Bottom-Up Default Analysis (BuDA): A Scenario Based Approach for Assessing MacroFinancial Linkages

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Outline

Outline

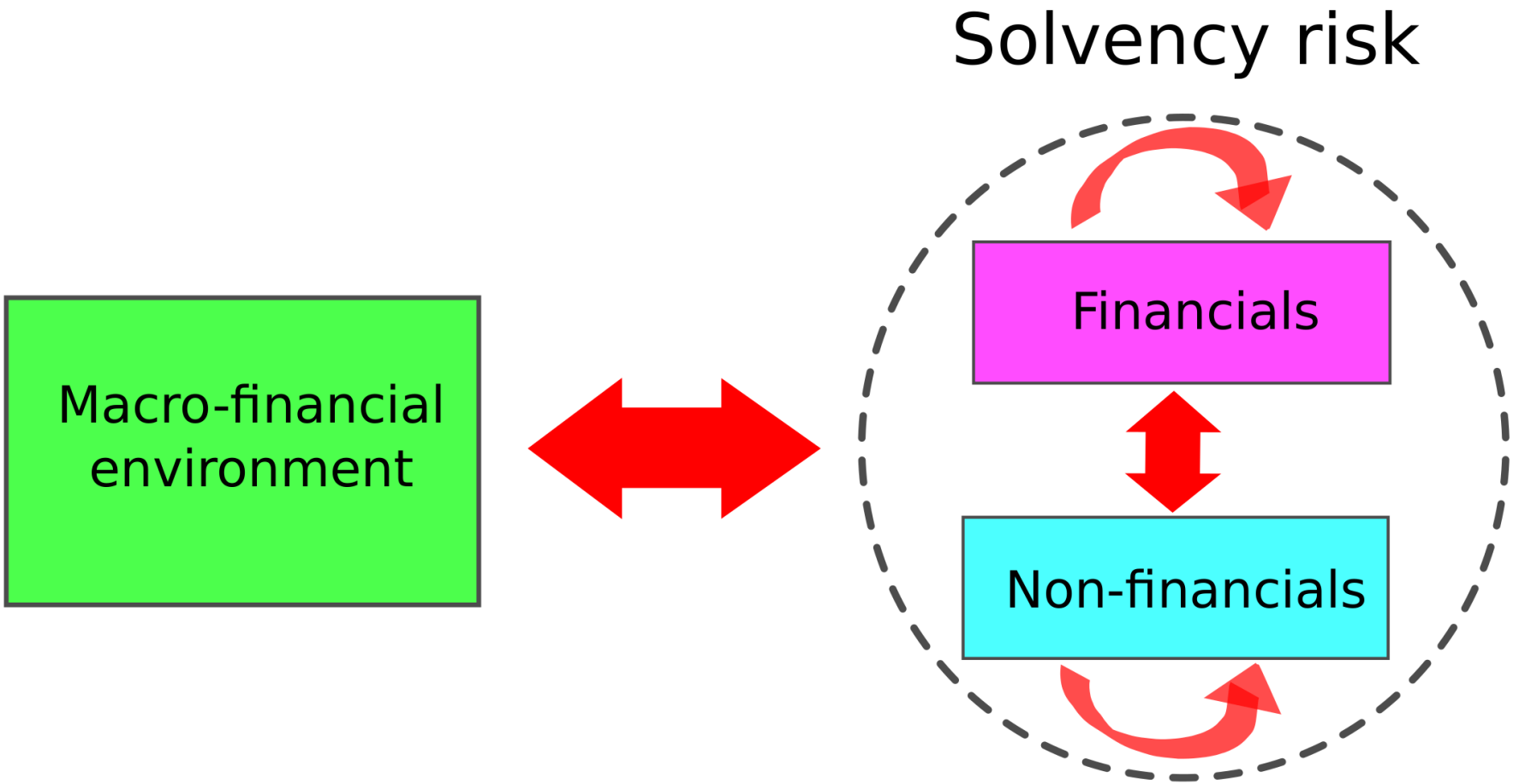
Macrofinancial Surveillance

- Builds on a sound qualitative understanding of the economy
- Identifies risks and vulnerabilities
  - firm level, i.e. microprudential
  - system-wide, i.e. macroprudential
- Captures macrofinancial linkages
  - business cycle
  - financial cycle

Macrofinancial Linkages

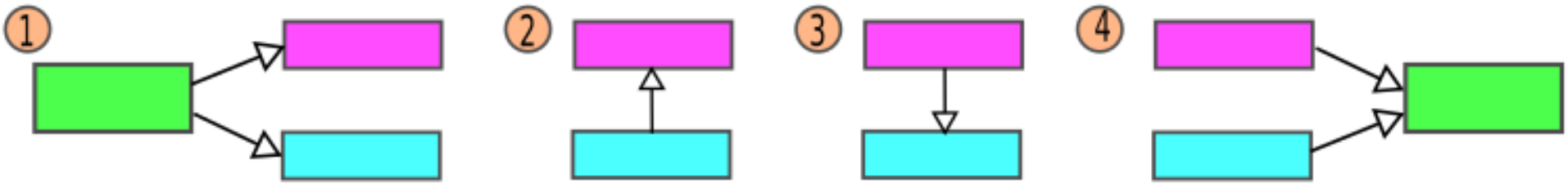
- Macrofinancial linkages matter for
  - Financial sector surveillance
  - Macroprudential policy design
- Modeling macrofinancial linkages is hard . . .
- . . . due to numerous feedback loops
  - Macrofinancial environment and firms
  - Financial firms
  - Non-financial firms
  - Financial and non-financial firms

Modeling macrofinancial linkages is difficult



Sequential Modeling of MacroFinancial Linkages

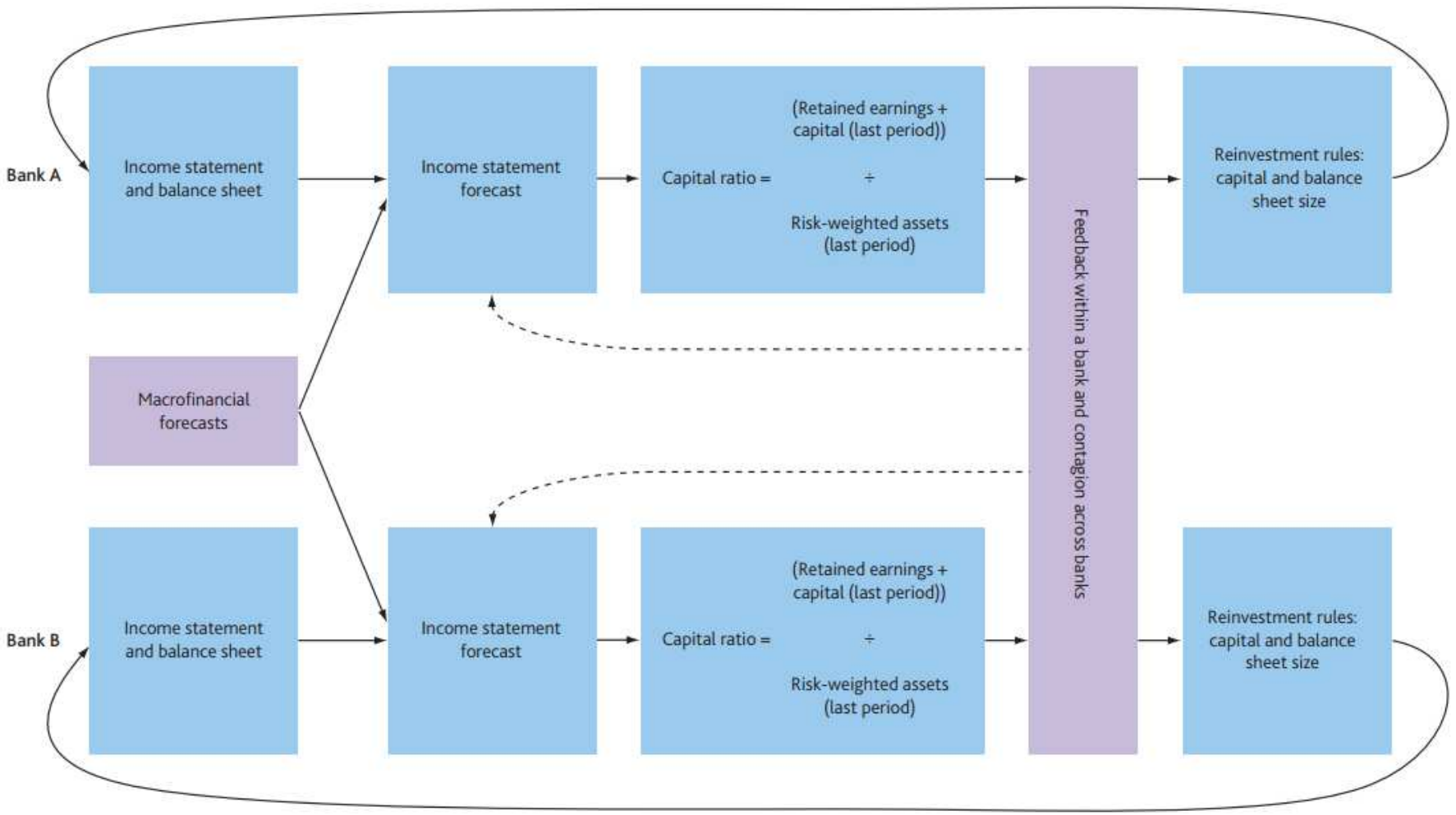
- Simplify modeling
- Break the problem in steps



