

EWS Models in Practice

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Financial Vulnerabilities*

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Structure of the presentation

- Part I: EWS models: why do we need them and what are they?
- Part II: Macro-based EWS models
- Part III: Market-based EWS models
- Part IV: Balance-sheet based risk analysis
- Part V: interpretation of EWS results and caveats

Part I

- Why EWS models?
- Main users of EWS models
- Essential elements of EWS models
- Major types of EWS models

Why EWS models?

- Macroeconomic crises are frequent and costly

Table 2. Output loss from crises (in percent of GDP)

All Crises	1880-1914	1919-1939	1945-1971	1973-1997
All Countries	9.76	13.42	5.24	8.29
Industrial Countries	7.68	12.29	2.39	6.25
Emerging Markets	10.37	16.46	8.6	9.21

Source: Bordo and Eichengreen (2002).

Why EWS Models?

- Frequency of currency crises and banking crises

Table 1. Crisis Frequency

Years	Banking Crises	Currency Crises	Twin Crises	All Crises
1880-1914	2.3	1.23	1.38	4.9
1919-1939	4.84	4.30	4.03	13.17
1945-1971	0	6.85	0.19	7.04
1973-1997	2.29	7.48	2.38	12.15

Source: Bordo and Eichengreen (2002).

Institutions use EWS models

- Private sector (different horizon and definition)

- Goldman Sachs GS-watch
- CSFB EMRI
- Deutsche Bank Alarm Clock

- Public sector

- BIS
- Federal reserve Board of Governors
- ASEAN
- ADB
- ECB

What causes crises?

- Different crises, different determinants?
 - Disequilibria in the trade account or capital account
 - Private sector imbalance or public sector deficit
 - Real shock or financial shock
- “first-generation” and “second generation” of crises models
 - 1st generation: macroeconomic imbalances
 - 2nd generation: self-fulfilling speculative attacks, contagion, and weakness in domestic financial markets
- The need to identify common symptoms and robust models

Theoretical Currency Crisis models

- First-generation crisis models
 - Krugman (1979)-Flood-Garber (1984) model: macroeconomic policies inconsistent with pegged exchange rate (suggested factors: fiscal deficit/GDP, M2 growth)
 - Extended model: introduce traded and non-traded goods and terms of trade change (suggest factors: current account balance, real exchange rate changes)

Theoretical Currency Crisis models

- Second generation models
 - Obstfeld's (1986) self-fulfilling multiple equilibria model
 - Loose relation between fundamentals and crisis and possibility for contagion
 - Modified version (Morris and Shin 1998) assumes information discrepancies between agents → (nonlinear) relation between fundamentals and crisis

Theoretical Currency Crisis models

- Third generation models
 - Krugman (1998): moral hazard (due to implicit guarantee) lead to excessive borrowing → asset prices could be useful indicators of crisis
 - Chang and Velasco (2001): illiquidity resulting from bank-run (cut of credit line), weak fundamentals, excessive foreign borrowing → crisis →
 - Suggest factors: short-term external debt in the banking system, bank profitability

EWS models at the IMF

- Mexican (1994-1995) and Asian Crises (1997)
- Macro-based indicators of currency crises
 - KLR
 - DCSD
- Market-based models
 - Implied PDF
 - Balance-sheet based vulnerability indicators

Elements of an EWS model

- Objective
- Definition of a crisis
- Contributing factors
- Methodology
- Model evaluation: in-sample and out-of-sample
- Interpretation of model results

Objectives

- What type of crisis?
 - Currency crisis:
 - Banking crisis:
 - Debt crisis:

Objectives

- Share similar factors but also important differences
 - Currency crises more often
 - A large portion of the debt crisis happened with or close to the currency crisis
 - Banking crisis is hard to identify and tend to protract thus has larger macroeconomic impact
 - Banking crisis also tends to occur with or right after a currency crisis

Crisis definition

- A large variation in the way “crisis” is defined in the literature
- Binary crisis variable:
- Continuous pressure index:

Methodology

- Event study: analyze a particular crisis episode or a set of crises that occur together in time
- Indicator approach: KLR
- Regression approach

Major types of EWS models

- Differ by crisis definition
 - Speculative pressure index (weighted average of exchange rate and reserve change)
 - “deep” currency crisis (GDP decline over 3%)
 - Use “real” rather than nominal exchange rate change
 - Separate threshold for exchange rate and reserve loss
 - Continuous crisis variable

Major types of EWS models (cont'd)

- Differ by methodologies
 - Different In-sample and out-of-sample performance tests
 - Different specification of Probit model
 - New measures and explanatory variables that contribute to vulnerability (contagion factors, trade and financial linkages, political instability, corporate balance sheet indicators, bank sector, equity flow, financial liberalization)

Major types of EWS models (cont'd)

- New methods
 - Artificial neural network (ANN)
 - Latent variable threshold model
 - Value-at-risk approach
 - Simultaneous modeling of both the mean and the variance of the crisis indicator
 - Autoregressive conditional hazard model
 - Restricted VAR
 - Fisher discriminant analysis
 - Markov-switching approach

Part II

- Macrovariable based EWS models

Specification of DCSD model

- Objective: predict “large” depreciation of the exchange rate and loss of official reserves
- Crisis definition:
 - Calculate an “exchange market pressure” index (weighted average of 1-month changes in exchange rate and reserves) (what are the weights?)
 - A crisis is when the index is very high relative to its historical average (more than 3 standard deviation above country average)
- Predicting horizon: 2 years (why?)

