
EUROPEAN CENTRAL BANK

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Towards a New Early Warning System of Financial Crises

(ECB Working Paper No. 145)

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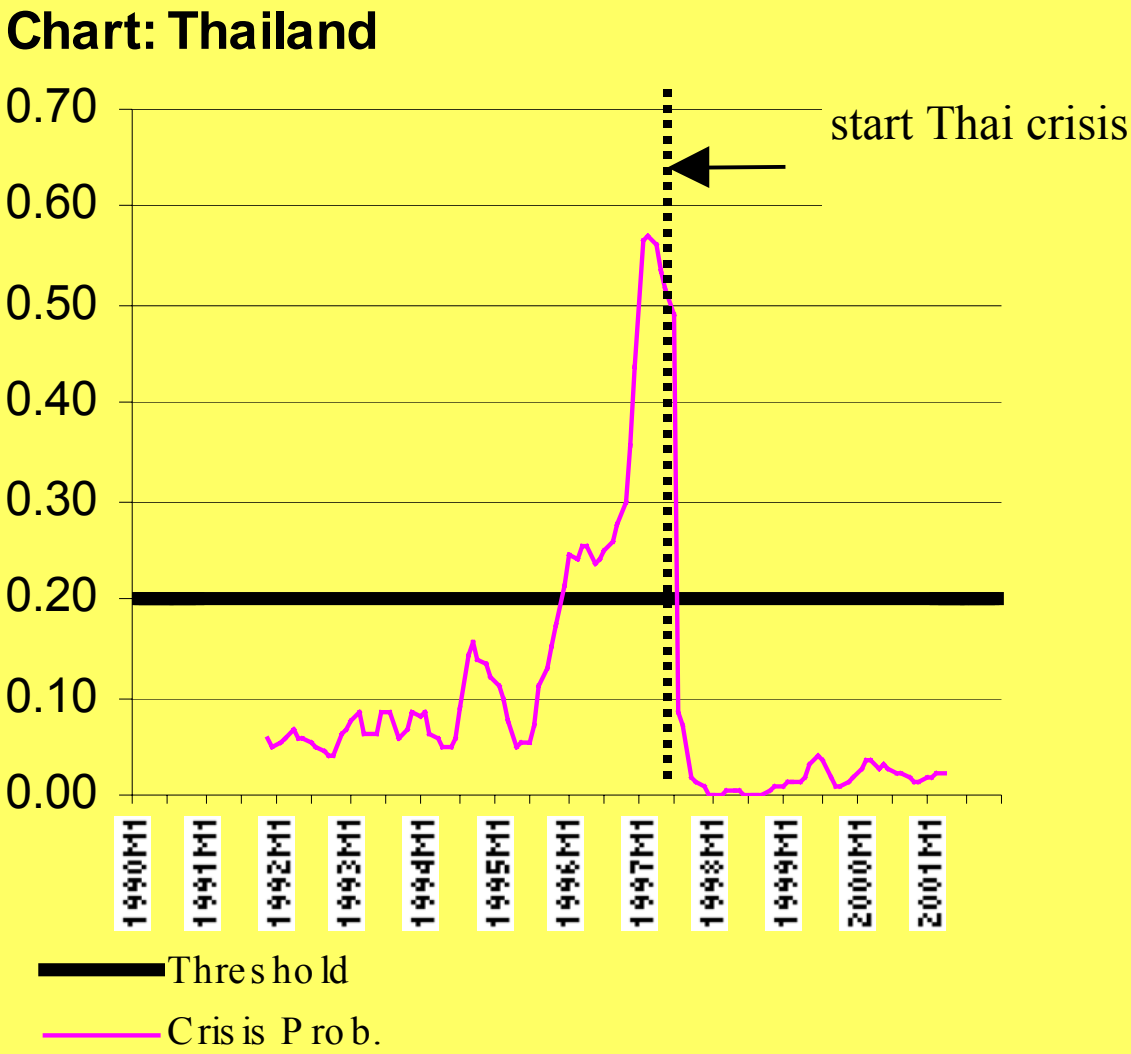
1. Motivation behind the Early Warning System (EWS)

- Financial crises in EMEs in the 1990s have been frequent and severe:
  - 26 out of 32 open EMEs experienced at least one financial crisis in the 1990s
  - strong recessions and financial turmoil
- Monitoring and detecting financial vulnerability of EMEs
- Forecast the probability of financial crises in individual EMEs
- An example...

1.1 The example of Thailand



1.2 Contribution of our EWS model to the literature

- Accounting for *post-crisis bias*: Development of a more appropriate econometric framework based on logit and multinomial logit models
- Broad model based on broad sample of 32 open EMEs during the 1990s
- Inclusion of contagion in the model

1.3 Structure of the presentation

- Description of the database underlying the EWS monitoring framework
- Methodology of existing EWS models: signalling approach vs. logit/probit approach
- Methodology: multinomial logit
- Empirical results
- Looking ahead: some policy implications

2. Database underlying the EWS model

32 EMEs (12 E.Europe/accession, 12 Asia, 8 Latin America)

x 50 macro variables

x 264 monthly data points (1980-present)

= more than 250,000 available data entries

- Sources: IMF IFS, WEFA WMM, BIS, JP Morgan
- Key importance: careful checking and correction of data mistakes

2.1 Categories of fundamentals

1. External Competitiveness
overvalued exchange rate
current account
trade balance
terms of trade
export - import growth

2. External exposure
total external debt
short-term external debt
FDI
portfolio investment
public external debt
total net capital inflows
short-term net capital inflows
forex reserves

3. Domestic real & public sectors
real GDP growth rate
fiscal position
public debt
inflation rate

4. Domestic financial sector
domestic credit to private sector
deposit rate to lending rate
size of M1, M2
equity market performance
bank deposit growth rate
real interest rate

5. Contagion
Contagion cluster
Trade competition
Financial interdependence

3. Methodological approaches of existing EWS models

- EWS models are generally "atheoretical"
- What type of crises do EWS models analyse?
  - Currency crises
  - Banking crises
  - Sovereign debt crises
  - Equity market contractions
- What do EWS attempt to predict?
  - the *timing* of crises
  - the *occurrence* of crises over a time horizon
  - the *vulnerability* of countries to financial crises

3.1 The Indicator Approach

- First developed at the IMF (Kaminsky, Lizondo and Reinhart, KLR, 1997)
- idea: extraction of signals from independent variables to predict crises
- weighting of the signals by independent variables based on each variable's noise-to-signal ratio
- result: encouraging results, but signalling excludes a lot of relevant information

3.2 The Probit/Logit Approach

- Successor of Indicator Approach and today "state-of-the-art" at the IMF, Fed and several investment banks
  - IMF: Berg-Pattillo (DCSD) model (1998,1999)
  - Fed: Kamin-Schindler-Samuel model (2001)
  - Deutsche Bank: DB Alarm Clock-DBAC (2000)
  - JP Morgan: Event Risk Indicator - ERI (1998)
  - CSFB: Emerging Markets Risk Indicator (2000)
  - Morgan Stanley: EWS Thermometer (2001)
  - academic: e.g. Frankel & Rose (1996)

3.3 The Logit model

- We have N countries i={1,2,…N} that we observe during T periods t={1,2,…T}
- For each country and each month we observe the binary variable Y

$$Y = \begin{cases} 1 & with \quad probability \quad \Pr(Y=1) = P \\ 0 & with \quad probability \quad \Pr(Y=0) = 1-P \end{cases}$$