- Examples
  - Bank of England RAMSI model (Burrows et al, 2012)
  - Bank of Canada MFRAF model (Anand et al, 2014)

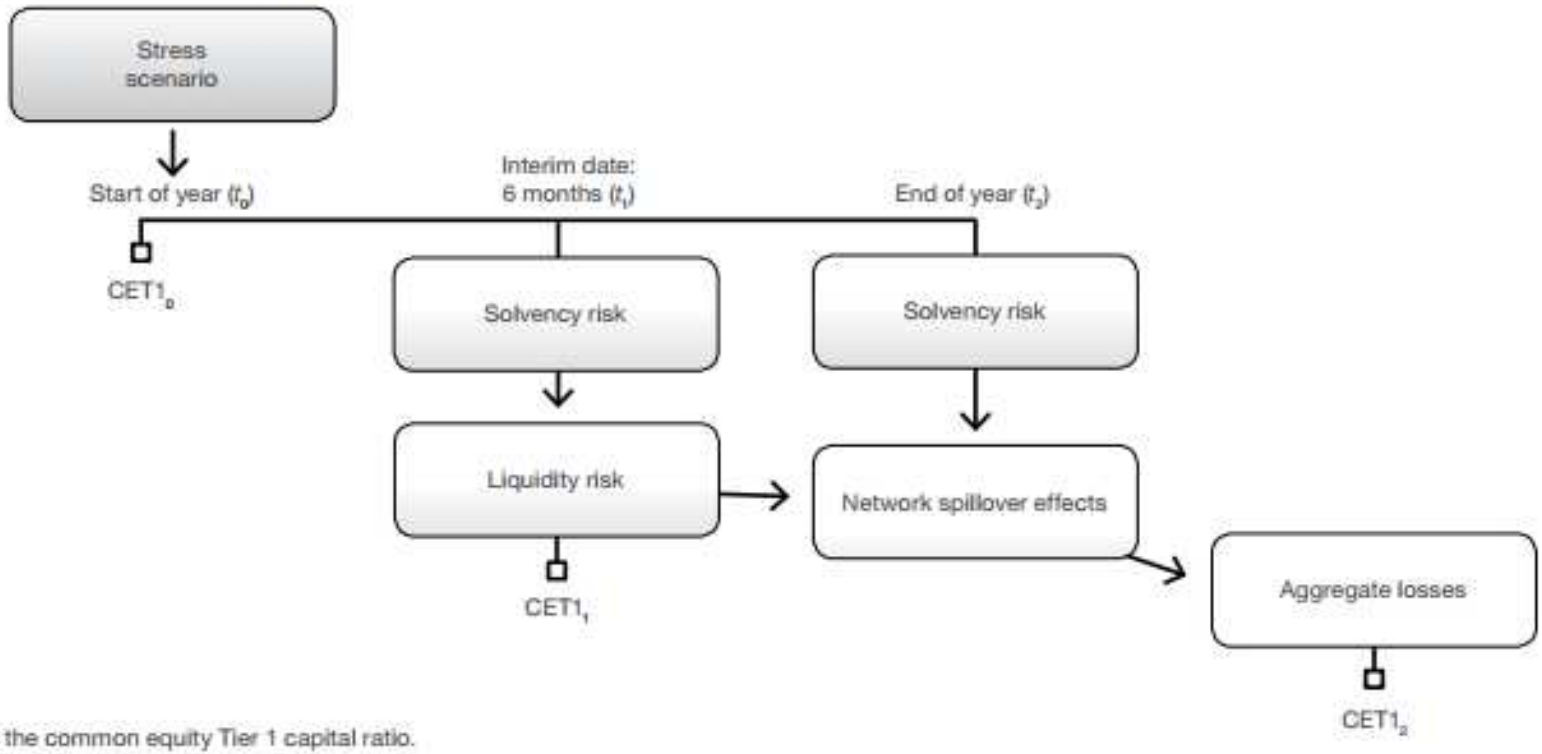
Bank of England RAMSI model

Figure 1 Stylised overview of RAMSI



Bank of Canada MFRAF model

Figure 1: MFRAF: A modular approach to systemic risk



Note: CET1 is the common equity Tier 1 capital ratio.

Source: Bank of Canada

Some Analytical Tools

Current toolkit

- Econometric models, i.e. VARs
- Structural models, i.e. DSGEs
- Network models
- Scenario analysis
- Stress tests
- Balance sheet and financial ratio analysis

A new addition

- BuDA: the Bottom-Up Default Analysis Framework

How BuDA Fits in Macrofinancial Surveillance

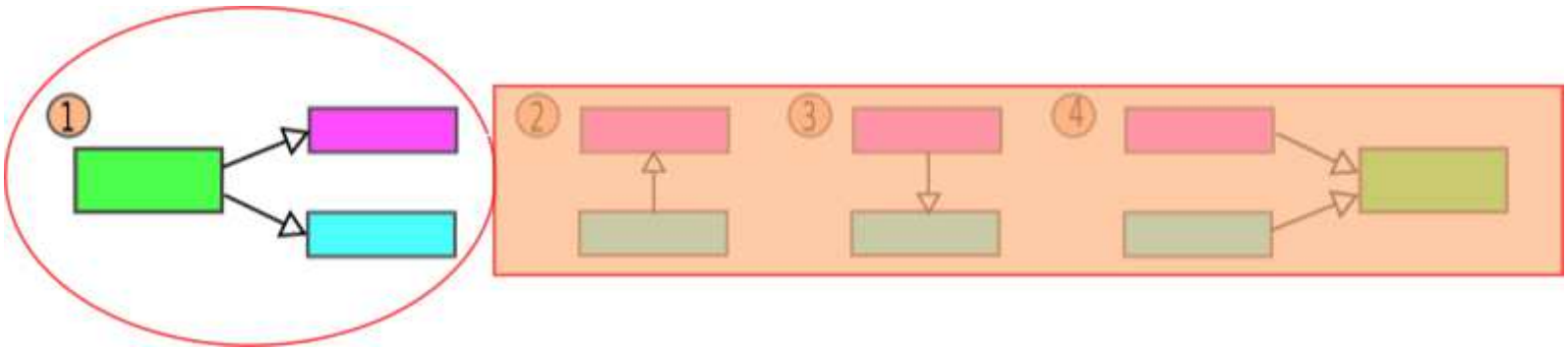
BuDA is one powerful tool combining

- Timely market information
- Balance sheet data
- Scenario analysis and stress tests
- Caveat: only publicly listed firms