DCSD (continued)

- Factors that contribute to currency crises (a parsimonious representation):
 - Overvaluation of real exchange rate
 - Current Account
 - Reserve growth (or loss)
 - Export growth
 - Short-term debt/reserves

DCSD (continued)

■ Method

- Multivariate panel Probit regressions with the factors measured in (country specific) percentile terms
- Produce estimates of the monthly probability of a crisis happening in the next 24 month period
- Coefficients are assumed to be the same for all the countries

DCSD (continued)

- Model coefficients corresponding to the most recent estimation is shown below:

Variable	Coefficient
Overvaluation	0.013
Current account	0.007
Foreign exchange reserves change	0.007
Export growth	0.002
Short-term debt/reserves	0.002

DCSD (continued)

- Convert the estimated probabilities to crisis indicator
 - The choice of a threshold
 - Minimization of false alarms and missed crises (equal weighting)
 - Same threshold across all countries (why?)

DCSD (continued)

- Performance of the model
 - In-sample: called 65 percent of the crises correctly, but issued many false signals (63%)
 - Out-of-sample: called more than half of the crisis correctly but mixed performance
 - Correctly signaled the Turkish devaluation in 19 out of the 24 months preceding the crisis
 - Partially called the crisis but much later and stopped issuing the signal prematurely

KLR Model

■ Indicator approach

- Each factor is measured relative to a variable-specific threshold
- Individual factor signals a crisis for the next 24 months when the value exceeds the threshold
- Threshold chosen based minimized noise-signal ratio B/A

	Crisis in 24 Months	No-Crisis in 24 months
Issue signal	A	B
No signal	C	D

KLR model (cont'd)

■ Crisis signal

- Aggregate index constructed from weighted factors; weights are the signal-noise ratio
- An optimal threshold is chosen based the ability of the aggregate index to forecast crises by minimizing the missed crises and false alarms

KLR model (cont'd)

- Factors used to predict currency crisis
 - money multiplier change
 - Real interest rate on deposits
 - Ratio of lending to deposit rates
 - Reserve/M2 growth
 - Excess M1 balances
 - Domestic credit/GDP growth
 - M2/reserve
 - Imports growth
 - Real interest rate differential
 - Real deposit stock growth
 - Industrial production growth
 - Stock index change
 - Terms of trade change

KLR model (cont'd)

- Model performance
 - In-sample: correct signals about 41%; high false alarms (65%)
 - Out-of-sample: correctly signals 49% of the crisis. signaled the Turkish devaluation but not the Argentina crisis

Table 2. KLR Risk Matrix

	Overall Status	Probability of Default	Reserves Growth ¹	Exports Growth ¹	Money Multiplier ² Change ³	Real Interest Rate of Deposits	Reserves / M2 Growth	Excess M1 Balances	Overvaluation ⁴	Domestic Credit/GDP Growth ¹	M2/Reserves	Current Account Deficit/GDP	Industrial Production Growth ¹	Terms of Trade Growth ¹
Argentina		14												
Bolivia		8												
Brazil		11												
Chile		11												
Colombia		11												
Cyprus		32												
Czech Republic		58												
Egypt		11												
Hungary		58												
India		11												
Indonesia		11												
Israel		11												
Jordan		42												
Korea		11												
Lebanon		8												
Malaysia		8												
Mexico		14												
Pakistan		14												
Peru		8												
Philippines		8												
Poland		8												
South Africa		11												
Slovak Republic		41												
Sri Lanka		8												
Thailand		11												
Turkey		42												
Uruguay		11												
Venezuela		11												
Zimbabwe		58												

¹ Growth rate over a 12-month period.

² Real Exchange Rate Overvaluation

³ 12-month growth¹ (-1)

Variable that signals higher risk of a currency crisis (for countries indicated to have high probability of a currency crisis).

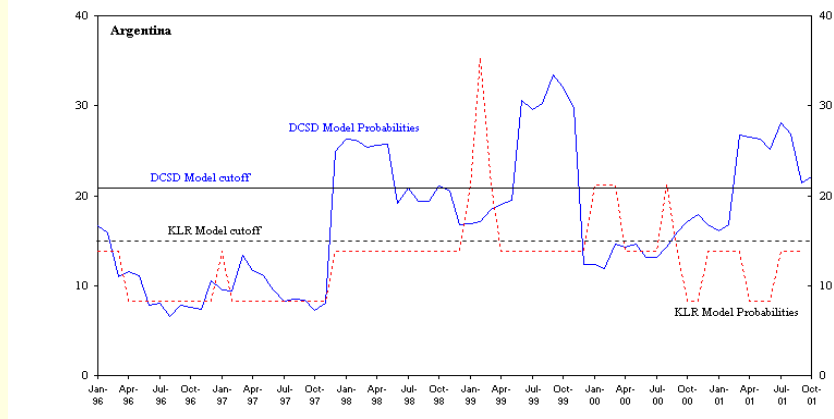
Variable that signals higher risk of a currency crisis (for countries indicated to have low probability of a currency crisis).

