Early Warning Systems: Theory and Practice

CARIBBEAN CENTRE FOR MONEY AND FINANCE

ASSESSING MACRO-PRUDENTIAL VULNERABILITIES AND POLICYFRAMEWORKS IN A REGIONAL CONTEXT

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Introduction

- Recent sub-prime crisis has renewed policy makers' interest in crisis prediction models
- Previous research into Early Warning Systems (Kaminsky and Reinhart, 1999 and Demirguc-Kunt and Detragiache,1998) has since been refined further by Barrell et al (2010, 2013).
- I will review our latest crisis prediction model alongside brief reviews of alternative techniques for macroprudential surveillance that are used by policymakers and IFIs.

Outline:

- Early Warning Systems (EWS):

(i) Signal Extraction
(ii) Binary Recursive Tree (BRT)
(iii) Logit Models

- Variables to be watched

- Evaluation using Macro Models

Traditional EWS Design

- A set of models have been explicitly used to predict systemic banking problems: logit, SE and BRT
- Such estimators have become popular because:

(i) Computationally easy

(ii) Intuitive to interpret

(iii) Utilise aggregate data

- SE is the easiest to execute and interpret followed by logit, followed by BRT
- Given our extensive research into logit EWS we focus on these but will outline the SE and BRT methodologies first.

Signal Extraction

- non-parametric approach which assesses the behaviour of single variables prior to and during crisis episodes.
- Logic: if aberrant behaviour of a variable can be quantitatively defined then whenever that variable moves from tranquil to abnormal activity, crisis is forewarned
- Note it is essentially a univariate approach (can create composites, see Borio and Lowe, 2002)

Signal Extraction contd.

- Let , i = a univariate indicator, j = a particular country, S= signal variable, X = potential financial stress variable
- An indicator variable relating to indicator i and country j is denoted by Xij and the threshold for this indicator is denoted as X*ij
- Let signal variable relating to indicator i and country j is denoted by: S ij
- This is a binary variable where S ij = {0,1}
- If the variable crosses the threshold, a signal is emitted and S ij = 1

$$\{ S_{ij} = 1 \} = \{ \mid X_{ij} \mid > \mid X^*_{ij} \mid \} \text{ ....(1)}$$

Signal Extraction contd.

- If the indicator remains within its threshold boundary, it behaves normally and does not issue a signal so $S\ ij = 0$

$$\{ S\ ij = 0 \} = \{ \mid Xij \mid < \mid X^{*}ij \mid \} \ldots\ldots\ldots\ldots (2)$$

- for a time series of t observations for country j and indicator i we can obtain a binary time series of signal or no-signal observations
- Note this time series will change as we vary the threshold ($X^{*}ij$)
- For the risk averse PM (low $X^{*}ij$) signals will be issued often (and vice versa)

Signal Extraction contd.

- Check this series against a banking crisis dummy to assess in sample performance (require min NTSR)