- aim of the model is to estimate the effect of the indicators X on the probability of a crisis P, with γ as the vector of marginal effects:

$$\gamma = \frac{dP}{dX'}$$

3.3 The Logit model

- In the logit model the probability of a crisis is a non-linear function of the indicators X:

$$\Pr(Y=1) = F(X\beta) = \frac{e^{X\beta}}{1+e^{X\beta}}$$

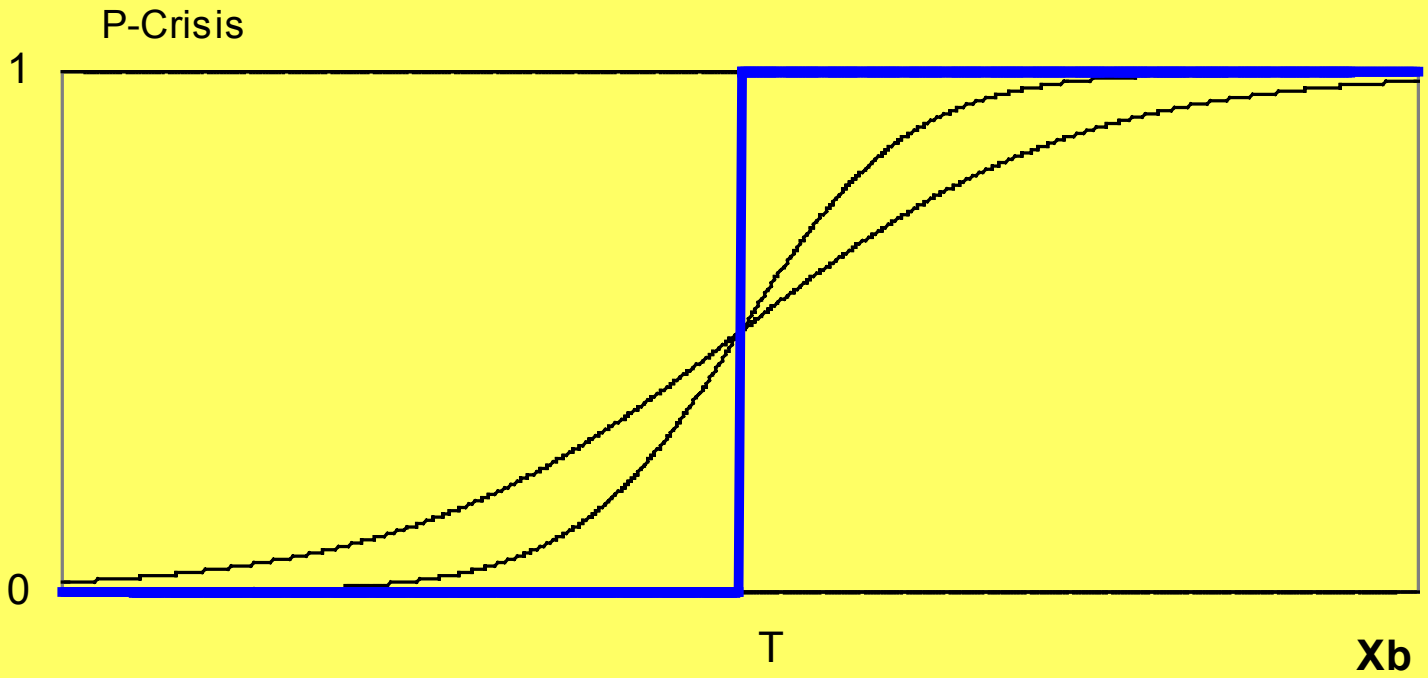
- Effect of the indicators on the odds:

$$\Omega(Y=1 \mid X) = \frac{P}{1-P} = e^{X\beta}$$

- Effect of the indicators on the odds ratio, given two realizations of X, e.g. X_1 and X_0, is:

$$\frac{\Omega(Y=1 \mid X_1)}{\Omega(Y=1 \mid X_0)} = e^{(X_1 - X_2)\beta}$$

The Logit Model



3.4 The Logit approach applied to EWS

- Step 1: Define the binary crisis variable CC:

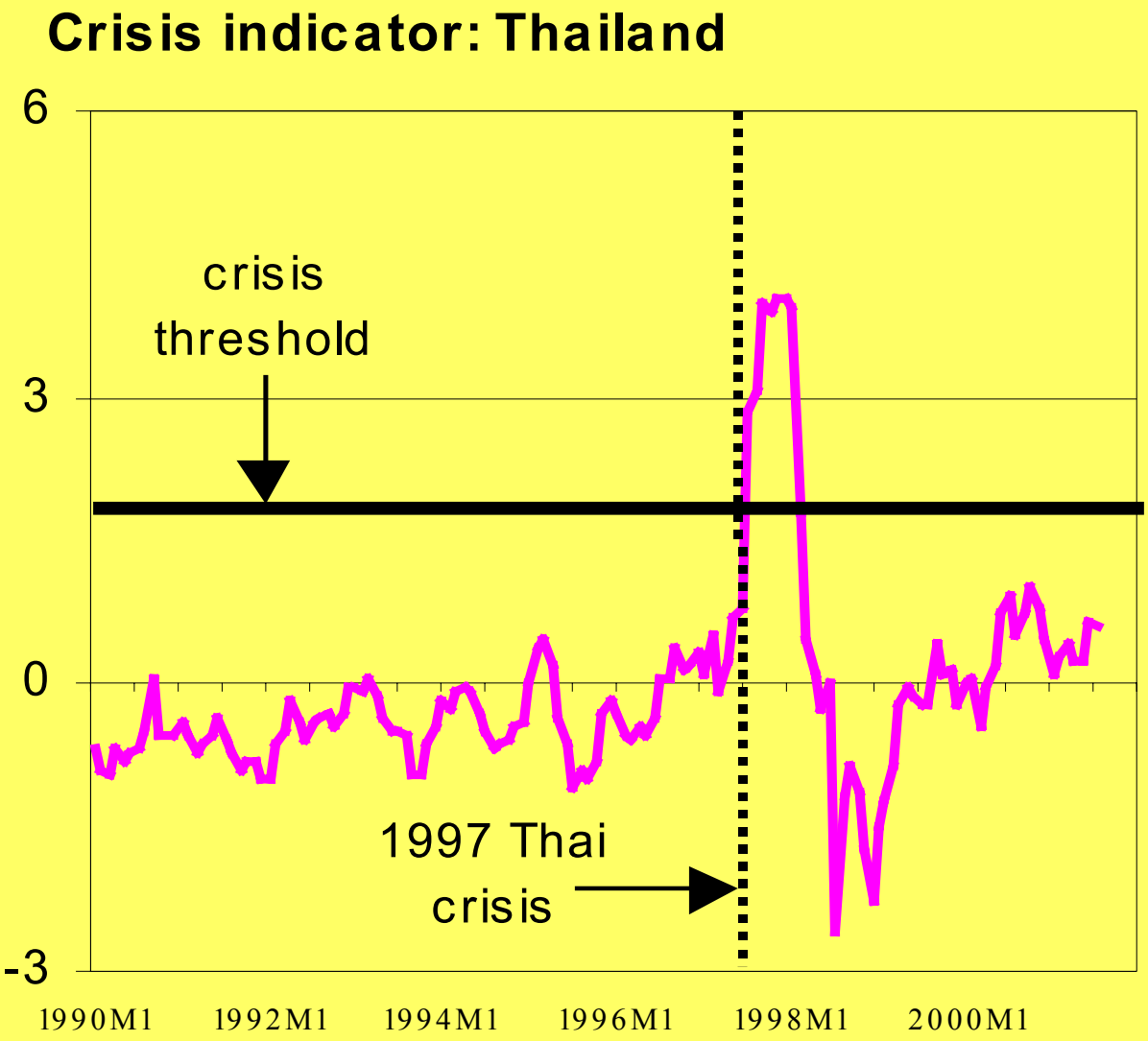
$$CC_{i,t} = \begin{cases} 1 & if \quad EMP_{i,t} > \overline{EMP_i} + 2\ SD(EMP_i) \\ 0 & if \quad otherwise \end{cases}$$

with

$$EMP_{i,t} = \omega_{RER}\left(\frac{RER_t - RER_{t-1}}{RER_{t-1}}\right) + \omega_r(r_t - r_{t-1}) - \omega_{res}\left(\frac{res_t - res_{t-1}}{res_{t-1}}\right)$$

as the weighted average of changes in the real exchange rate *RER*, in the real interest rate *r* and in forex reserves *res*