Table 1. Crisis Probabilities According to Different Models

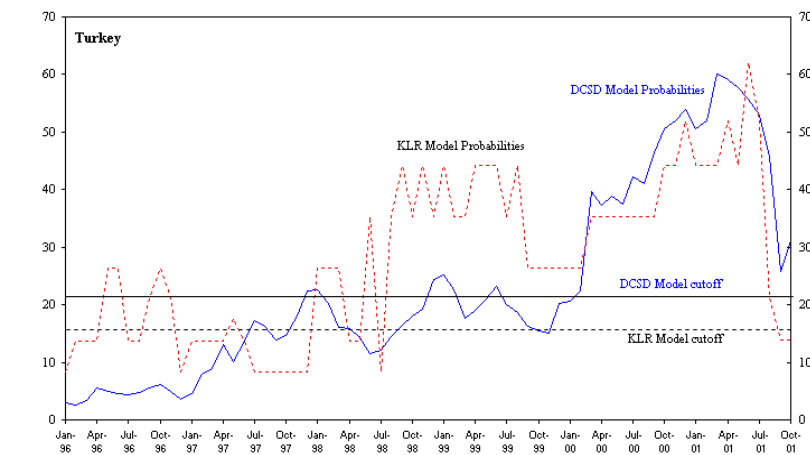
	DCSD				KLR				GS			
	Jun-03 Updates 1a/	Sep-03 Updates 1b/	Dec-03 Updates 1c/	Latest 1d/	Jun-03 Updates 2a/	Sep-03 Updates 2b/	Dec-03 Updates 2c/	Latest 2d/	Jun-03 Updates 3a/	Sep-03 Updates 3b/	Dec-03 Updates 3c/	Latest 3d/
Argentina	2	1	1	1	8	19	14	14	11	10	10	8
Bolivia	6	8	3	1	8	8	8	8				
Brazil	2	1	1	1	11	11	11	11	9	9	9	8
Chile	8	12	10	13	11	11	8	11	10	9	9	7
Colombia	4	6	4	5	11	11	11	11	10	9	9	8
Cyprus	17	32	31	57	15	33	11	32				
Czech Republic	10	13	15	20	11	56	13	58	11	10	10	6
Egypt	4	3	4	3	11	11	11	11	9	8	8	6
Hungary	41	37	46	50	41	31	56	58	9	9	9	9
India	7	3	3	4	11	11	8	11	13	12	12	10
Indonesia	3	4	4	4	11	8	8	11	11	14	10	13
Israel	3	6	3	13	15	15	29	11	9	8	8	
Jordan	8	8	8	8	11	11	11	42				
Korea	2	2	2	1	8	15	11	11	17	9	12	8
Lebanon	9	7	2	3	11	11	8	8				
Malaysia	3	2	2	1	8	8	8	8	8	7	8	8
Mexico	15	13	12	11	15	8	11	14	10	10	10	10
Pakistan	0	0	1	1	11	11	11	14				
Peru	4	3	4	3	8	8	11	8	8	8	8	7
Philippines	2	2	2	2	8	8	8	8	8	8	8	7
Poland	13	10	8	9	8	8	30	8	16	13	13	12
South Africa	2	3	2	4	11	11	11	11	12	11	14	11
Slovak Republic	16	10	11	10	31	41	41	41				
Sri Lanka	13	10	5	6	8	8	8	8				
Thailand	1	1	1	1	11	11	11	11	8	8	8	6
Turkey	19	19	22	18	33	43	43	42	10	12	10	7
Uruguay	11	5	1	0	43	43	11	11				
Venezuela	13	12	5	7	15	11	11	11	9	11	12	9

Out-of-sample performance

■ Predicted probabilities



Out-of-sample performance



Part III

- Market-based EWS models
 - Implied PDF
 - Implied default probability
 - Distance-to-default for banking distress

Implied PDF

- Financial asset prices contain information on market beliefs about the future
- In particular, option prices reflect market beliefs about the future prices of the underlying assets
- These information can be used to extract a probability distribution

Option-based Forex model

- The value of a European call option at time t is denoted as:

$$c(S_t, t, X, T) = e^{-r(T-t)} \int_X^{\infty} (S_t - X) \pi(S_T, T, S_t, t) dS_T$$

- Where S_t represents the time- t asset price, r the domestic risk-free continuously compounded discount rate, and $\pi(S_T, T, S_t, t)$ is the risk-neutral probability density function

Option-based Forex model

- The risk-neutral probability distribution of the terminal asset price S_T conditional on S_t is given by the second derivative of the option price with respect to the exercise price

$$\frac{\partial^2 c(S_t, t, X, T)}{\partial X^2} = e^{-r(T-t)} \pi(X, T, S_t, t)$$

