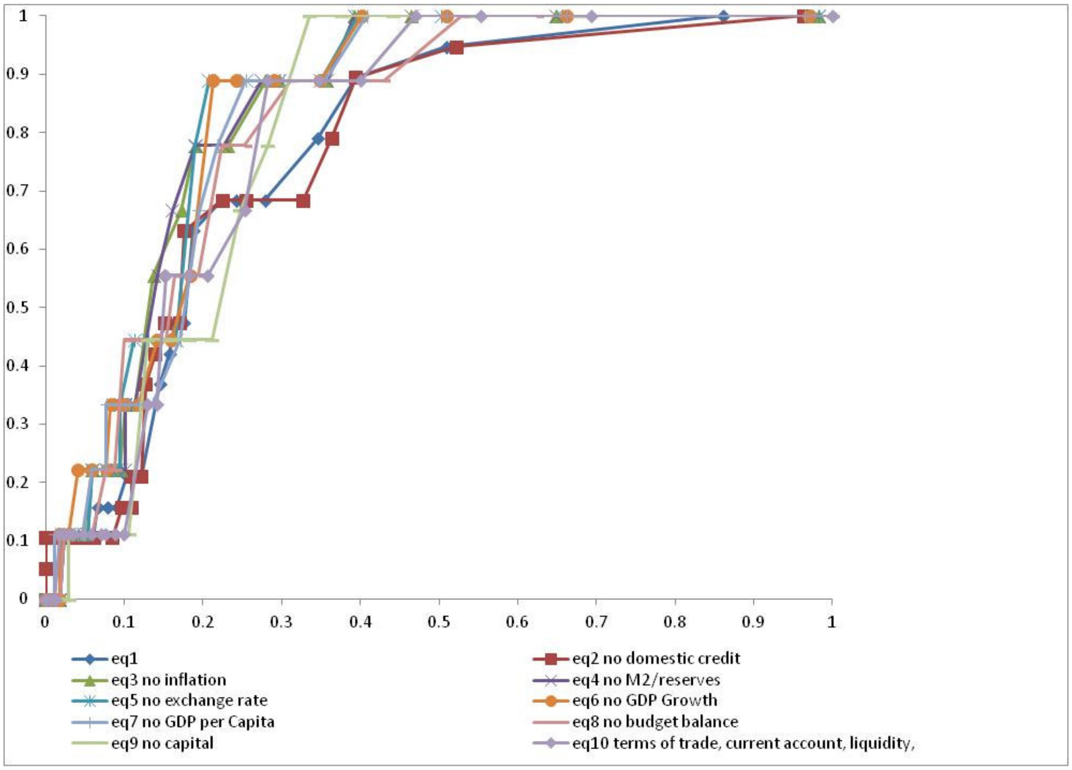
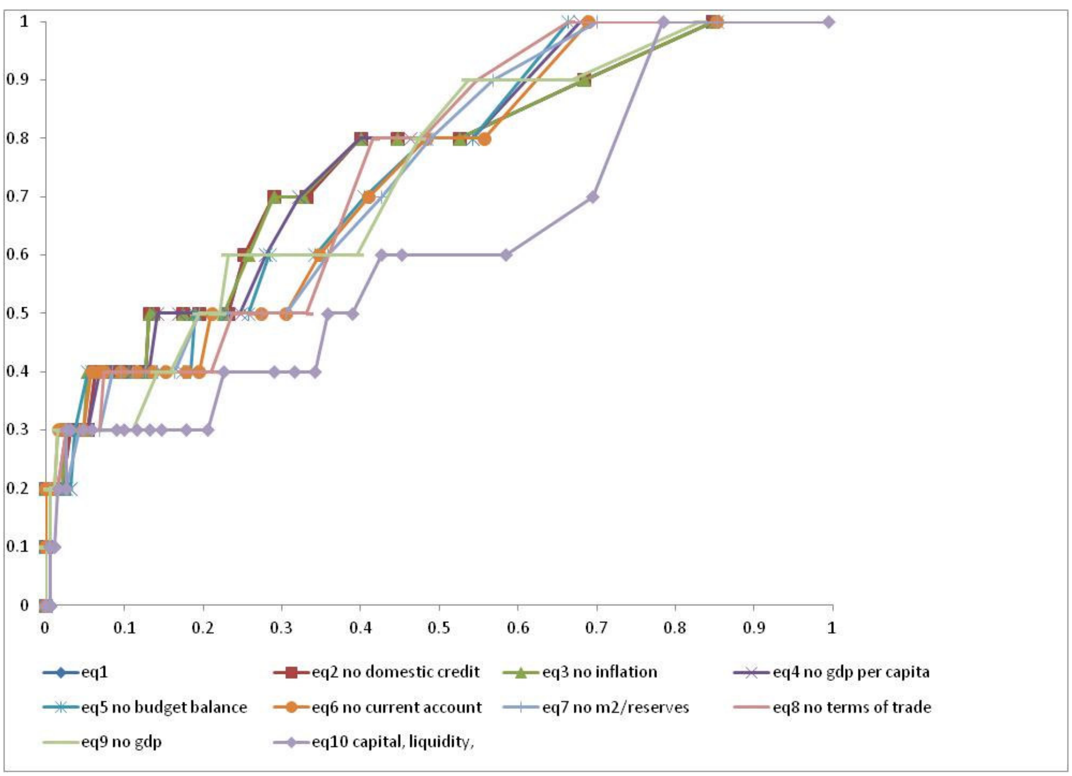