EMP example for Thailand



3.4 The Logit approach applied to EWS

- Step 2: Obtain a pre-crisis indicator Y for the 12 months prior to the start of a crisis CC

$$Y_{i,t} = \begin{cases} 1 & if \quad any \quad CC_t \mapsto CC_{t+12} = 1 \\ 0 & otherwise \end{cases}$$

- Step 3: Estimate the non-linear effect of variables $X_{i,t-1}$ on the binary crisis variable $Y_{i,t}$

3.4 The Logit approach applied to EWS

- Step 4: Calculate the probability $P_{i,12}$ of a crisis in country *i* in any of the following 12 months

$$\Pr(Y_{i,t} = 1) = F(X_{i,t-1}\beta) = \frac{e^{X_{i,t-1}\beta}}{1 + e^{X_{i,t-1}\beta}}$$

3.4 The Logit approach applied to EWS

- Step 5: Extract a signal $S_{i,t}$ for a crisis if $P_{i,12}$ passes a probability threshold T_i:
  - T_i is chosen exogenously so as to "optimise" the trade-off between Type-1 errors - signalling a non-event if a crisis occurred (missing signal) - and Type-2 errors - signalling a crisis when none occurs (wrong signal)

3.5 The “trade-off” issue

	$S_{i,t} = 0$: No signal was issued	$S_{i,t} = 1$: Signal was issued
$Y_{i,t} = 0$: No crisis within 12 months	A Correct call of non-event	B Type 2 error - Wrong call
$Y_{i,t} = 1$: Crisis within 12 months	C Type 1 error - Missing signal	D Correct call of crisis

3.5 The "trade-off" issue

- The choice of the threshold requires a trade-off between Type-1 and Type-2 errors
- Type-2 errors may generally be less worrisome for a policy-institution (versus e.g. an investment bank):
  - Type-1 errors are more costly from a welfare perspective
  - sending a signal and no crisis occurring may reflect corrective action taken by policy-makers: this is the aim of an Early Warning System!!!

4. Performance of existing EWS models

- The IMF-DCSD model: Goodness-of-fit

	$S_{i,t} = 0$	$S_{i,t} = 1$	total
$Y_{i,t} = 0$	1965	525	2490
$Y_{i,t} = 1$	167	311	478
total	2132	836	2968

% of obs. correctly called:	76.7
% of crises correctly called:	65.1
% of false alarms of total alarms:	62.8
% prob. of crisis given an alarm:	37.2
% prob. of crisis given no alarm:	7.8

4. Performance of existing EWS models

- Overall, the performance is encouraging though many pre-crises periods are missed
- however, modest performance leaves much room for improvement

5. Towards an ECB EWS model

- 32 open EMEs, monthly data for 1992-now
- inclusion of contagion and other relevant variables in the model
- more appropriate econometric technique correcting for the *post-crisis bias*

5.1 What causes currency crises?

- Small set of variables: covering different categories & most significant in estimation:

1. External Competitiveness
overvalued exchange rate
current account / GDP ratio

2. External exposure
short-term debt / reserves

3. Domestic real & public sectors
real GDP growth rate

4. Domestic financial sector
domestic credit to private sector

5. Contagion
Equity market contagion

5.2 Pooled logit model: core 20 country sample

variable	Coef.	Std. Err.	z	P>|z|
Overvaluation	0.163	0.012	13.980	0.000
Lending boom	0.010	0.002	5.310	0.000
S-t debt/reserves	0.003	0.001	2.450	0.014
CA / GDP	-0.046	0.015	-3.060	0.002
Fin. Contagion	0.025	0.014	1.840	0.066
Growth	-0.040	0.019	-2.110	0.034
Const.	-2.789	0.184	-15.200	0.000
# obs	1550			
Pseudo R2	0.307			

5.2 Goodness-of-fit: Pooled logit model

20 country in-sample performance

	$S_{i,t} = 0$	$S_{i,t} = 1$	total
$Y_{i,t} = 0$	1140	164	1304
$Y_{i,t} = 1$	82	164	246
total	1222	328	1550

	ECB	IMF
% of obs. correctly called:	84.1	76.7
% of crises correctly called:	66.7	65.1
% of false alarms of total alarms:	50.0	62.8
% prob. of crisis given an alarm:	50.0	37.2
% prob. of crisis given no alarm:	6.7	7.8

5.2 Summary of results from benchmark logit EWS

- Benchmark model performs much better than IMF-DCSD and other models
- overall performance is promising:
  - 84% of all observations were correctly predicted
  - two thirds of all crisis correctly called
  - in only 6.7% of cases was the signalling of a non-event followed by an actual crisis

5.3 Exploiting panel data properties

- Pooling data ignores between and within information
- Logit with random effects versus logit with fixed effects
- preferred model is random effects logit as it provides a trade-off of within and between information
- the results show some, though limited improvement in performance

5.3 Goodness-of-fit: Random effects logit model

20 country in-sample performance

	$S_{i,t} = 0$	$S_{i,t} = 1$	total
$Y_{i,t} = 0$	1147	157	1304
$Y_{i,t} = 1$	79	167	246
total	1226	324	1550

% of obs. correctly called:	84.8
% of crises correctly called:	67.9
% of false alarms of total alarms:	48.5
% prob. of crisis given an alarm:	51.5
% prob. of crisis given no alarm:	6.4