BuDA within the Sequential Modeling Approach

The **Bottom-Up Default Analysis** BuDA Framework

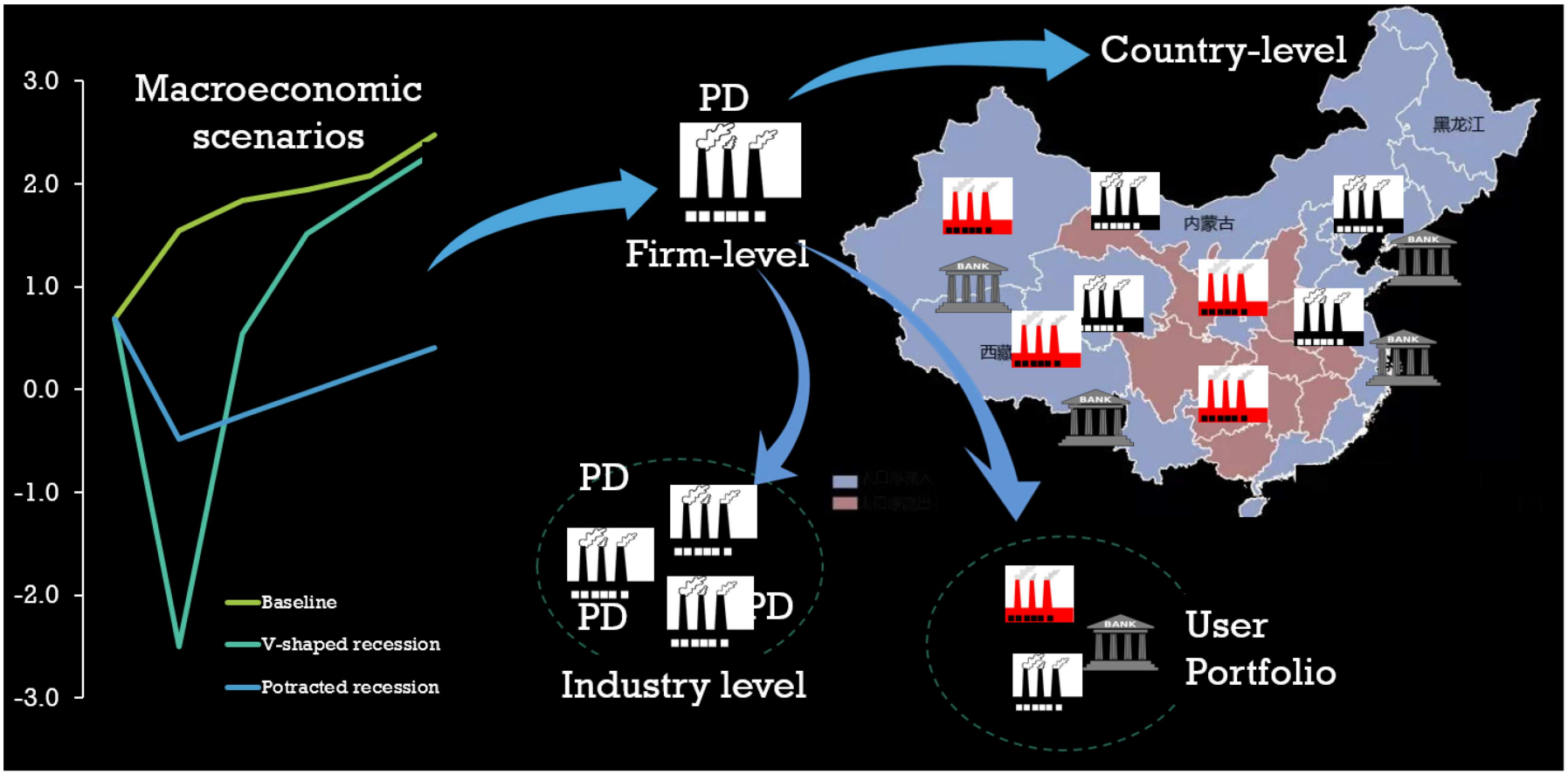
- Maps macrofinancial scenarios to firms' solvency risk



- Mapping based on a **bottom-up** approach
- Focus on default risk, i.e. probabilities of default