Figure 3: ROC Curves for General to Specific Latin America Model



regression 4, which contains 6 more variables than the truncated model (budget balance, terms of trade, M2/reserves, current account, GDP growth and exchange rates). Given the increased monitoring costs that would result from using these extended models versus the succinct versions, we evaluate the loss in terms of crisis calls and non-crisis calls at the in-sample threshold. These results are shown in Table 6.

Table 6: Comparisons of Model Accuracy

	Asia		Latin America	
Regression Number	Equation 5	Equation 10	Equation 4	Equation 10
AUC	0.838	0.807	0.687	0.61
Correct Crisis Calls (%)	7/8 (89%)	8/9 (89%)	7/10 (70%)	6/10 (60%)
Correct Non-Crisis Calls (%)	111/170 (65%)	111/170 (65%)	129/190 (68%)	109/190 (57%)

In the Asian context, there is no difference between the models in terms of the ability to identify crises since both approaches yield a success rate of 89%. Reducing the number of target variables from 8 to 5 does not compromise the ability to identify non-crisis episodes but significantly lowers the monitoring costs for policy makers at the threshold they would use for an EWS.

For Latin America, 6 additional variables are required to call one extra crisis (Argentina, 1989) although the information they carry improves the success of non-crisis identification. Nevertheless, the substantial increase in monitoring costs that would arise from using the extended model, alongside the macroeconomic consequences of any policy changes in these additional instruments, may be hard to justify and should be subject to a cost-benefit analysis.

Section 5: Conclusion

To our knowledge, our results represent the first attempt at testing the roles of bank capital adequacy and liquidity in Asian and Latin American crises. Event studies, logit estimations and ROC curve analyses suggest these variables are valuable leading indicators of crises, although capital seems relevant in the Latin American context. There are significant differences between the regions so the pooling assumptions of extant studies should be addressed.

We find no direct role for credit growth in either region. Credit/ GDP is a crisis determinant in Latin America where bank activity expanded when financial liberalisation was not accompanied by adequate prudential supervision. In Asia, crises were characterised by exposure to terms of trade deteriorations and reliance on short-term foreign capital flows without adequate liquidity protection from diversified funding sources.

Capital adequacy and liquidity ratios appear to supersede many “traditional” crisis determinants as leading indicators and can thus be used to improve EWS design for these regions. In this context, there are trade-offs between model simplicity, which implies less monitoring costs and complexity which may improve accuracy. However AUCs show that capital and liquidity can be used in a parsimonious model without any substantial loss in crisis predictive accuracy in either region.