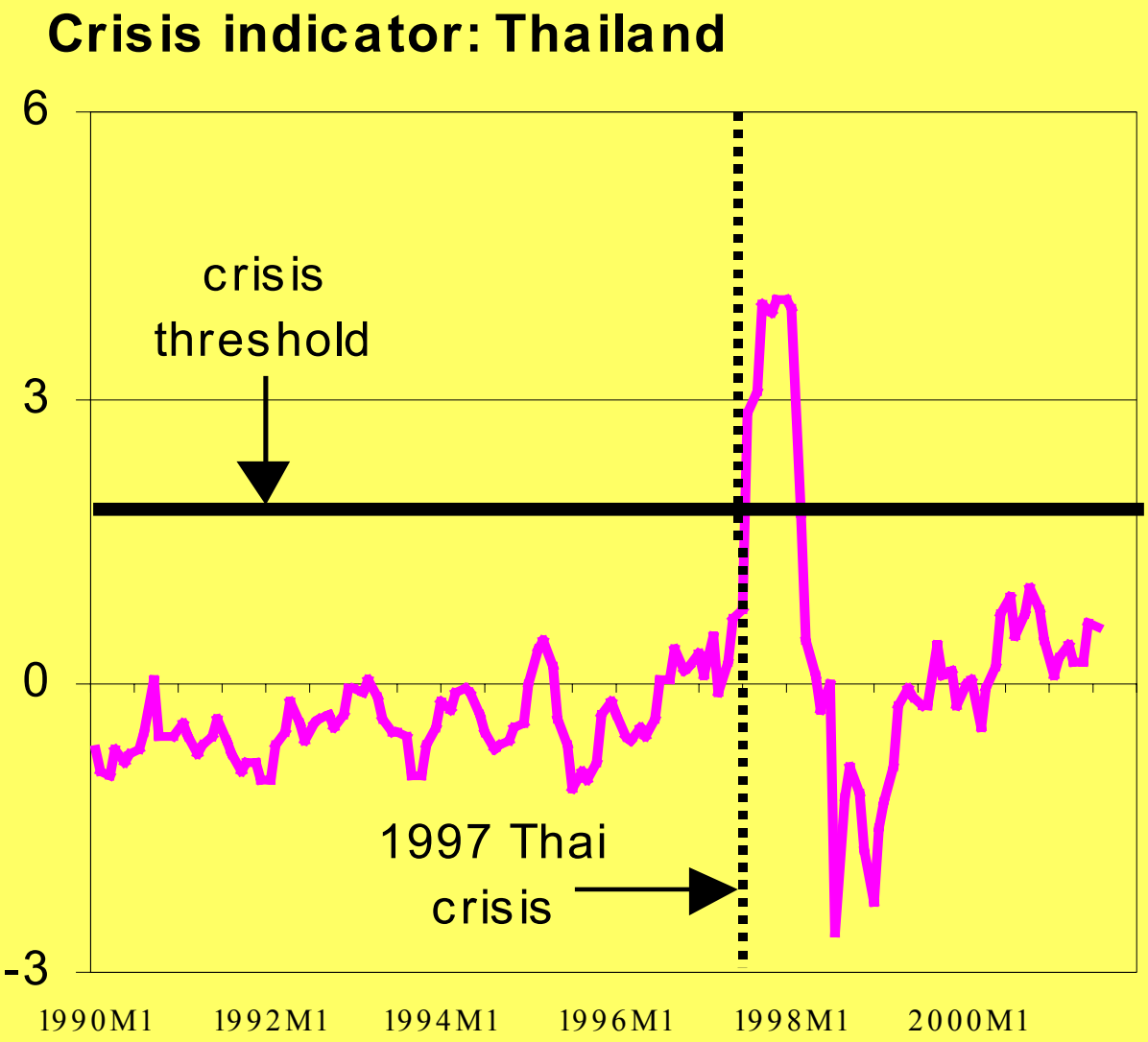
5.3 The post-crisis bias

- Recall that aim is to predict crises, i.e. to extract information and signals *before* a crisis occurs
- key problem is that model results may be driven by data *during* and immediately *after* a crisis, and not by the data before the crisis
- this bias potentially applies to <u>all</u> types of financial stability models including crises

Mean values of key indicators (20-country sample)

	(1) Average, all periods	(2) Average, year Preceding crisis (Y=1)	(3) Average, normal periods (Y=0)	(4) Average, year following crisis (Y=2)	(5) Average, Y=0 or Y=2.
Overvaluation	0.28	10.71	0.38	-7.50	-1.56
Lending Boom	15.24	41.55	8.15	18.38	10.70
S.Term Debt / res.	94.09	118.14	82.94	110.26	89.72
Cur. Account/GDP	-0.06	-2.66	0.37	0.46	0.39
Fin. Contagion	0.38	0.33	-0.01	1.88	0.39
Growth	4.31	3.92	5.95	-0.47	4.38

Post-crisis bias: example of Thailand



5.3 The post-crisis bias

- How to deal with the post-crisis bias :
  - drop observations during/directly after a crisis
  - multinomial logit

5.4 Multinomial Logit (MLogit) model

- MLogit allows for more than two possible states of $Y_{i,t}$:

$$Y_{i,t} = \begin{cases} 1 & if \quad any \quad CC^1_{t+1} \mapsto CC^1_{t+12} = 1 \\ 2 & if \quad any \quad CC^1_t \mapsto CC^1_{t-12} = 1 \\ 0 & otherwise \end{cases}$$

- Results show substantial improvement in predictive power of model

5.4 Multinomial logit model: core 20 country sample

variable	Coef.	Std. Err.	z	P>|z|
	pre-crisis period $Y_{i,t} = 1$			
Overvaluation	0.161	0.013	12.870	0.000
Lending boom	0.013	0.002	6.300	0.000
S-t debt/reserves	0.004	0.001	3.610	0.000
CA / GDP	-0.055	0.017	-3.220	0.001
Fin. Contagion	0.039	0.015	2.560	0.011
Growth	-0.060	0.023	-2.620	0.009
Const.	-2.866	0.215	-13.330	0.000
	post-crisis period $Y_{i,t} = 2$			
Overvaluation	-0.078	0.010	-8.230	0.000
Lending boom	0.010	0.002	4.620	0.000
S-t debt/reserves	0.004	0.001	4.210	0.000
CA / GDP	0.018	0.010	1.740	0.083
Fin. Contagion	0.052	0.012	4.430	0.000
Growth	-0.235	0.018	-13.010	0.000
Const.	-1.183	0.135	-8.760	0.000
# obs	1549			
Pseudo R2	0.333			

Note: Tranquil period $Y_{i,t} = 0$ is the comparison group.

5.4 Goodness-of-fit: Multinomial logit model

20 country in-sample performance, T=20

	$S_{i,t} = 0$	$S_{i,t} = 1$	total
$Y_{i,t} = 0$	853	135	988
$Y_{i,t} = 1$	61	171	232
$Y_{i,t} = 2$	297	32	329
total	1180	369	1549

	Mlogit ECB	**logit ECB**	**logit IMF**
% of obs. correctly called:	83.9	84.1	76.7
% of crises correctly called:	73.7	66.7	65.1
% of false alarms of total alarms:	44.1	50.0	62.8
% prob. of crisis given an alarm:	55.9	50.0	37.2
% prob. of crisis given no alarm:	6.7	6.7	7.8

5.4 Goodness-of-fit: Multinomial logit model

20 country in-sample performance

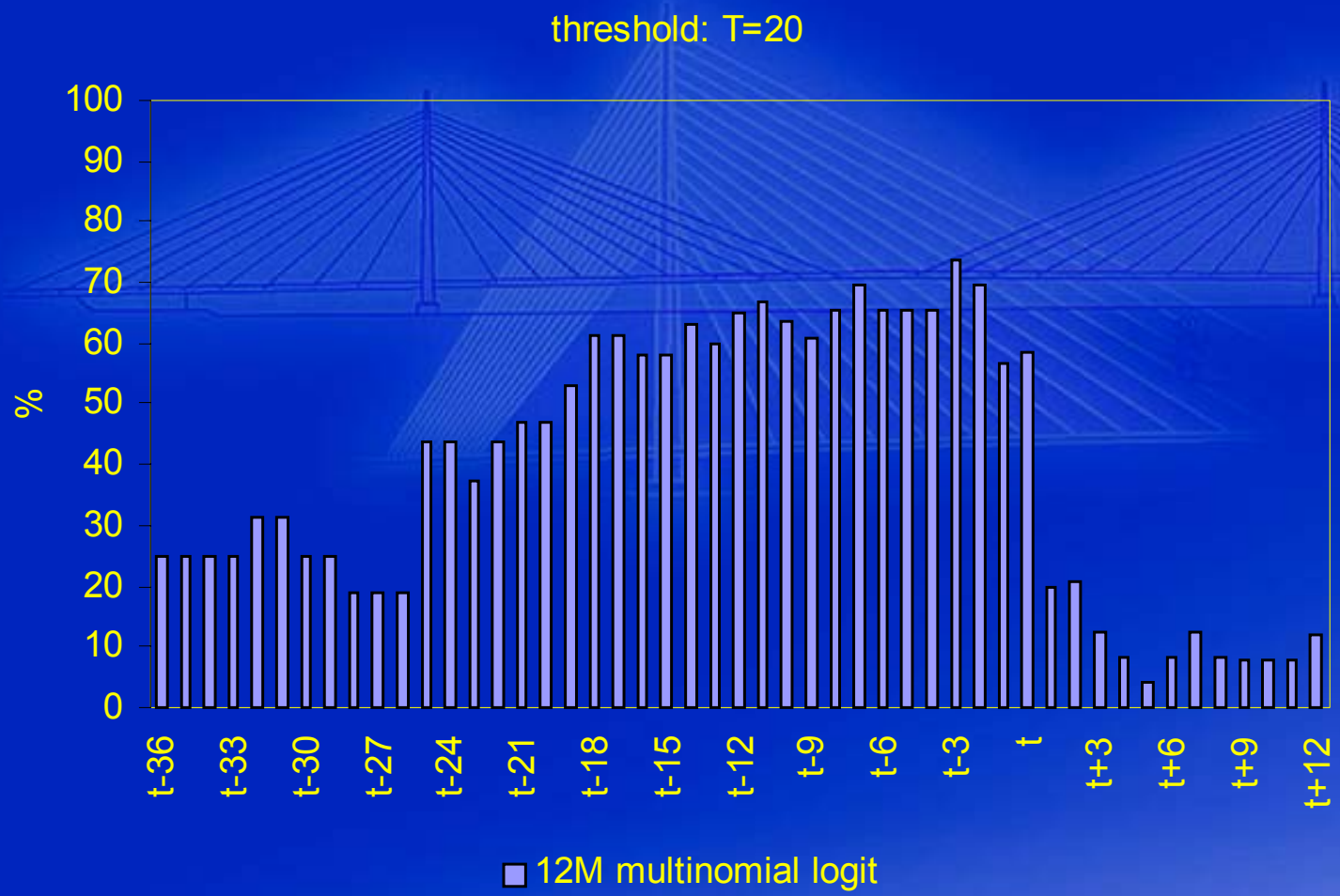
	$S_{i,t} = 0$	$S_{i,t} = 1$	$S_{i,t} = 2$	total
$Y_{i,t} = 0$	819	133	36	988
$Y_{i,t} = 1$	61	170	1	232
$Y_{i,t} = 2$	140	32	157	329
total	1020	335	194	1549