$$NTSR = \frac{\dfrac{B}{B+D}}{\dfrac{A}{A+C}} = \frac{Type\ II}{1 - Type\ I}$$

	CRISIS	NO CRISIS
SIGNAL	A	B
NO SIGNAL	C	D

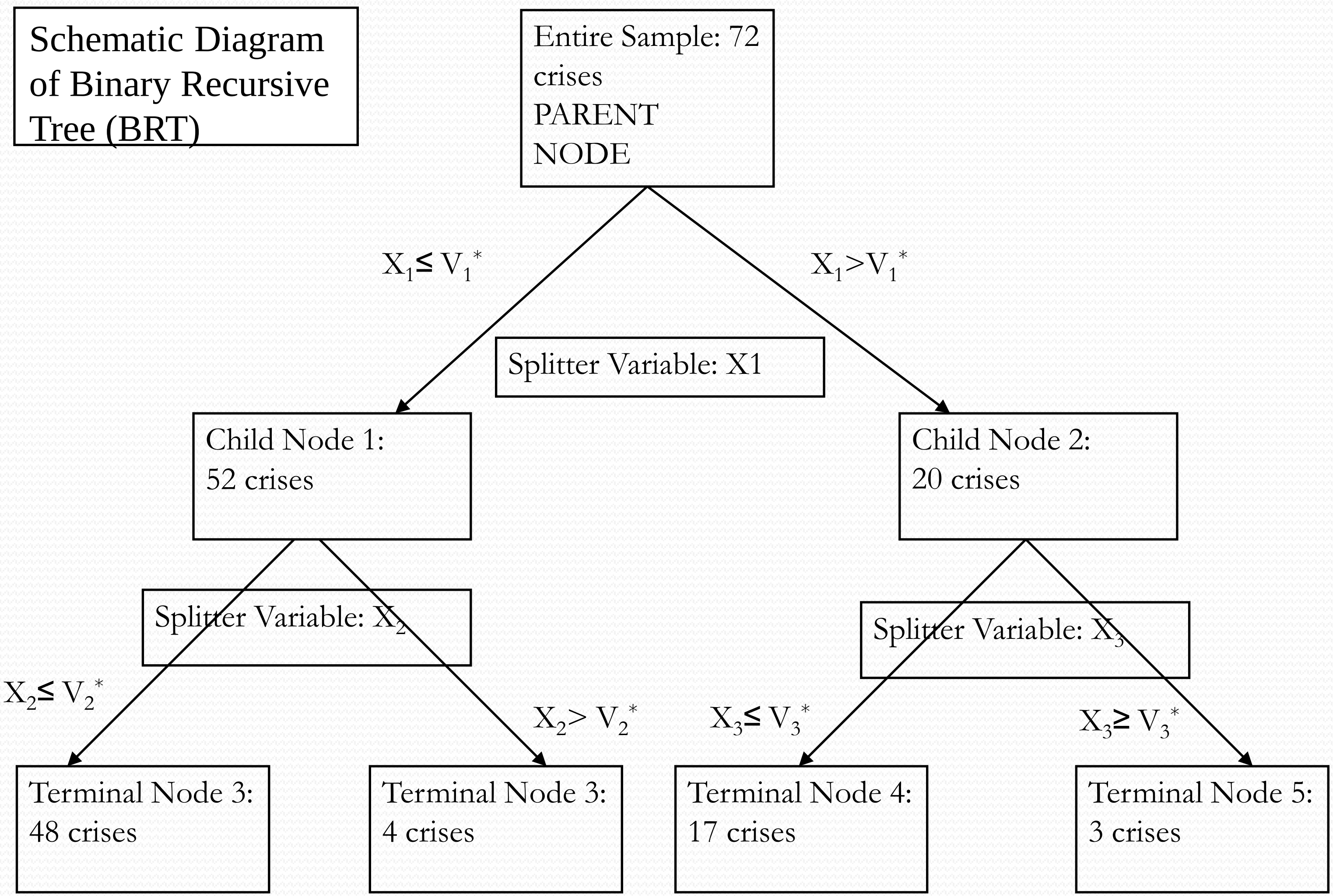
Type II error

Type I error

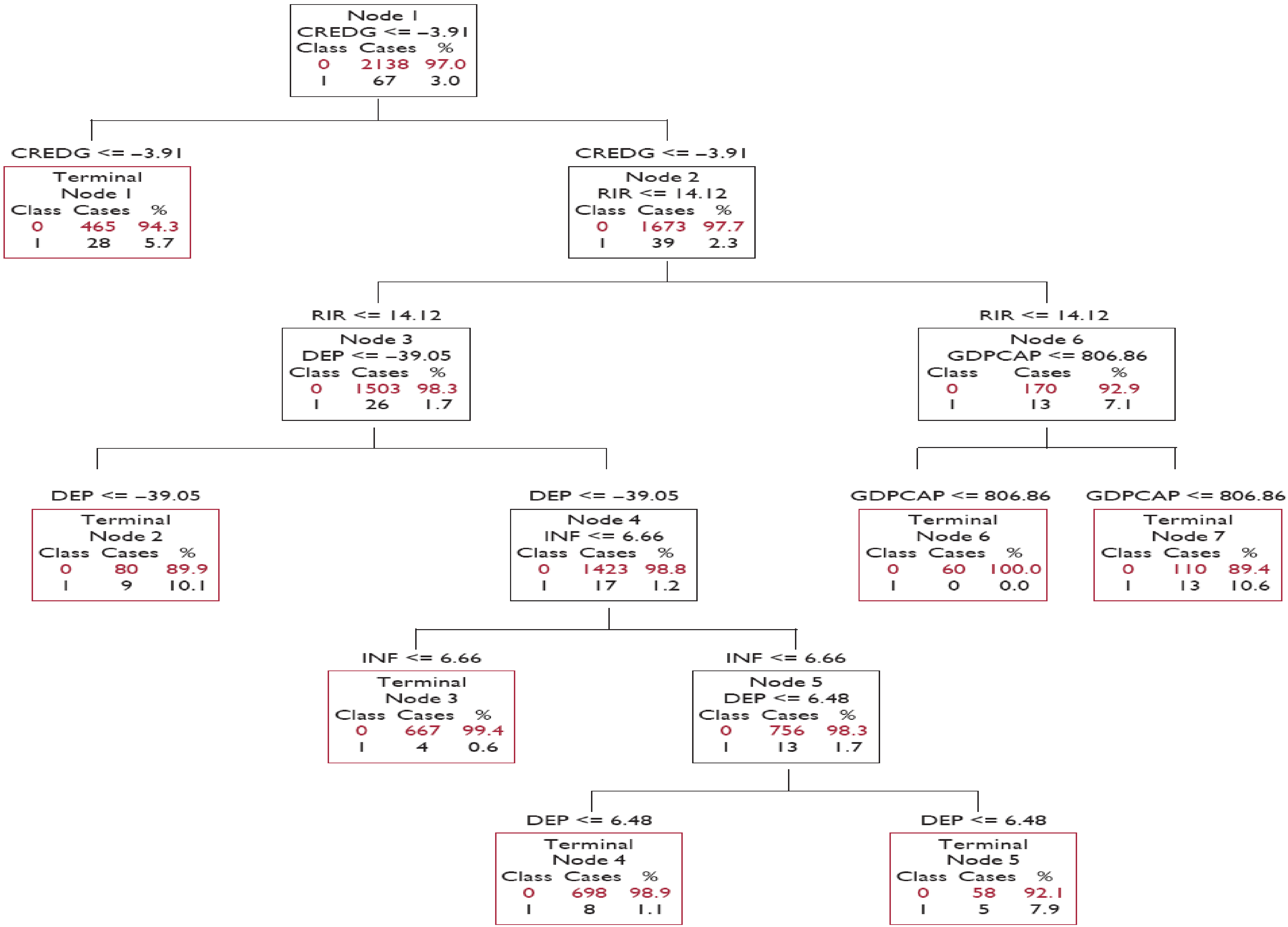
Binary Recursive Tree (BRT)

- Duttagupta and Cashin (2008) – banking crises
- Ghosh and Ghosh (2002) - currency crises
- Roubini et al. (2003) – sovereign debt crises
- Davis, Karim and Liadze (2011) – LA vs. Asia
- The BRT process analyses a set of variables to reveal a particular value of the explanatory variable that best explains crises.
- Once this primary splitter is identified, BRT ranks the next best explanatory variable and so on.
- No underlying distributions need be satisfied: non-parametric
- In successively splitting the data BRT constructs a “tree”.

BRT contd



Schematic Diagram of Binary Recursive Tree (BRT)
Entire Sample: 72 crises
PARENT NODE
$X_1 \leq V_1^*$
$X_1 > V_1^*$
Splitter Variable: X1
Child Node 1:
52 crises
Child Node 2:
20 crises
Splitter Variable: X_2