Our results have implications for Asian and Latin American financial regulators concerned with the impacts of Basel III on their banking systems. The increased capital and liquidity standards could have a beneficial impact in Latin America but higher capital ratios may unnecessarily tax Asian banks. Given that we find no direct role for credit growth, the impact of countercyclical capital buffers need to be evaluated in both regions. Our results provide a starting point for further analysis.

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Data Appendix:

Table A.1: Data Sources for Capital Adequacy

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ARGENTINA	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (1)	✓ (2)	✓ (3)	✓ (3)	✓ (1)	✓ (7)		✓ (6)	✓ (7)	✓ (8)	✓ (8)	✓ (9)			✓ (8)
BOLIVIA																			
BRAZIL	✓ (7)	✓ (8)	✓ (10)	✓ (11)	✓ (7)	✓ (7)	✓ (6)	✓ (6)	✓ (4)	✓ (17)		✓ (20)	✓ (17)	✓ (19)	✓ (18)	✓ (17)			✓ (26)
CHILE		✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (1)	✓ (3)		✓ (3)	✓ (3)	✓ (3)	✓ (4)	✓ (4)			✓ (6)
MEXICO	✓ (4)	✓ (4)	✓ (4)	✓ (4)	✓ (5)	✓ (6)	✓ (5)	✓ (5)	✓ (4)	✓ (5)		✓ (7)	✓ (5)	✓ (6)	✓ (10)	✓ (9)			✓ (9)
PANAMA										✓ (1)		✓ (1)		✓ (1)	✓ (1)	✓ (1)			✓ (1)
PERU	✓ (1)	✓ (1)	✓ (1)							✓ (1)				✓ (1)		✓ (3)			✓ (4)
VENEZUELA	✓ (5)	✓ (4)	✓ (4)	✓ (3)	✓ (1)	✓ (1)	✓ (2)	✓ (1)				✓ (1)	✓ (1)	✓ (1)	✓ (1)	✓ (1)			✓ (2)
INDONESIA	✓ (2)	✓ (3)	✓ (3)	✓ (3)	✓ (3)	✓ (3)	✓ (4)	✓ (4)	✓ (2)	✓ (6)		✓ (9)	✓ (12)	✓ (13)	✓ (14)	✓ (13)			✓ (13)
KOREA	✓ (7)	✓ (7)	✓ (7)	✓ (8)	✓ (8)	✓ (8)	✓ (9)	✓ (10)	✓ (10)	✓ (15)		✓ (24)	✓ (28)	✓ (27)	✓ (28)	✓ (29)			✓ (20)
MALAYSIA	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (2)	✓ (4)	✓ (4)		✓ (5)	✓ (7)	✓ (7)	✓ (7)	✓ (9)			✓ (16)
PHILIPPINES	✓ (1)	✓ (1)	✓ (1)	✓ (1)	✓ (2)	✓ (2)	✓ (2)			✓ (6)		✓ (8)	✓ (6)	✓ (7)	✓ (8)	✓ (8)			✓ (14)
SINGAPORE	✓ (2)	✓ (2)	✓ (3)	✓ (3)	✓ (4)	✓ (4)	✓ (4)	✓ (3)	✓ (3)	✓ (5)		✓ (5)	✓ (6)	✓ (6)	✓ (6)	✓ (6)			✓ (6)
THAILAND	✓ (3)	✓ (1)	✓ (2)	✓ (3)	✓ (3)	✓ (3)	✓ (3)	✓ (3)	✓ (3)	✓ (9)		✓ (12)	✓ (11)	✓ (10)	✓ (12)	✓ (12)			✓ (9)

LEGEND: ✓ indicates data is available; ( ) indicates the number of banks for which data is available; missing data is obtained from IMF Global Financial Stability Reports or country reports (for Panama). Post 1998 data uses IMF Global Financial Stability Reports