% of obs. correctly called:	74.0
% of crises correctly called:	73.3
% of false alarms of total alarms:	49.3
% prob. of crisis given an alarm:	50.7
% prob. of crisis given no alarm:	6.0

5.5 An "intuitive" goodness-of-fit analysis:

- "missing" a pre-crisis period does not necessarily mean missing a crisis
- in fact, the Mlogit sent no signal at all only in the case of the Singapore 1998 crisis and the Pakistan 1996
- for almost all other crises the model sent at least 6 signals in the 12 months prior to the onset of a crisis

Signal distribution, T=12



Signal distribution, T=24

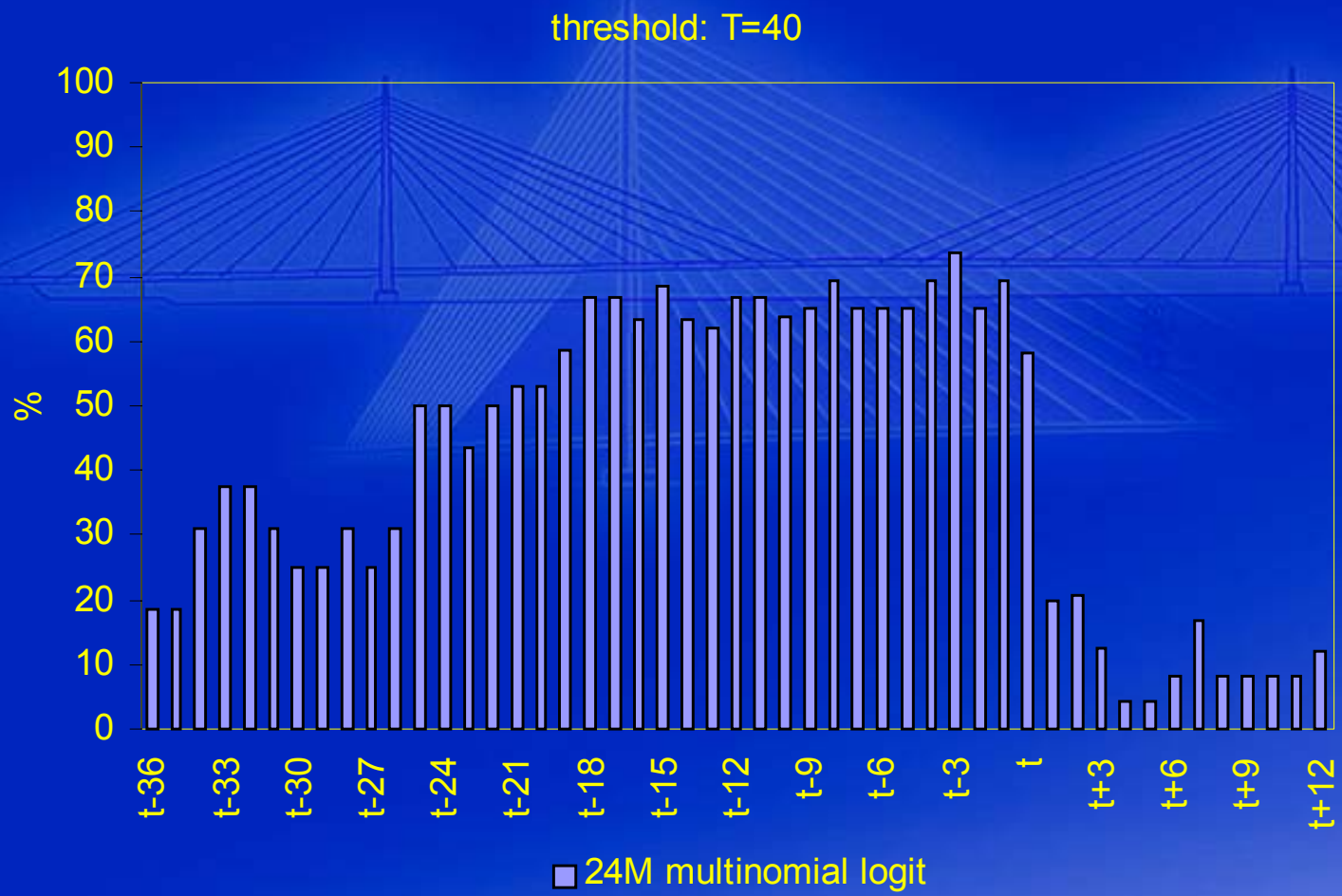


Chart 4 : Argentina

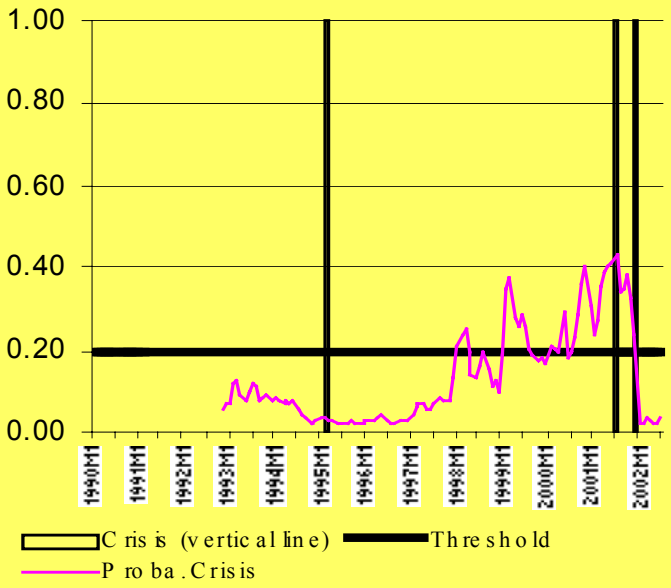


Chart 5 : Brazil

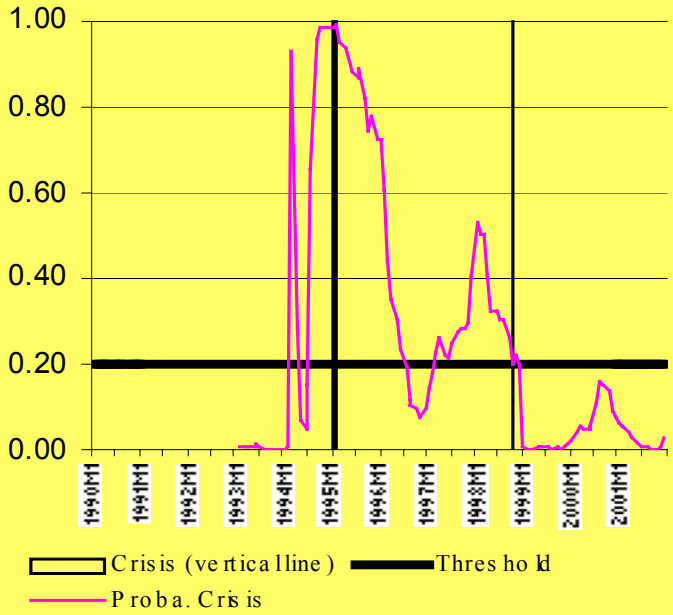


Chart 6 : Mexico

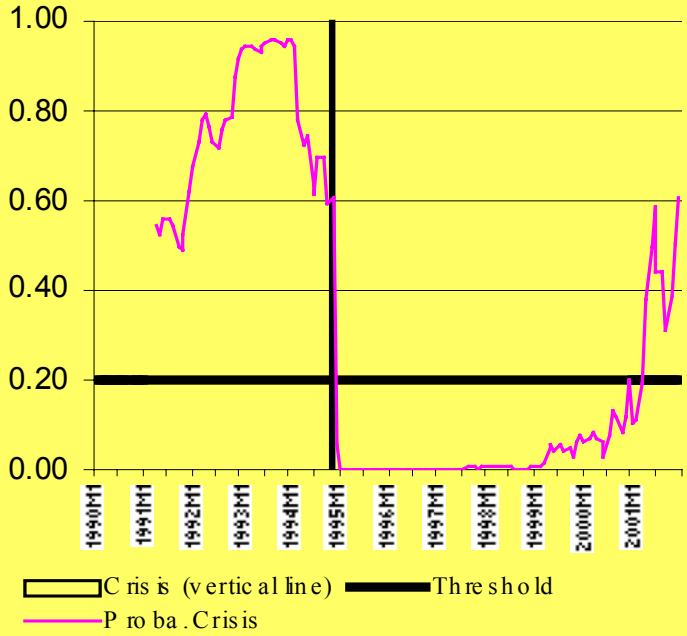


Chart: Venezuela

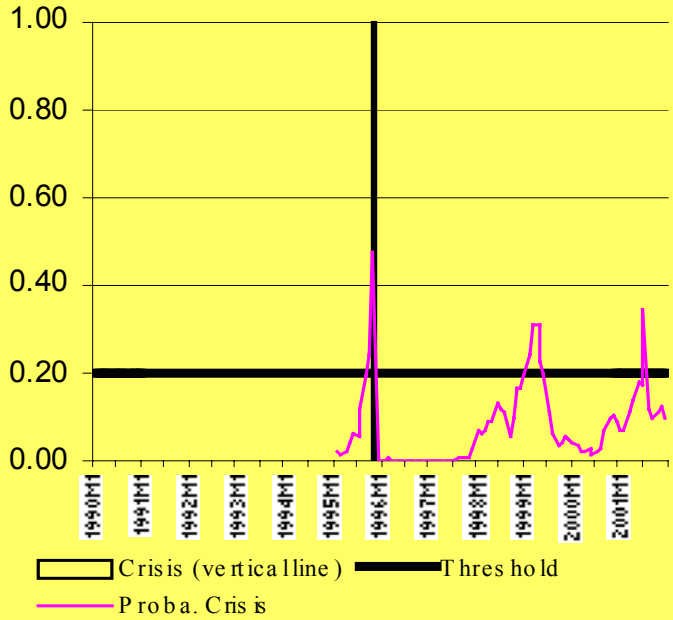


Chart: Turkey

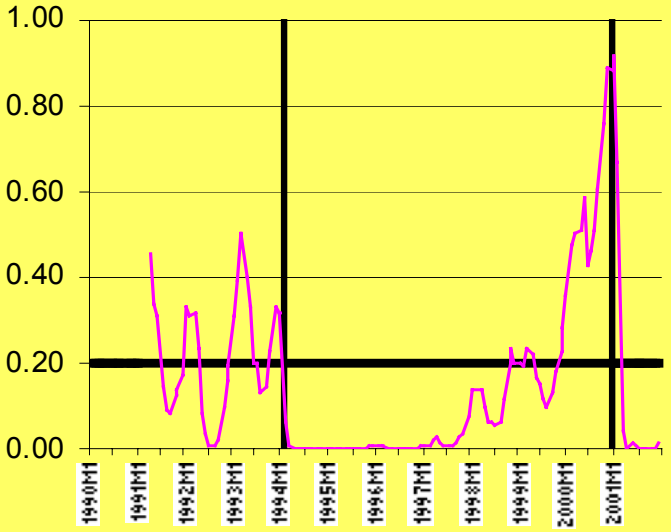


Chart: Russia

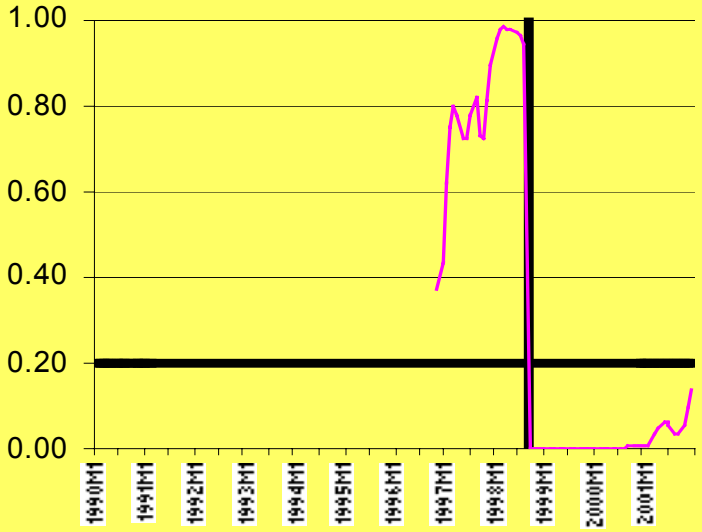


Chart: Poland

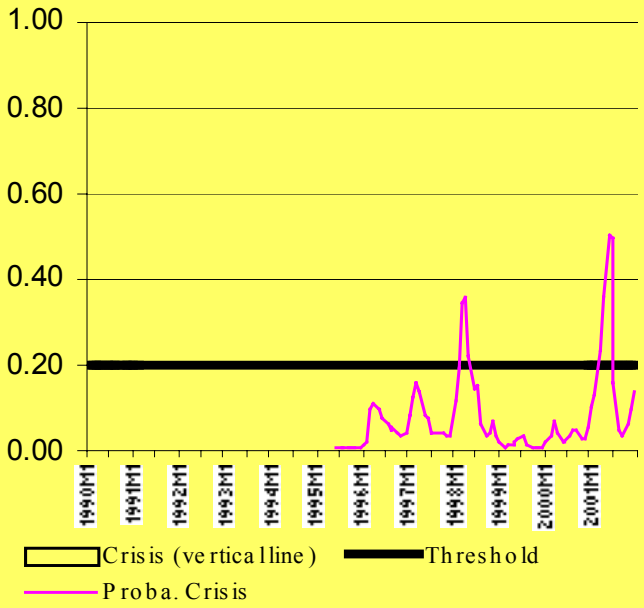


Chart: Czech Rep.