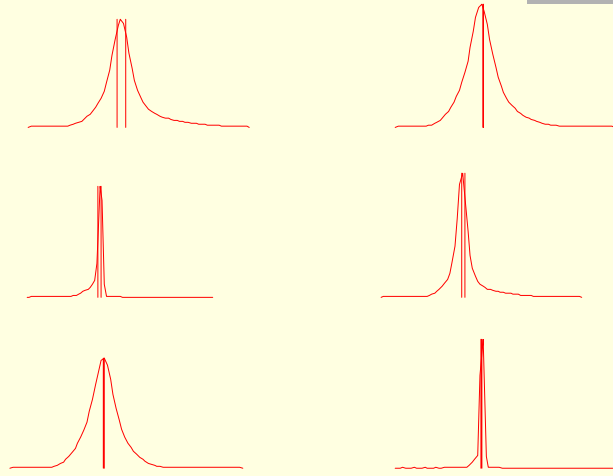
Option-based Forex model

- Black-Scholes model is used as the benchmark for option pricing
 - Assumes the spot exchange rate follows a geometric Brownian motion
 - Domestic and foreign interest rates are constant over the life of the option
 - Volatility is also a constant

Option-based Forex model

- Exchange rate is log normally distributed under the assumptions and price formulas result easily
- There is a one-to-one relationship between the volatility σ and the option price
- Therefore, foreign exchange options can be expressed in units of volatility
- Based on the volatility function of the option and the Black-Scholes formula, one can derive numerically the *implied* probability density function

Implied Probability Distributions for Selected Countries (3-month)



Implied Probability Distributions for Selected Countries (3-month)

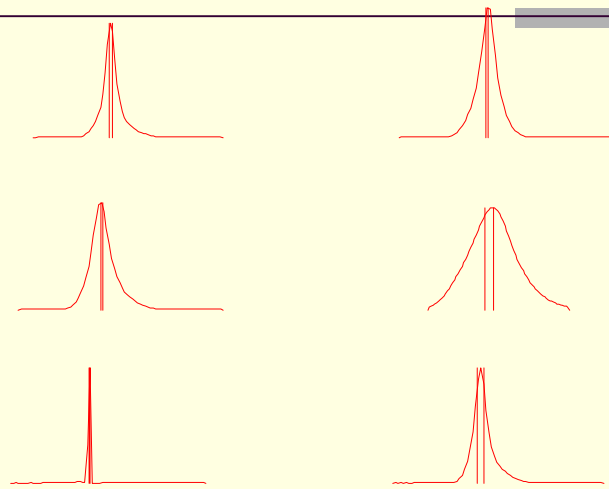


Table 6. Summary Statistics

	Spot	Mean	Median	St. Deviation	Skewness	Kurtosis
Local Currency / U.S. Dollar						
Brazil	2.96	3.06	3.00	0.26	1.27	6.19
Chile	586.00	586.00	579.62	43.69	0.61	4.40
China	8.28	8.16	8.18	0.22	-2.02	7.27
Colombia	2687.00	2728.50	2685.60	173.48	1.80	8.71
Czech Republic	25.90	25.96	25.79	1.60	0.22	3.79
Hong Kong SAR	7.77	7.76	7.73	0.09	-1.90	8.42
Indonesia	8432.50	8547.50	8463.20	407.09	0.85	5.38
Korea	1167.30	1173.70	1169.30	51.19	-0.11	3.69
Mexico	10.93	11.07	10.94	0.61	0.73	4.36
Malaysia	3.80	3.99	3.96	0.55	0.20	2.98
Peru	3.48	3.50	3.47	0.11	4.79	32.37
Philippines	56.35	57.74	57.07	2.51	1.04	5.17
Poland	3.89	3.94	3.89	0.27	0.66	4.46
Thailand	39.18	39.22	39.09	0.97	-0.48	4.31
Taiwan POC	33.22	33.04	33.02	0.69	-1.26	5.21
Venezuela	1918.00	2012.00	1911.60	236.32	1.19	3.73
South Africa	6.73	6.84	6.73	0.77	0.77	4.51
Local Currency / Euro						
Czech Republic	32.57	32.57	32.33	1.14	0.40	4.19
Poland	4.90	4.94	4.88	0.28	0.79	4.82
Local Currency / Yen						
Hong Kong SAR	14.01	14.01	13.89	0.62	0.43	4.02
Korea	10.72	10.81	10.77	0.47	-0.12	3.67
Malaysia	0.03	0.04	0.04	0.00	0.41	3.44
Philippines	1.93	1.88	1.85	0.12	1.12	5.47
Thailand	0.36	0.36	0.36	0.01	0.40	3.97

Implied default probability

Default probability from sovereign bonds

- Price of a risky bond at time t is given by:

$$B_t = \frac{[(1-p_t) + \mu p_t]C}{1+r_t} + \frac{[(1-p_t)^2 + \mu p_t(1-p_t)]C}{(1+r_t)^2} + \dots + \frac{[(1-p_t)^N + \mu p_t(1-p_t)^{N-1}](C+100)}{(1+r_t)^N}$$

- Where p_t is the constant risk neutral default probability, C is the fixed coupon, and μ is the recovery rate upon default