Splitter Variable: X_3
$X_2 \leq V_2^*$
$X_2 > V_2^*$
$X_3 \leq V_3^*$
$X_3 \geq V_3^*$
Terminal Node 3:
48 crises
Terminal Node 3:
4 crises
Terminal Node 4:
17 crises
Terminal Node 5:
3 crises



Node 1
CREDG <= –3.91
Class Cases %
0 2138 97.0
1 67 3.0
CREDG <= –3.91
Terminal Node 1
Class Cases %
0 465 94.3
1 28 5.7
CREDG <= –3.91
Node 2
RIR <= 14.12
Class Cases %
0 1673 97.7
1 39 2.3
RIR <= 14.12
Node 3
DEP <= –39.05
Class Cases %
0 1503 98.3
1 26 1.7
RIR <= 14.12
Node 6
GDPCAP <= 806.86
Class Cases %
0 170 92.9
1 13 7.1
DEP <= –39.05
Terminal Node 2
Class Cases %
0 80 89.9
1 9 10.1
DEP <= –39.05
Node 4
INF <= 6.66
Class Cases %
0 1423 98.8
1 17 1.2
GDPCAP <= 806.86
Terminal Node 6
Class Cases %
0 60 100.0
1 0 0.0
GDPCAP <= 806.86
Terminal Node 7
Class Cases %
0 110 89.4
1 13 10.6
INF <= 6.66
Terminal Node 3
Class Cases %
0 667 99.4
1 4 0.6
INF <= 6.66
Node 5
DEP <= 6.48
Class Cases %
0 756 98.3
1 13 1.7
DEP <= 6.48
Terminal Node 4
Class Cases %
0 698 98.9
1 8 1.1
DEP <= 6.48
Terminal Node 5
Class Cases %
0 58 92.1
1 5 7.9