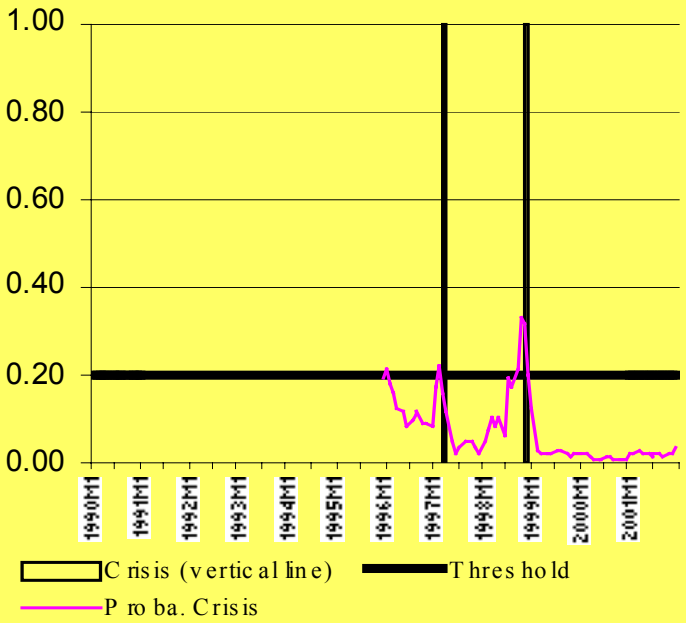


Chart: Thailand

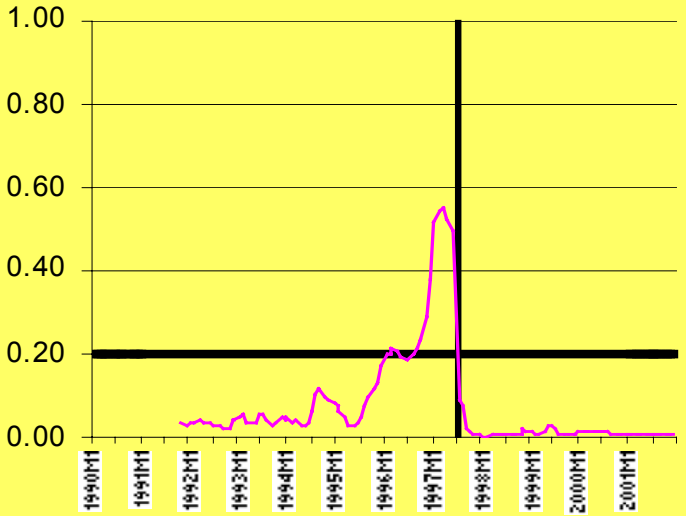


Chart: Indonesia

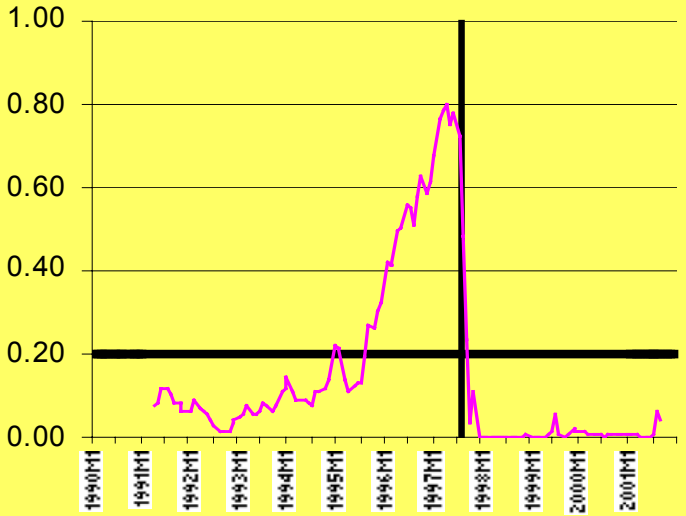


Chart: Malaysia

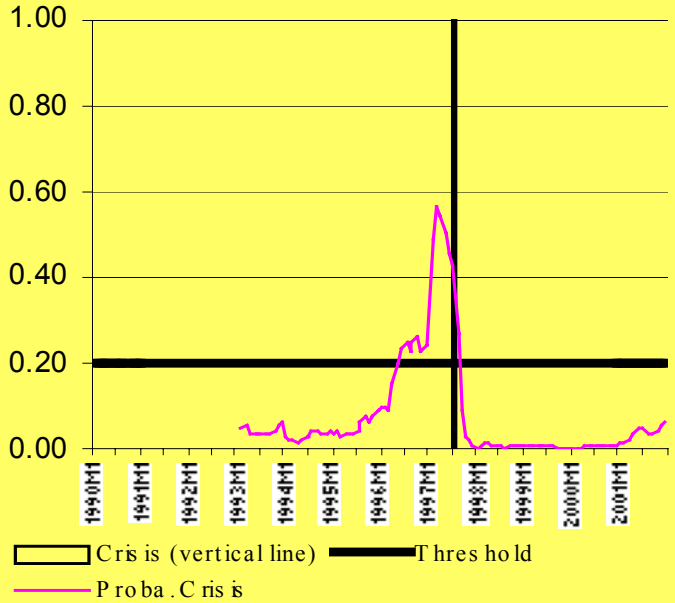
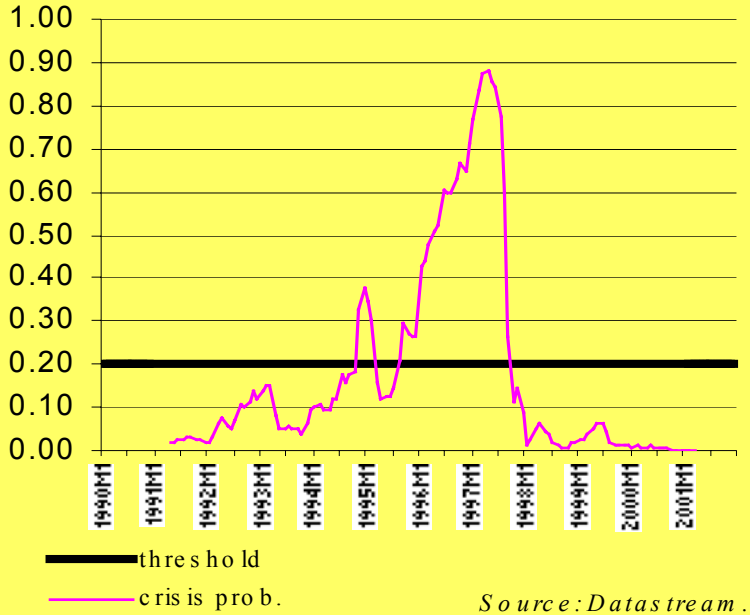


Chart: Philippines



Source: Datastream.