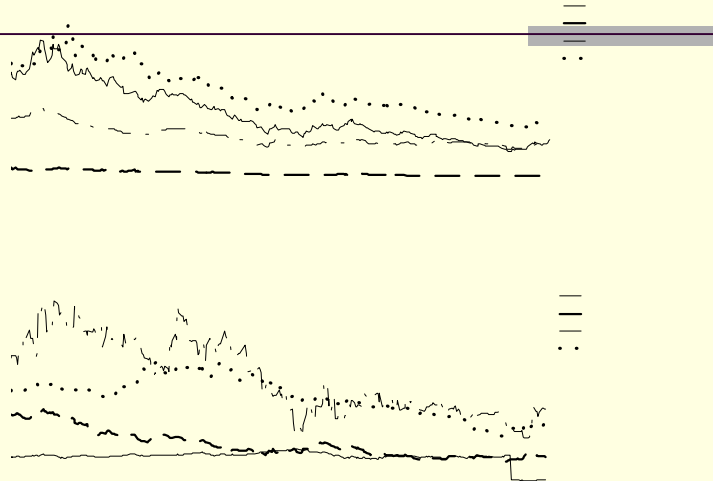
Default probability from sovereign bonds

- Assuming zero recovery, the probability of a default at time t in the remaining life of a bond with N coupons outstanding is given by:

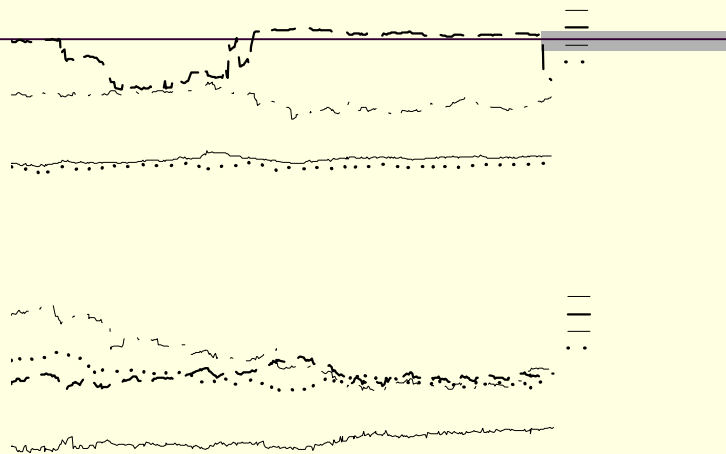
$$P_t = 1 - (1 - p_t)^N = \sum_{j=1}^N p_t (1 - p_t)^{j-1}$$

- Given the market price of a bond at time t, the formula can be used to derive the implied risk-neutral default probability

Sovereign Default Probabilities



Sovereign Default Probabilities



Sovereign Forex Long-Term Ratings and Outlooks

	Moody's		Standard and Poor's		Fitch IBCA	
	Rating	Outlook	Rating	Outlook	Rating	Outlook
Brazil	B2	stable	B+	stable	B+	stable
Bulgaria	Ba2	stable	BB+	stable	BB+	positive
Chile	Baa1	stable	A	↑ stable	A-	positive
Colombia	Ba2	negative	BB	stable	BB	negative
Ecuador	Caa2	stable	CCC+	stable	CCC+	stable
Egypt	Ba1	stable	BB+	negative	BB+	stable
India	Baa3	↑ stable	BB	stable	BB+	↑ stable
Indonesia	B2	stable	B	stable	B+	↑ stable
Jordan	Ba2	stable	BB	stable	NR	n.a.
Lebanon	B2	negative	B-	stable	B-	stable
Malaysia	Baa1	positive	A-	stable	BBB+	stable
Mexico	Baa2	positive	BBB-	stable	BBB-	stable
Pakistan	B2	stable	B	positive	NR	n.a.
Paraguay	Caa1	stable	SD	n.a.	NR	n.a.
Peru	Ba3	stable	BB-	stable	BB-	stable
Philippines	Ba2	↓ negative	BB	stable	BB	stable
Poland	A2	stable	BBB+	negative	BBB+	positive
Romania	Ba3	↑ stable	BB	positive	BB	↑ stable
South Africa	Baa2	positive	BBB	stable	BBB	stable
Thailand	Baa1	↑ stable	BBB	positive	BBB	stable
Turkey	B1	stable	B+	↑ stable	B+	↑ stable
Uruguay	B3	negative	B-	stable	B-	stable
Venezuela	Caa1	stable	B-	stable	B-	stable

Moody's ² S&P and IBCA

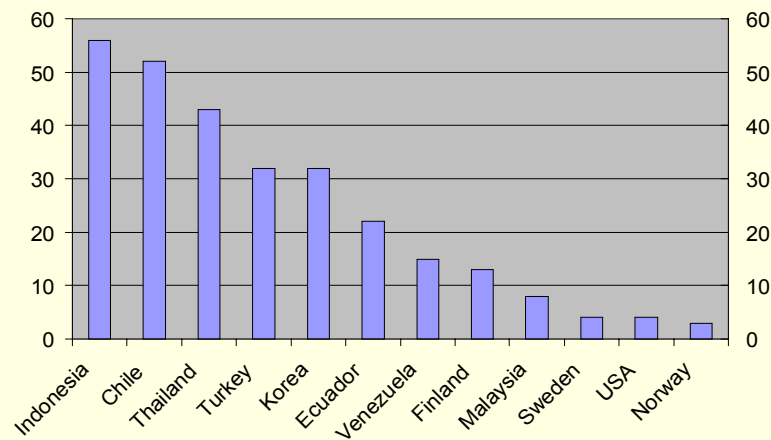
Aaa, Aa, A, B AAA, AA+, AA, AA-, A+, A, A-, BBB+, BBB, BBB-
 Ba, B BB+, BB, BB-, B+, B, B-
 Caa, Ca, C, ICCC+, CCC, CCC-, CC, C