Advantages of BRT

- Able to detect non-linear variable interactions
- Able to identify explanatory variable effect conditional on other variables' behaviour
- Can identify threshold effects
- Does not assume any specific variable distributions within countries or across countries

Logit EWS

- The multivariate logit estimator relates the likelihood of banking crisis occurrence to a vector of explanatory variables:
- Probability that the banking dummy takes a value of one (crisis occurs) at time t is given by the value of the logistic cumulative distribution evaluated for the data and parameters at time t:

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

Evolution of Logit EWS: D&D(1998) to Barrell et al (2010)

- Seminal work by Demirguc-Kunt and Detragiache (1998): 65 countries; 31 crises; 1980 – 94.
- However used a heterogeneous mix of developed and developing economies and thus banking systems
- Used mix of macro + financial variables; no bank specific variables.
- Used contemporaneous variables, $\therefore$ not true EWS

Evolution of Logit EWS: D&D(1998) to Barrell et al (2010) contd

- Davis, Karim and Liadze (2010): used updated DD(98) + current account + short term debt on 14 Latin American and 6 Asian economies; 1980-2008

Box 1: List of Variables (with variable key)	
Variables used in previous studies: Demirguc-Kunt and Detragiache (2005); Davis and Karim (2008a).	1. Real GDP Growth (%) (YG)
	2. Real Interest Rate (%) (RIR)
	3. Inflation (%) (INFL)
	4. Fiscal Surplus/ GDP (%) (BB)
	5. M2/ Foreign Exchange Reserves (%) (M2RES)
	6. Real Domestic Credit Growth (%) (DCG)
	7. Real GDP per capita (GCAP)
	8. Domestic credit/GDP (%)
	9. Depreciation (%) (DEP)
	10. Change in Terms of Trade (%) (TOT)

Evolution of Logit EWS: D&D(1998) to Barrell et al (2010) contd

- Findings: heterogeneous countries should NOT be pooled: crisis determinants differ by region

Crisis Determinants by Region	Pooled	Asia	Latin America
Real GDP Growth	✓	✓	✓
Real Interest Rate			
Inflation			
Fiscal Surplus/ GDP			
M2/ Foreign Exchange Reserves		✓	
Real Domestic Credit Growth	✓	✓	
Real GDP per capita	✓	✓	✓
Domestic credit/GDP		✓	
Depreciation		✓	
Terms of Trade		✓	
**Current account/GDP			
**External short term debt/ GDP			

Evolution of Logit EWS: D&D(1998) to Barrell et al (2010) contd

- Barrell et al (2010 a,b): all logit models based on 14 OECD economies:
  Belgium, Canada, Denmark, Finland, France, Germany , Italy, Japan, Netherlands, Norway, Sweden, Spain, UK and the US; 1980-2007; 14 crises
- Barrell et al (2010a)
- Barrell et al (2010b)

Evolution of Logit EWS: D&D(1998) to Barrell et al (2010) contd

- Given the difference in crisis determinants across regions.....

❖ Barrell et al (2010a)

- Tested OECD banking crisis determinants: traditional DD(98) variables + new additions: capital adequacy, liquidity, real property price growth
- Result: Traditional variables drop out! → only the new additions remain → capital adequacy, liquidity, real property price growth are main OECD crisis determinants

Evolution of Logit EWS: Variables to be Watched

- Barrell et al (2010b)
- Re-estimated 2010a model but added variable that was associated with sub-prime: current account deficit (% of GDP)
- Final 2010b specification:

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

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

Evolution of Logit EWS: Variables to be Watched contd

- 2010b specification out-of-sample performance:

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

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

Conclusion

- Alternative ways to construct EWSs but practical considerations should dominate choice:

(i) computational ease: how easy is it to re-estimate on a rolling bases; changing/ new desk officers need to be able to replicate

(ii) data availability

(iii) out-of-sample performance

- Also need to consider invertability of estimator for practical policy use: once variable impacts are known can we work backwards to deduce necessary regulatory adjustments?
- Beneficial to have confidence intervals for the above: non-parametric signal extraction and BRT do not provide this
- Therefore ideal approach would use a mix of estimators
- However Barrell et al (2010b) is most parsimonious, robust and effective OECD crisis predictor.
- If resource constraints, then this approach can be used as a starting point for desk officers wishing to develop EWS further