Chart: Korea

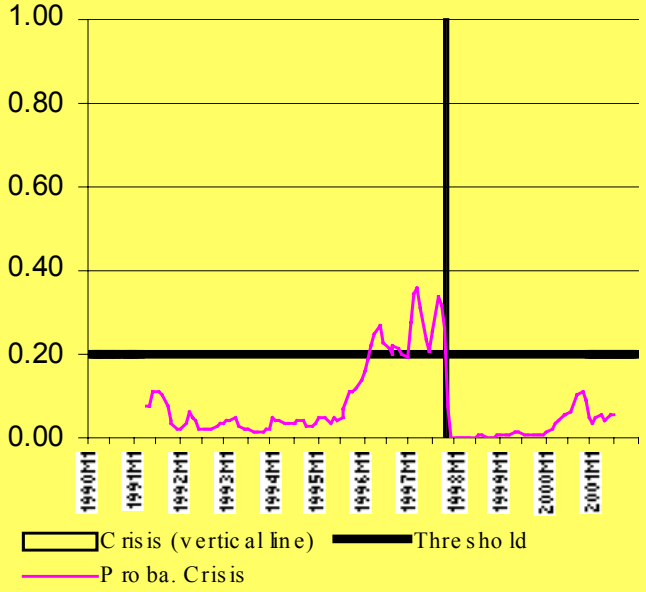
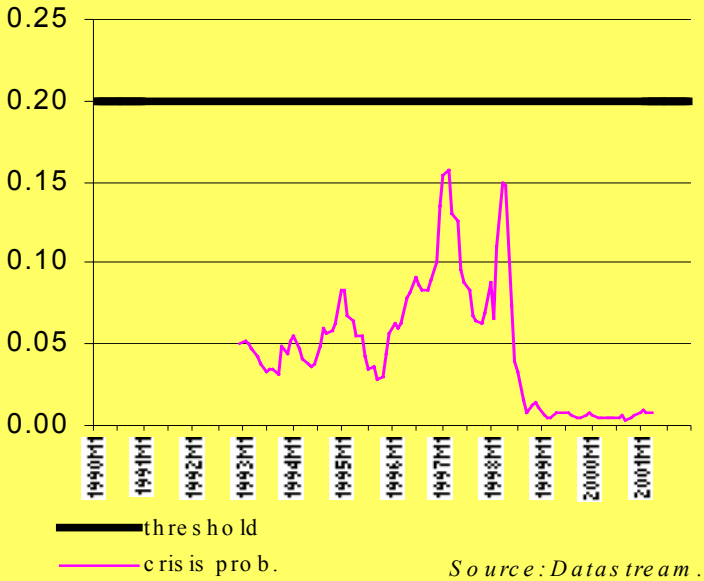


Chart: Singapore



Source: Datastream.

Chart: Hong Kong

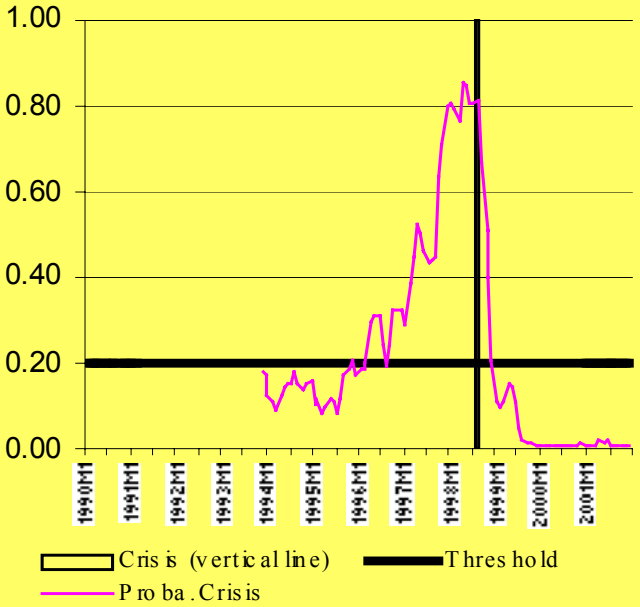
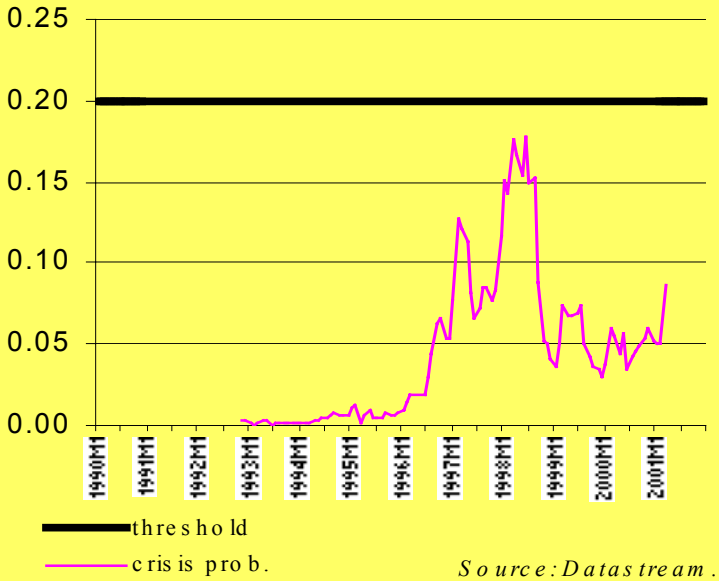


Chart: China



Source: Datastream.

6. Out-of-sample performance: the 1997 crises

	Crisis Countries	Crisis Prob	Non Crisis Countries	Crisis Prob
HIT	Colombia (98M9)	0.69	Argentina	0.04
	Indonesia (97M8)	0.46	Brazil	0.12
	Malaysia (97M7)	0.31	Chile	0.11
	Philippines (97M10)	0.69	China	0.09
	Russia (98M9)	0.31	Czech Rep.	0.14
	Taiwan (97M10)	0.21	Hungary	0.06
	Thailand (97M7))	0.33	Mexico	0.03
			Poland	0.12
			Turkey	0.01
MISS	Hong Kong (98M8)	0.15		
	Korea (97M11)	0.16		
	Singapore (97M10)	0.16		

6. Out-of-sample performance: the 1997 crises

- Predicting the Asian crisis:
  - results show that the crisis was correctly signalled for most Asian countries
  - the three missed crises occurred in Singapore, Hong Kong and Korea
  - these three countries had relatively sounder fundamentals than their neighbours and their predicted probabilities were close to the signalling threshold of 20%

6. Out-of-sample performance: the 1998 crises

	Crisis Countries	Crisis Prob	Non Crisis Countries	Crisis Prob
HIT	Brazil (98M10)	0.36	Argentina	0.15
	Chile (98M9)	0.37	Czech Republic	0.03
	Colombia (98M9)	0.42	China	0.19
	Hong Kong (98M8)	0.71	Hungary	0.04
	Russia (98M9)	0.88	Indonesia	0.01
			Korea	0.02
			Malaysia	0.03
			Mexico	0.04
			Philippines	0.12
			Poland	0.12
			Singapore	0.18
			Thailand	0.02
			Turkey	0.16
			Venezuela	0.11
MISS			Taiwan	0.26

6. Out-of-sample performance: the 1998 crises

- Predicting the Russian and Brazilian crises:
  - results show that the crisis was correctly signalled for Russia and Brazil, and also for Colombia, Hong Kong and Chile
  - the model missed the Taiwanese crisis, though this event was relatively minor
  - no crisis was missed

8. Issues:"the Lucas Critique"

- If policy makers were to draw the lessons from the model, this could undermine its relevance as a forecasting tool but:
- 1/ policy-makers only partially control the variables in the model
- 2/ policy-makers face their own constraints (political economy)
- 3/ this issue was already present in past crisis episodes
- The model can be periodically updated and potential structural changes tested

8. Issues: applicability to G7 countries

- The variables used in the model cannot be directly transferred to analyse weaknesses of the G7 countries due to:
  - 1/ the international role of the euro, the dollar and the yen
  - 2/ the size of the G7 economies relative to capital inflows
  - 3/ better banking supervision in developed economies
  - 4/ debt is mostly denominated in domestic currency

9. Conclusions and scope for future analytical work

- Presented Logit/Mlogit model performs favourable in comparison to existing models
- EWS model should be a valuable "objective" complement to "subjective" policy-makers judgement
- model may provide a promising step towards a comprehensive EWS of predicting EME crises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