Outline

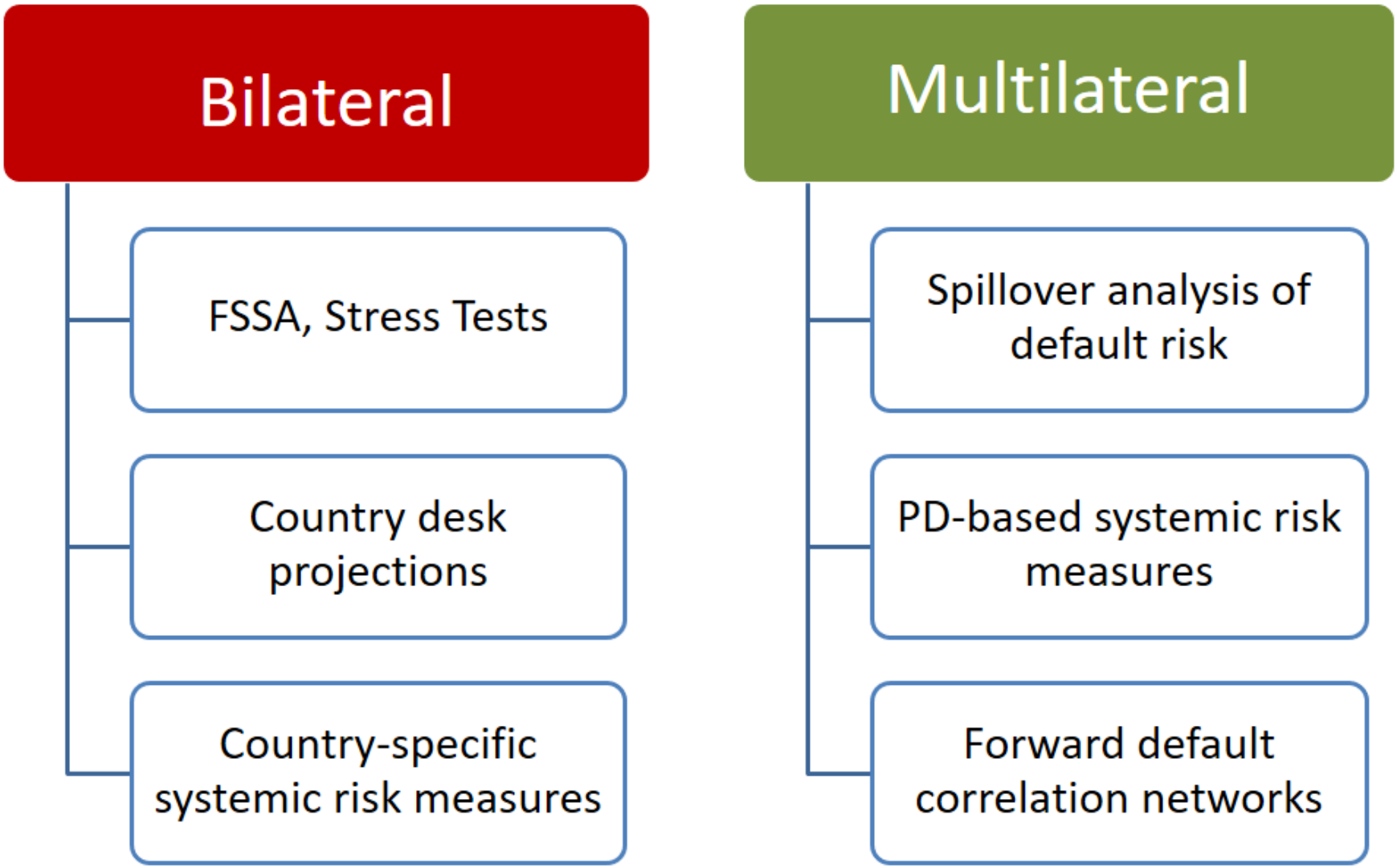
BuDA uses a Bottom-Up Approach



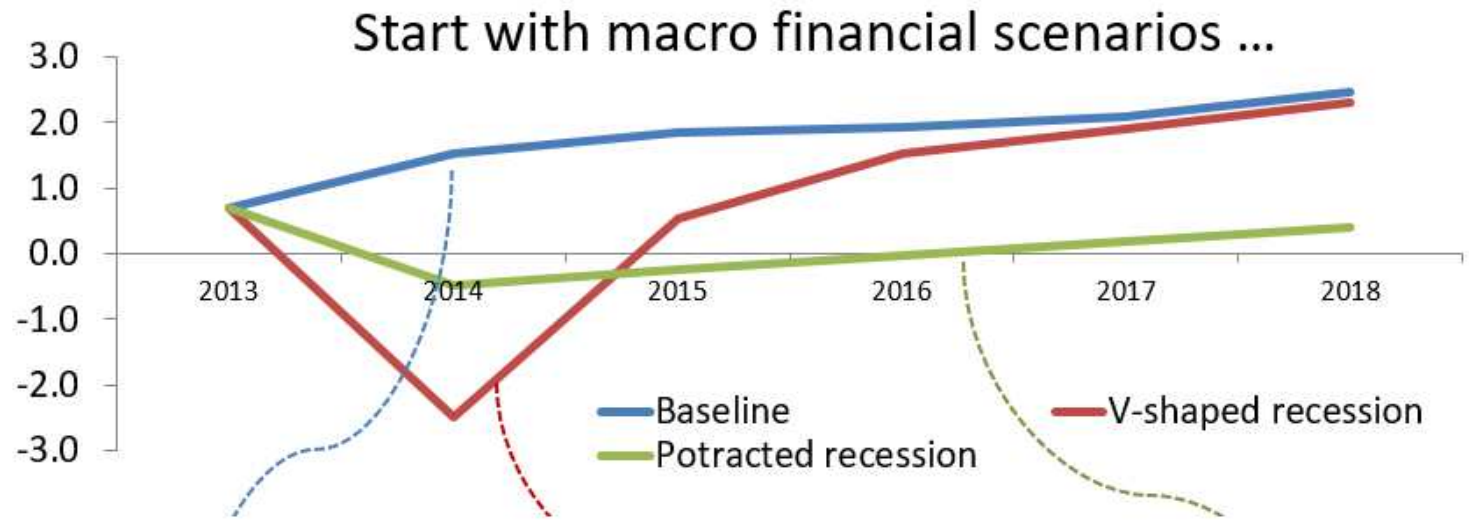
Advantages of the Bottom-Up Approach

- Single out systemic firms in the analysis
- Analyze specific business sectors
- Focus on large debtors of banking sector
- Identify most vulnerable firms
- Specify arbitrary group of firms (portfolio)
- Suitable for surveillance work

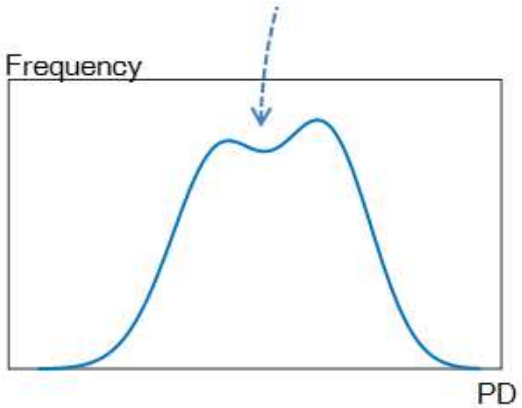
Surveillance Applications of the Bottom-Up Approach

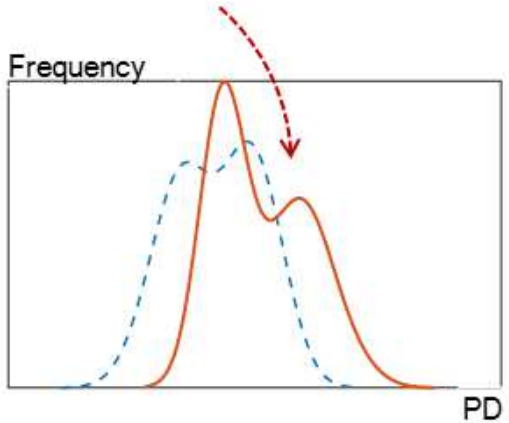


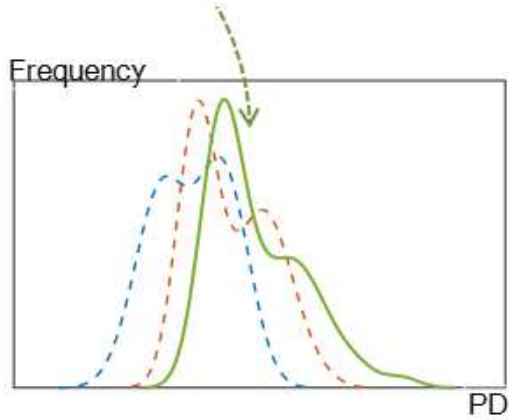
BuDA generates default risk distributions



... and estimate ex-post distribution of PDs of individual firms



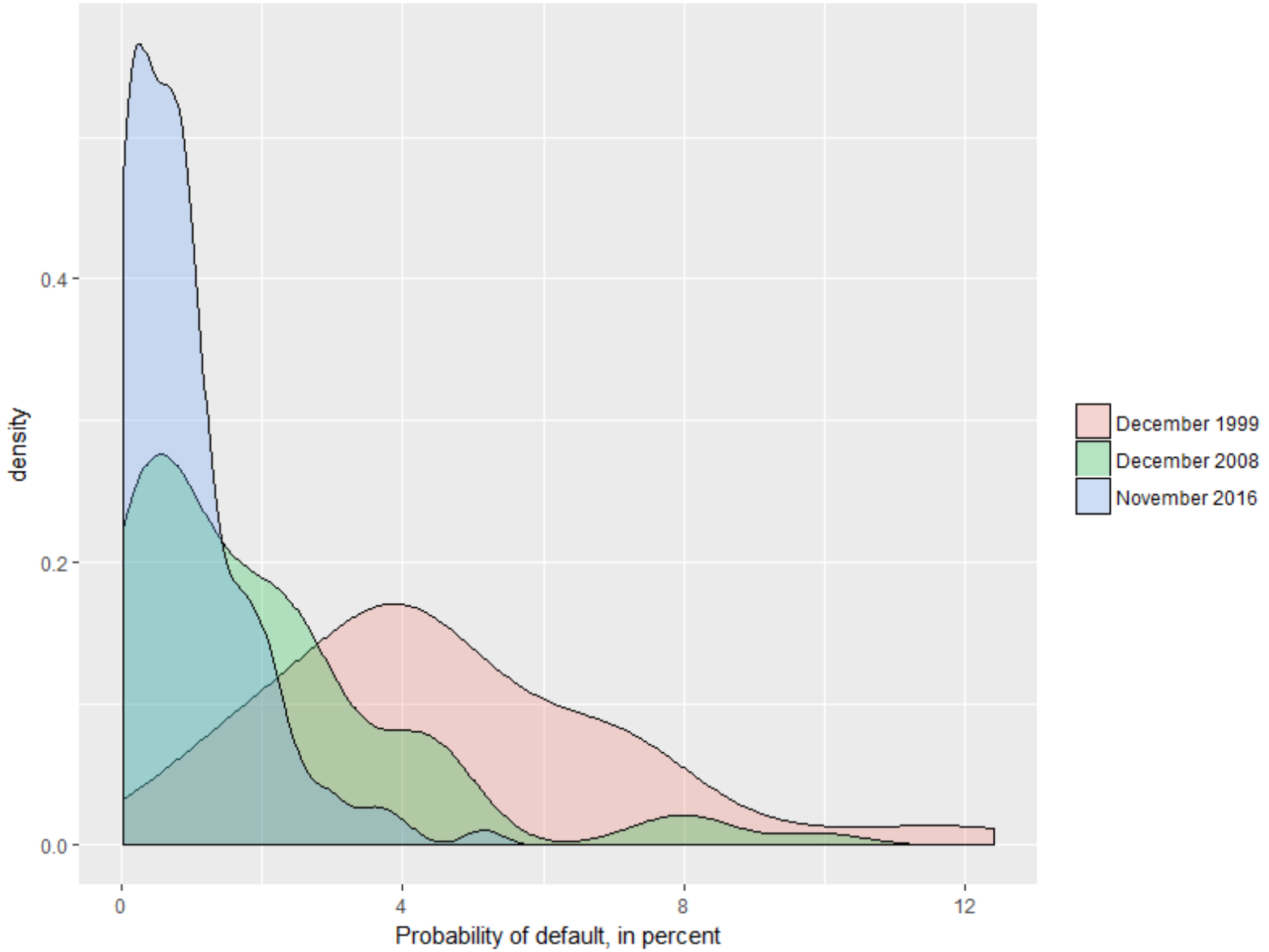




Why risk distributions matter

- Distribution more informative than aggregate risk measures
- Basis for modeling aggregate fluctuations
  - Granular origins of aggregate fluctuations (Gabaix, 2011)
  - Network origins of aggregate fluctuations (Acemoglu et al, 2012)
- Useful for constructing early warning and/or cyclical indicators