¹ NR denotes no rating; SD denotes selective default; *+ / *- denote review for a possible upgrade/downgrade
² In addition, numbers from 1 (highest) to 3 may also be attached to differentiate borrowers within a given rating

Option-based bank vulnerability indicator

Option-based bank vulnerability indicator

Banking Crisis Cost, percentage of GDP



FORECASTING BANKING FAILURES

Macroeconomic Approach

- Macroeconomic policies cause crisis
- Banking crisis predicted using macroeconomic variables
- Gonzales-Hermosillo et al (1997), Demirguc-Kunt and Detragiache (1998), others

Bank Balance-Sheet Approach

- Poor banking practices cause crisis
- Bank failure predicted by balance-sheet data
- Cole and Gunther (1998), Gilbert et al (1999), Jagtiani et al (2003), others

FORECASTING BANKING FAILURES

Market Indicators Approach

- Equity and Debt prices contain information on bank conditions beyond that of balance sheet data
- Equity and Debt data
 - High Frequency
 - Forward Looking
- Evanoff et Wall (2001), Bongini et al (2002), Gropp et al (2002), Krainer and Lopez (2003), others

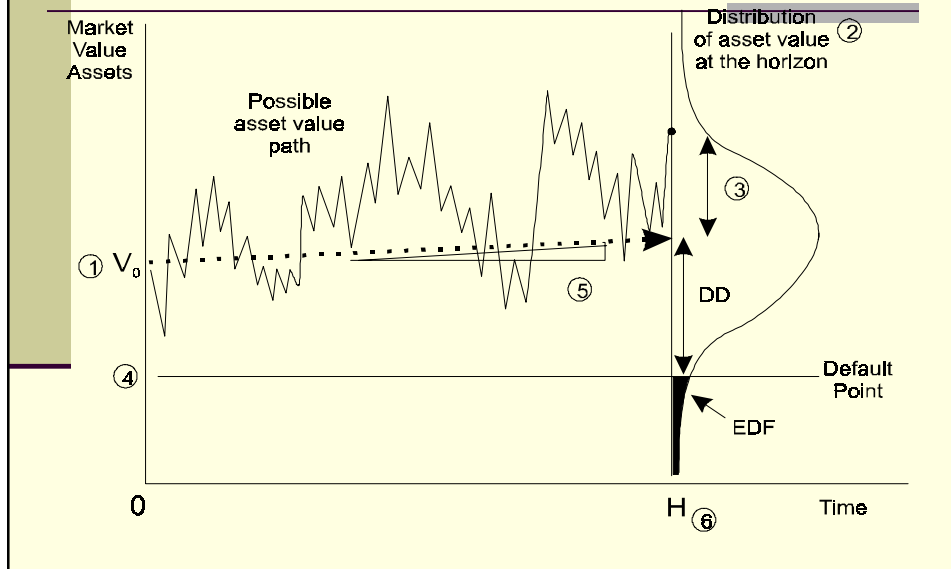
Option-based bank vulnerability indicator

- Uses Equity Prices, Balance-Sheet Data (Gropp et al)
- Based on Merton's (1974) model
 - Equity is a call option on bank's asset value
 - Default point = value of liabilities
 - Bank fails if assets less than default point at maturity
 - Bank risk indicator is the *Distance to Default* (DD)

$$DD = \frac{\text{Asset Value minus Default Point}}{\text{Asset Volatility}}$$

- DD is "complete" and "unbiased" (Gropp et al)
- DD can forecast bank failure/ financial distress

The Distance-to-Default



GETTING THE MODEL TO WORK (1)

- Sample period: July 1997 – July 2003
- 38 banks in 14 emerging markets countries
- Monthly equity prices and annual balance-sheet data
- Default point defined as total liabilities

Getting the model to work (2)

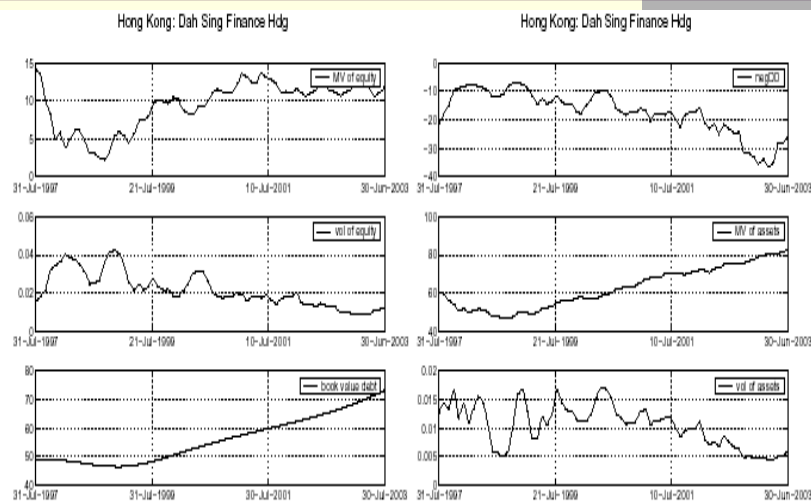
- With estimates of value of equity, volatility of equity, and debt, we solve for the value of the asset V and its volatility using the non-linear equations from Merton's model.