Distribution of default risk, Chinese financial firms



Scenario Variables

- Real GDP growth
- Inflation rate
- Policy rate
- NEER
- Money market rate
- 10-year government bond yield

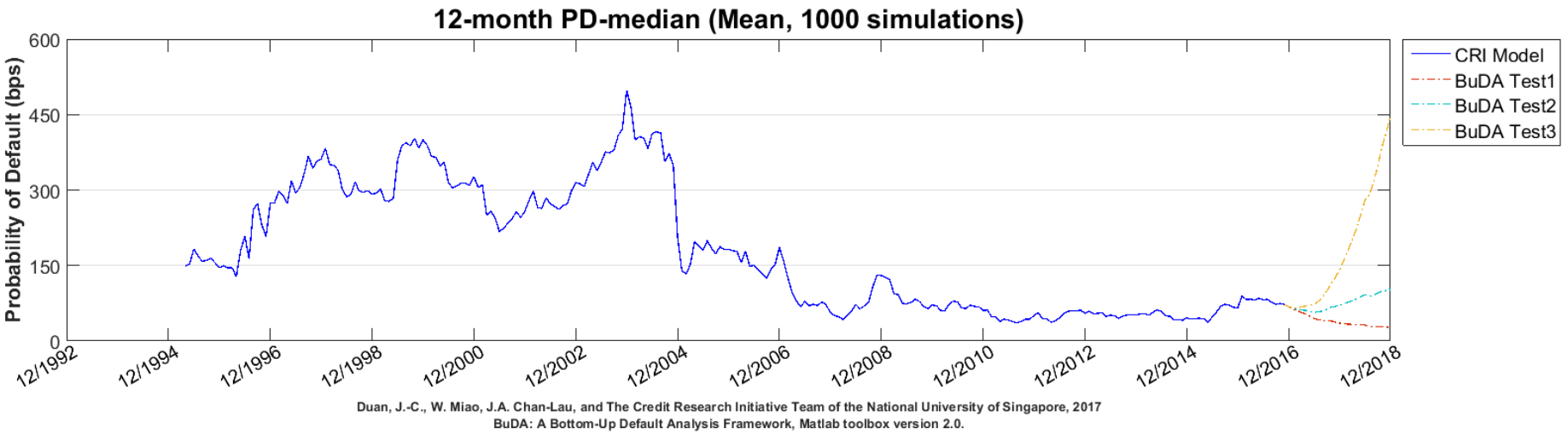
Scenarios

Two-year scenarios

- Baseline
  - 6.0 percent GDP growth
- Adverse
  - 4.5 percent GDP growth
- Severe
  - 2.8 percent GDP growth

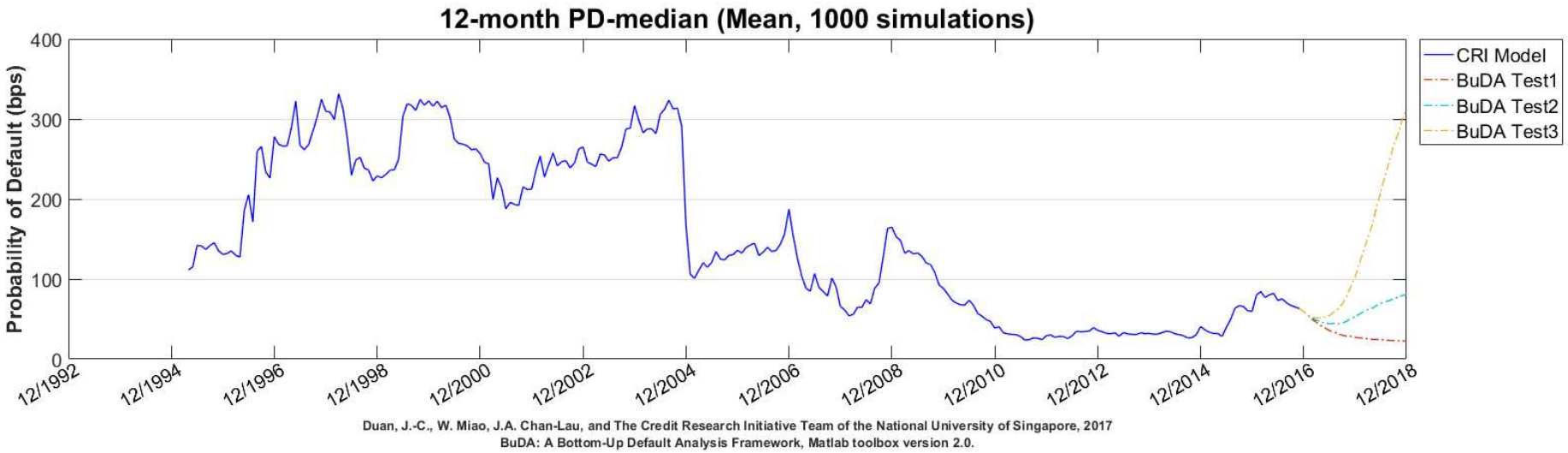
Results

135 financial firms



Results

2075 non-financial firms

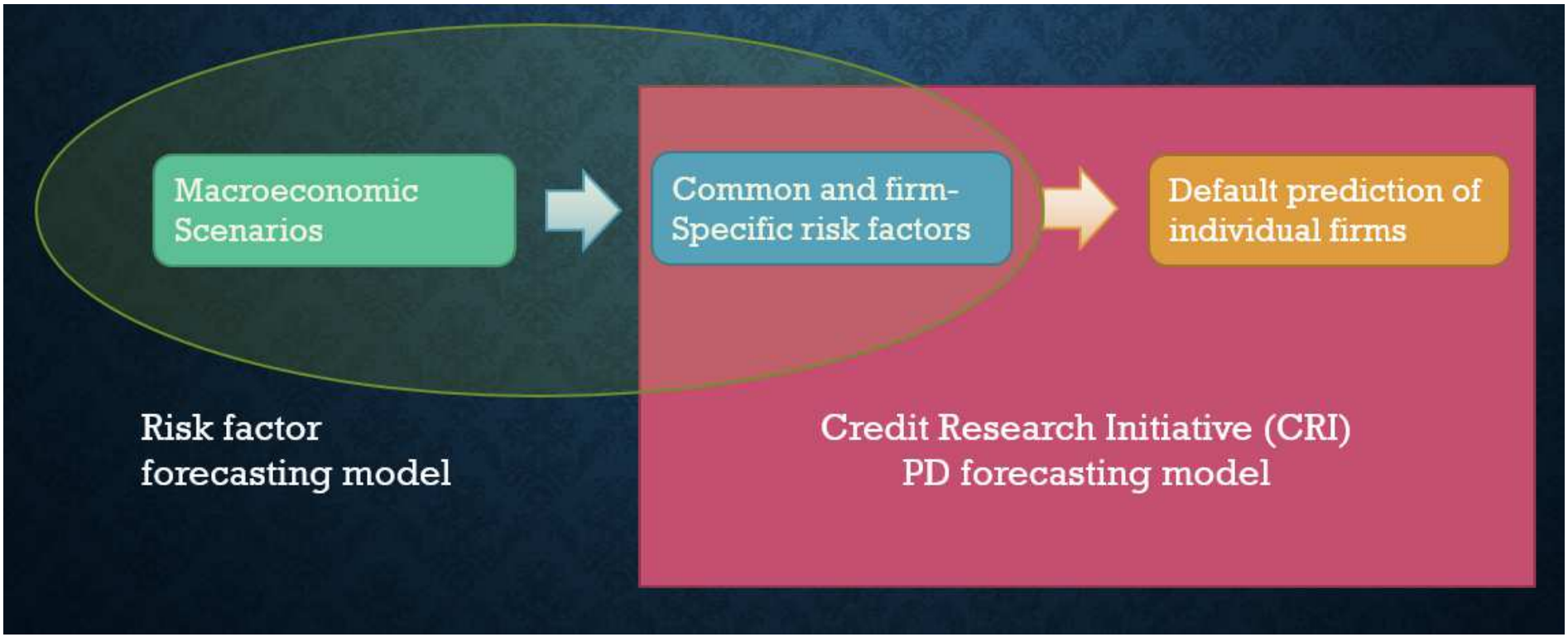


Outline

A Two-Step Approach

The Two Steps

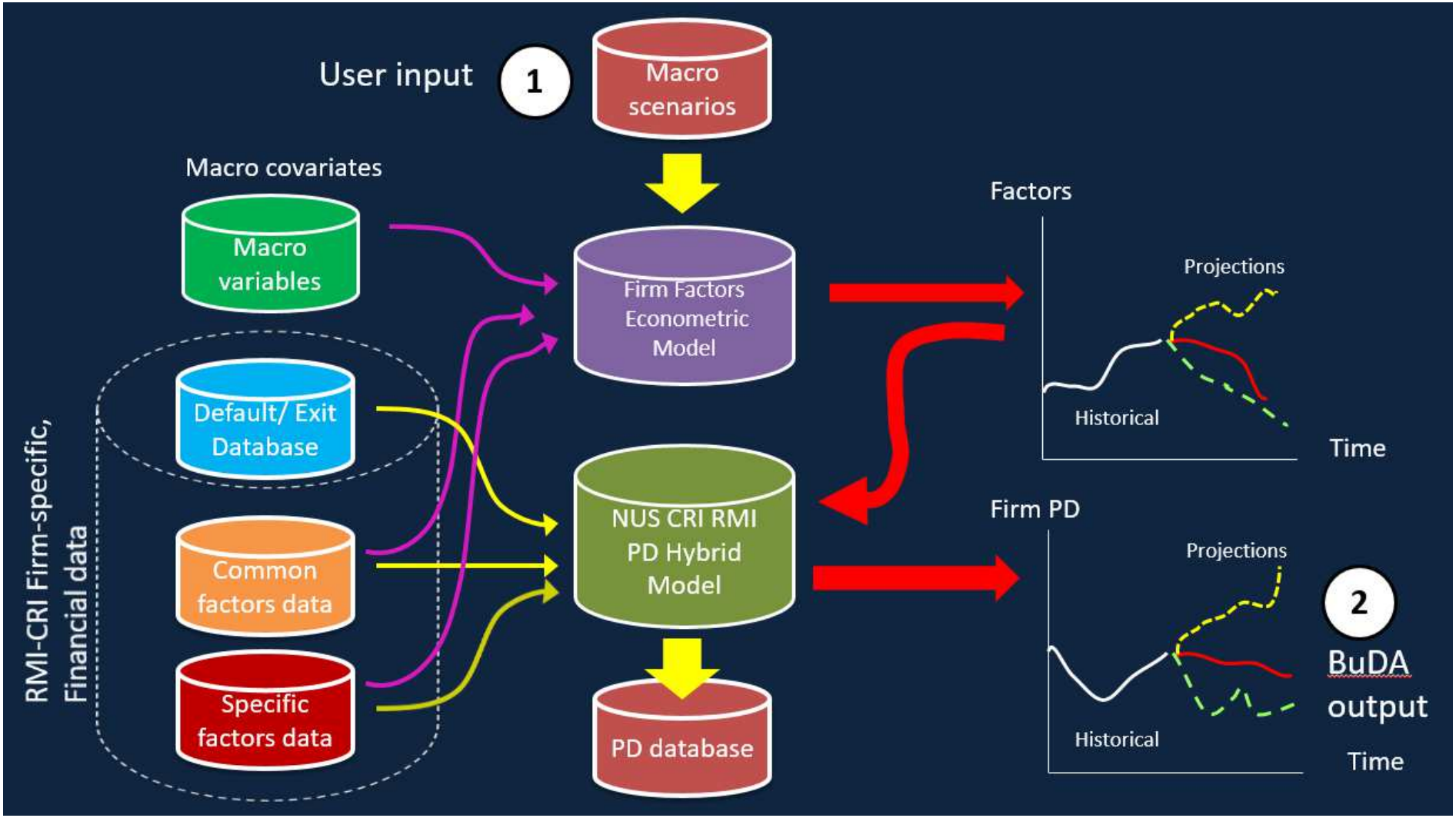
- Step 1: Risk factor prediction model using scenario variables
- Step 2: PD forecasting model, conditional on risk factors



Risk Factors for Forecasting PDs

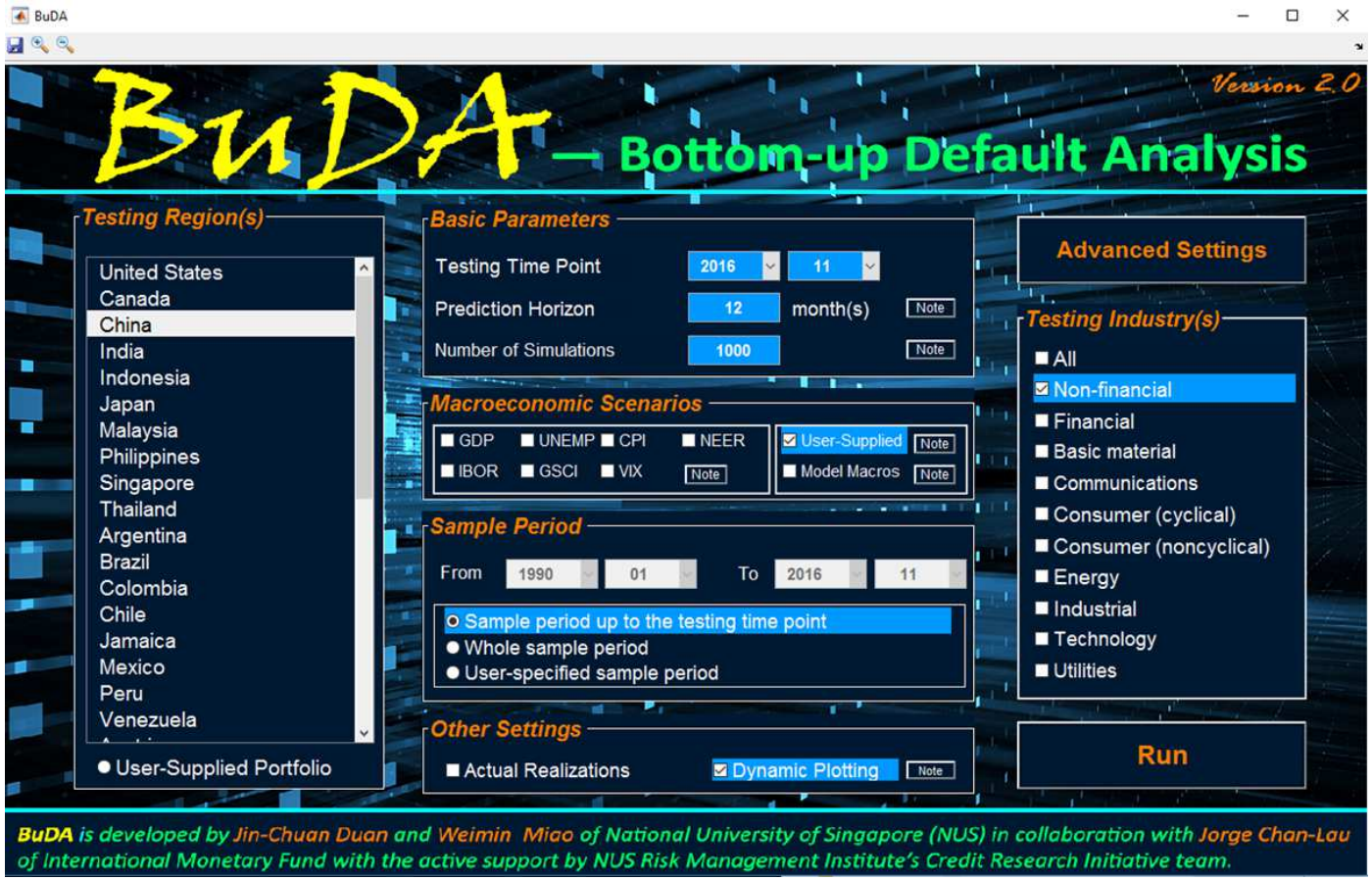
Nature	Description	Level/Trend 1,2/
Economy-wide	Return of domestic stock market index	Current
	Short-term domestic interest rate	Current
Firm-specific	Financial statements-based factors	
	Liquidity (cash + short-term investments/total assets)	Trend and level
	Profitability (Net income/total assets)	Trend and level
	Market-based factors	
	Distance-to-default (volatility adjusted leverage)	Trend and Level
	Size (market capitalization relative to median market capitalization)	Trend and Level
	Market misvaluation (market cap + total liabilities/ total assets)	Current
	Idiosyncratic volatility	Current