$$E = V\Phi(d_1) - D\exp(-rT)\Phi(d_2)$$

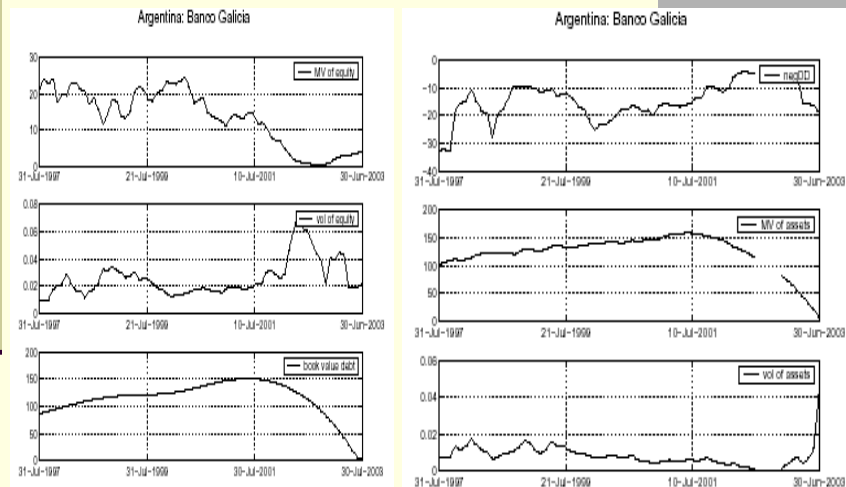
$$\Phi(d_1)\sigma V = \sigma_E E$$

- We price equity as a call option with one year maturity at the beginning of each period t while holding the debt constant for one year.
- we can derive a risk-neutral distance-to-default indicator for each period t .

Distance-to-default Indicators: example 1



Distance-to-default Indicators: example 2



In-Sample Performance of DD Indicator

- Map the indicator to actual credit event
- A credit event: a rating downgrade to CCC or below
- T-test at forecasting horizon of 3, 6 and 9 months
- Probit/Logit regressions

In-Sample Performance of DD Indicator

- DD indicators differ for banks with and without downgrades at all testing horizon.
- DD indicator is able to issue warning signals with at least 9 months lead before a credit event

In-Sample Performance of DD Indicator: Probit/Logit

	α_1	P-value
3-month	0.07	0.1%
6-month	0.06	3%
9-month	0.06	5%
12-month	0.06	19%

Out-of-Sample forecasting

- Out-of-sample forecasting exercise is restricted to Argentine banks because of limited sample size and lack of changes in credit ratings of many of the banks in sample
- Out-of-sample forecasting requires tradeoff between type I and II errors
- Threshold selected based on the method of KLR of minimizing the missed crises and false alarms

Out-of-sample forecasting

Probability of financial distress	Forecasting Horizon	
	3-month	6-month
Banco de Galicia	14%	11%
Banco Hipotecario	13%	11%

Part IV

- Balance-sheet based approach to risk analysis

Moody's MfRisk

- MfRisk measures sectoral and country risk exposures.
- Methodological framework
 - Sectoral linkages through "economic" balance sheets.
 - Contingent claim analysis (CCA) of sectoral assets and liabilities.
- MfRisk can generate "scenarios" for a variety of shocks:
 - Exchange rate and Domestic interest rates.
 - Stock market declines.
 - Debt composition and debt levels.
 - Drop in foreign exchange reserves.
 - Increased Rollover risk.

Building Blocks – Balance Sheet Linkages

Assets	Liabilities
Corporate Sector	
- Corporate Assets	- Loans - Corporate Equity
Banking Sector	
- Loans - Financial Guarantee	- Deposits - Equity
Government Sector	
- Domestic Assets - Foreign Reserves	- Financial Guarantee to Banks - Foreign Debt - Local Currency Debt & Other Liabilities

Building Blocks – Contingent Claim Analysis

- Contingent Claim Analysis used to value loans to corporate sector and financial guarantees.
- CCA for a firm (Merton1974)
 - Firm financed with equity E and zero-coupon debt D with face value DB (default barrier).
 - Firm defaults when debt matures in period T if its assets V cannot meet repayment DB.

Building Blocks – Contingent Claim Analysis

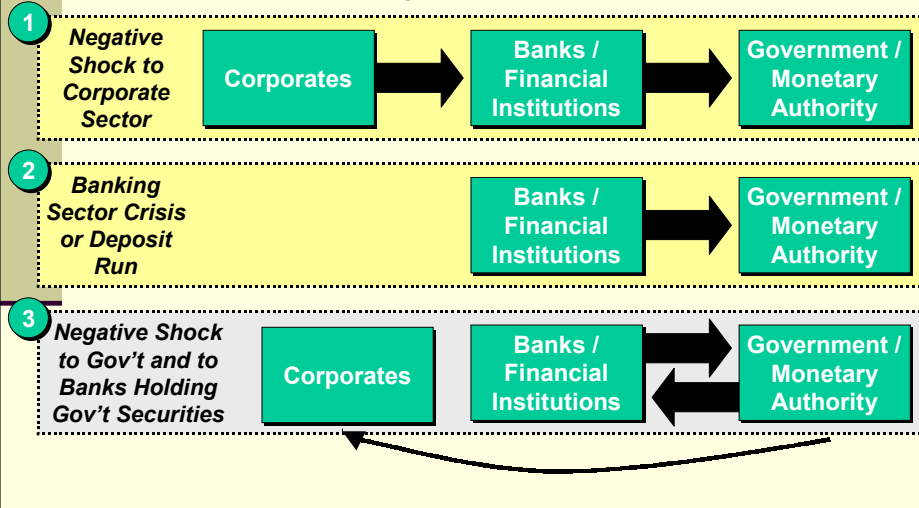
- Assets = Equity + Debt
 - $V = E + D$.
- Equity and Debt are implied “options” on the firm asset value:
 - $E(t) = E_t \max [A(T) - DB, 0]$.
 - $D(t) = DB - E_t \max [DB - A(T), 0]$.
- Equity value observed from market prices, debt value requires knowing asset value, V , and volatility, σ .