1/ The level is computed as the 12-month average value of the factor.
2/ The trend is computed as the difference between the current value of the factor and its 12-month average


User input
1
Macro scenarios
Macro covariates
Macro variables
Default/ Exit Database
Common factors data
Specific factors data
RMI-CRI Firm-specific, Financial data
Firm Factors Econometric Model
NUS CRI RMI PD Hybrid Model
PD database
Factors
Projections
Historical
Time
Firm PD
Projections
Historical
Time
2
BuDA output

Matlab ready-to-use stand-alone program

- Updated on a quarterly basis
- Available upon request



PD Modeling

Default and Insolvency

- Default: obligor's failure to honor its payment or delivery obligations
- Insolvency
  - Obligor's asset value falls below its liabilities
  - Balance-sheet insolvency does not necessarily lead to default
- Cash-flow insolvency: when a balance-sheet solvent obligor defaults due to illiquidity

Types of Default

- Payment defaults
  - Inability to pay within the grace period
  - Sovereign repudiation or refusal to accept a claim as valid
  - Sovereign moratorium or stoppage of payments for some period of time
- Bankruptcy or bankruptcy protection
- Involuntary debt reorganization
- Other such as conservatorship

Default Risk Models

- Two ways to model default risk
  - Structural models
  - Reduced-form models

Structural Models

- Build on Merton's call option analogy
- Basis for Distance-to-Default measures
- Need to calibrate unobserved asset values
  - Market value proxy
  - Volatility restriction
  - KMV method
  - MLE method

Reduced Form Models

- Statistical relationship between observed defaults and predictors
- Choice of predictors
  - Economic intuition
  - Data mining
- Statistical techniques
  - Discriminant analysis
  - Binary response models: logit/probit
  - Duration analysis
  - Spot intensity models
  - Forward intensity models

Models Need to Factor in Exits other than Default

Year	Active Firms	Defaults	(%)	Other Exit	(%)
1991	4012	32	0.80%	257	6.41%
1992	4009	28	0.70%	325	8.11%
1993	4195	25	0.60%	206	4.91%
1994	4433	24	0.54%	273	6.16%
1995	5069	19	0.37%	393	7.75%
1996	5462	20	0.37%	463	8.48%
1997	5649	44	0.78%	560	9.91%
1998	5703	64	1.12%	753	13.20%
1999	5422	77	1.42%	738	13.61%
2000	5082	104	2.05%	616	12.12%
2001	4902	160	3.26%	577	11.77%
2002	4666	81	1.74%	397	8.51%
2003	4330	61	1.41%	368	8.50%
2004	4070	25	0.61%	302	7.42%
2005	3915	24	0.61%	291	7.43%
2006	3848	15	0.39%	279	7.25%
2007	3767	19	0.50%	352	9.34%
2008	3676	59	1.61%	285	7.75%
2009	3586	67	1.87%	244	6.80%
2010	3396	25	0.74%	242	7.13%
2011	3224	21	0.65%	226	7.01%

Spot vs. Forward Intensity Models

- Instantaneous default and other exit intensities at time t λ_t and ϕ_t
- The spot combined exit forward intensity is

$$\psi_t(\tau) = -\frac{\ln E_t(\exp(-\int_t^{t+\tau}(\lambda_s + \phi_s)ds)}{\tau}$$

- The forward combined exit intensity is

$$g_t(\tau) = \psi_t(\tau) + \psi_t'(\tau)\tau$$

- The forward default intensity is

$$f_t = e^{\psi_t(\tau}\tau \lim_{\Delta_t \to 0} \frac{E_t[\int_{t+\tau}^{t+\tau+\Delta t} \exp(-\int_t^s(\lambda_u + \phi_u)du)\lambda_s ds]}{\Delta t}$$

The Duan-Sun-Wan Forward Intensity Model

- Duan, Sun and Wang (2012, *J of Econometrics*)
  - Two Poisson processes (conditionally independent)
    - Default/bankruptcy
    - Other exits
  - Use spot intensities
    - Instantaneous rate of occurrence
    - Function of covariates
  - Does not require time series dynamics of covariates
  - Forward intensities model explicitly as function of covariates
  - Pseudo maximum likelihood estimation

PD Model Implementation and Database

The Analytical Engine

- The DSW model powers the Credit Research Initiative PD database
- Coverage: 65000 firms in 121 countries
- Data freely available from CRI web site upon registration
  - `rmicri.org`
- Data also available in major data platforms
  - Bloomberg
  - TR Eikon
  - DataScope Select

Data Sources

- Sample period: 1991 - present, monthly data
- Default events
  - Bloomberg
  - Corporate announcements in stock exchanges
  - Credit rating agencies
  - News sources
- Economy-wide risk factors
  - Bloomberg
  - Thomson Reuters Datastream
- Stock market data: Bloomberg BackOffice

Data Sources

- Financial data
  - Bloomberg BackOffice
  - Compustat
- Financial statement data from quarterly/semi-annual/annual reports
- Priority rules applied when multiple data sources are available at the same time skip
- Financial statement data used until next valid statement comes out

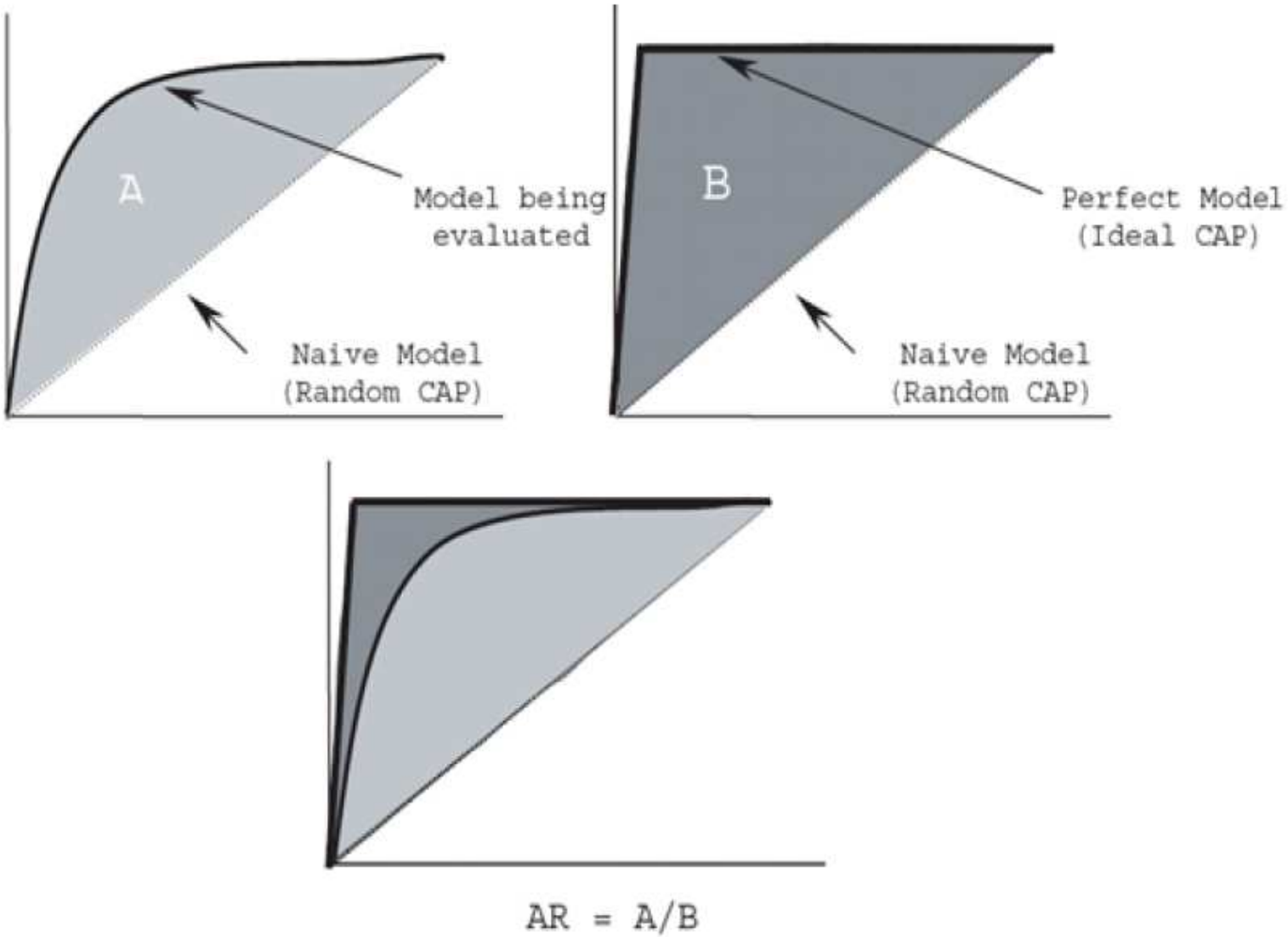
Model Calibration

- Monthly calibration
- Separate calibrations
  - North America
  - Europe
  - Asia-Pacific Developed Economies
  - Asia-Pacific Developing Economies
  - China
  - India
- BuDA imports from the database
  - Calibrated models
  - Risk factors data
  - Historical PDs