Building Blocks – Contingent Claim Analysis

- Unobserved Asset Value and Volatility can be recovered from observable data using Black-Scholes-Merton option pricing model.
- Observable data input required:
 - Balance Sheet Data.
 - Equity prices.
 - Equity volatility.

Estimating Economy-wide Risk Transfer

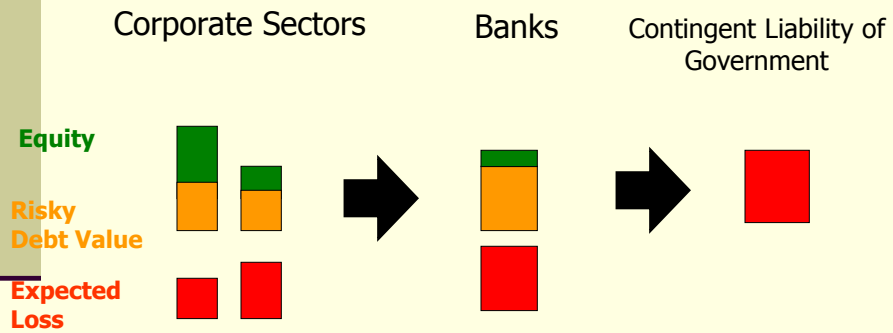
Three Examples of Risk Transmission



Risk Transmission from Corporate Sector to Banks to Public Sector: Initial Stage



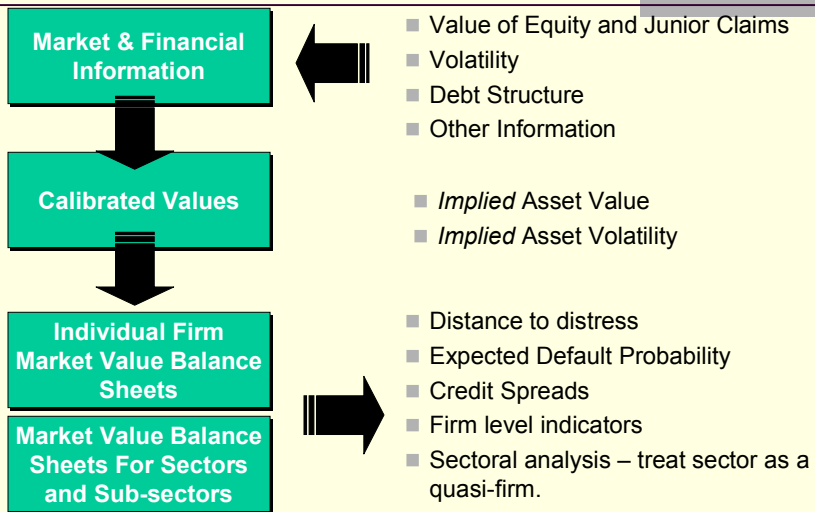
Risk Transmission from Corporate Sector to Banks to Public Sector: Final State



Moody's MfRisk

- Merton's framework can be used to analyze the inter-relation
- Can be used to:
 - Valuing sovereign risk of default
 - Valuing implicit guarantee to financial institutions
 - Measure risk transmission between sovereign, financial sector, and corporate sector

Contingent Claim Vulnerability Indicators



Some MfRisk Shortcomings

- Firm specific framework (Merton, KMV) may be not adequate for sectoral risk analysis.
- No information about time to maturity.
- Forward-looking inputs cannot be entered by user, i.e. implied volatility measures.
- “Black box.”

Part V

- Interpretation of the results
- Pros and cons of EWS models
- Future direction

Interpretation of the results

- Results are model-dependent
- Different models may be inconsistent
- Performance tend to mixed: poor in-sample and out-of-sample accuracy

Interpretation of the results

- Instability in DCSD model coefficients (dropped crises)
- “jumps” in KLR model (due to indicator approach)
- Data sets are frequently revised
- Market prices contain “noises”
- Model specification issue

Pros of EWS models

- Systematic, objective, consistent method which helps avoid analysts' bias
- Single measure of risk in some statistically optimal way (vs. large number of indicators giving different signals)
- Performs better than “market views”

Cons of EWS models

- No model works for all crises
- Exact timing of crisis is difficult to predict
- Risk of data mining or overfitting of the model
- False alarms
- Missing crises

Future direction

- Improve accuracy
- Models for debt and banking crises