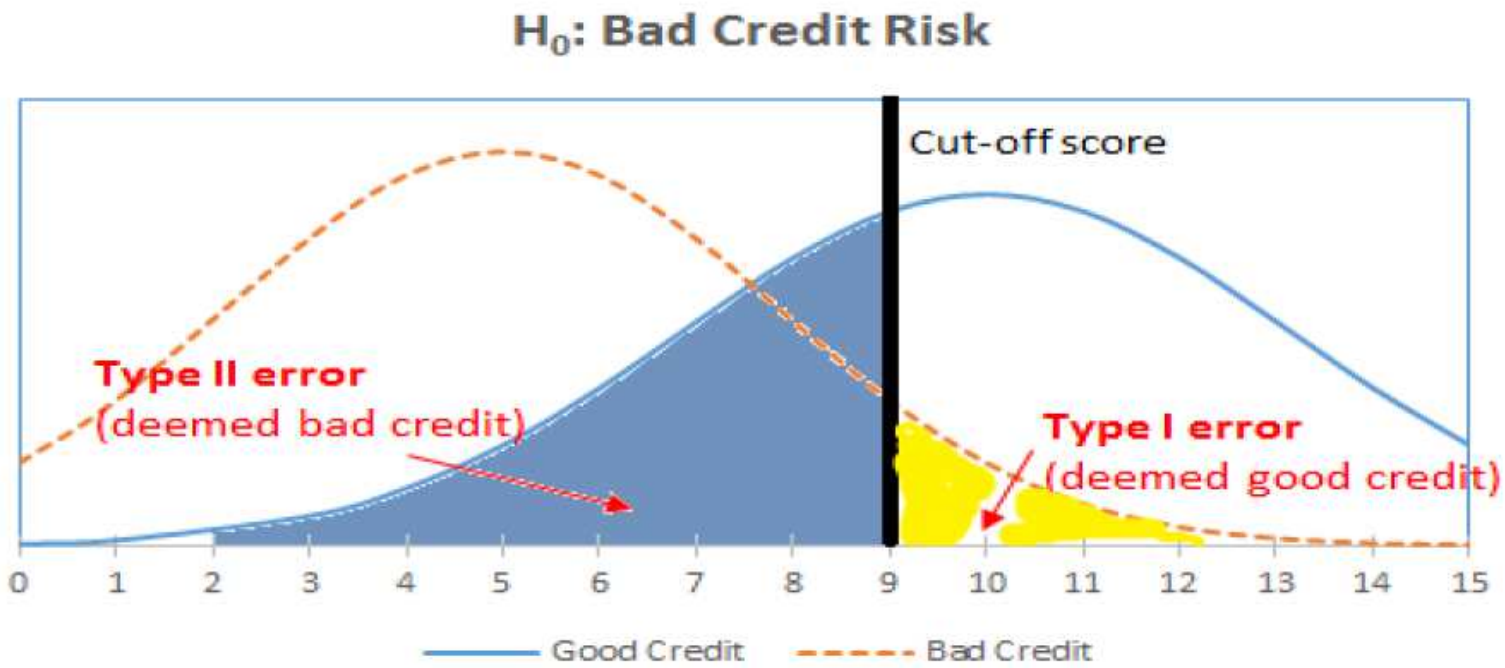
PD Model Accuracy - Accuracy Ratio

- The Cumulative Accuracty Profile (CAP) serves to assess out-of-sample performance
- To plot CAP, order firms by default likelihood in horizontal axis
- In vertical axis, plot percent of actual defaulters with default likelihood at least equal to that in the horizontal axis

PD Model Accuracy - Accuracy Ratio



PD Model Accuracy - Type I and II errors

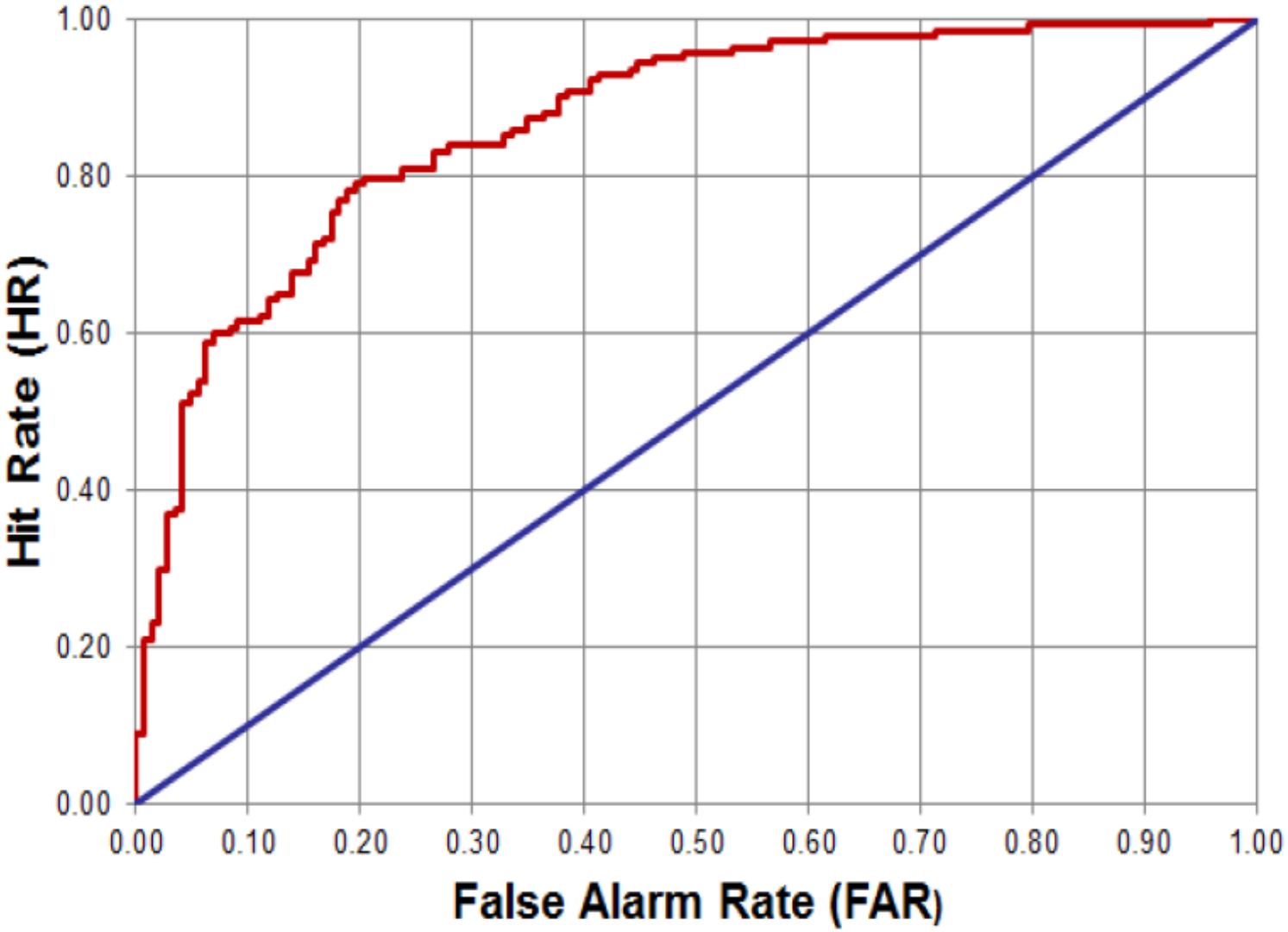


PD Model Accuracy - ROC

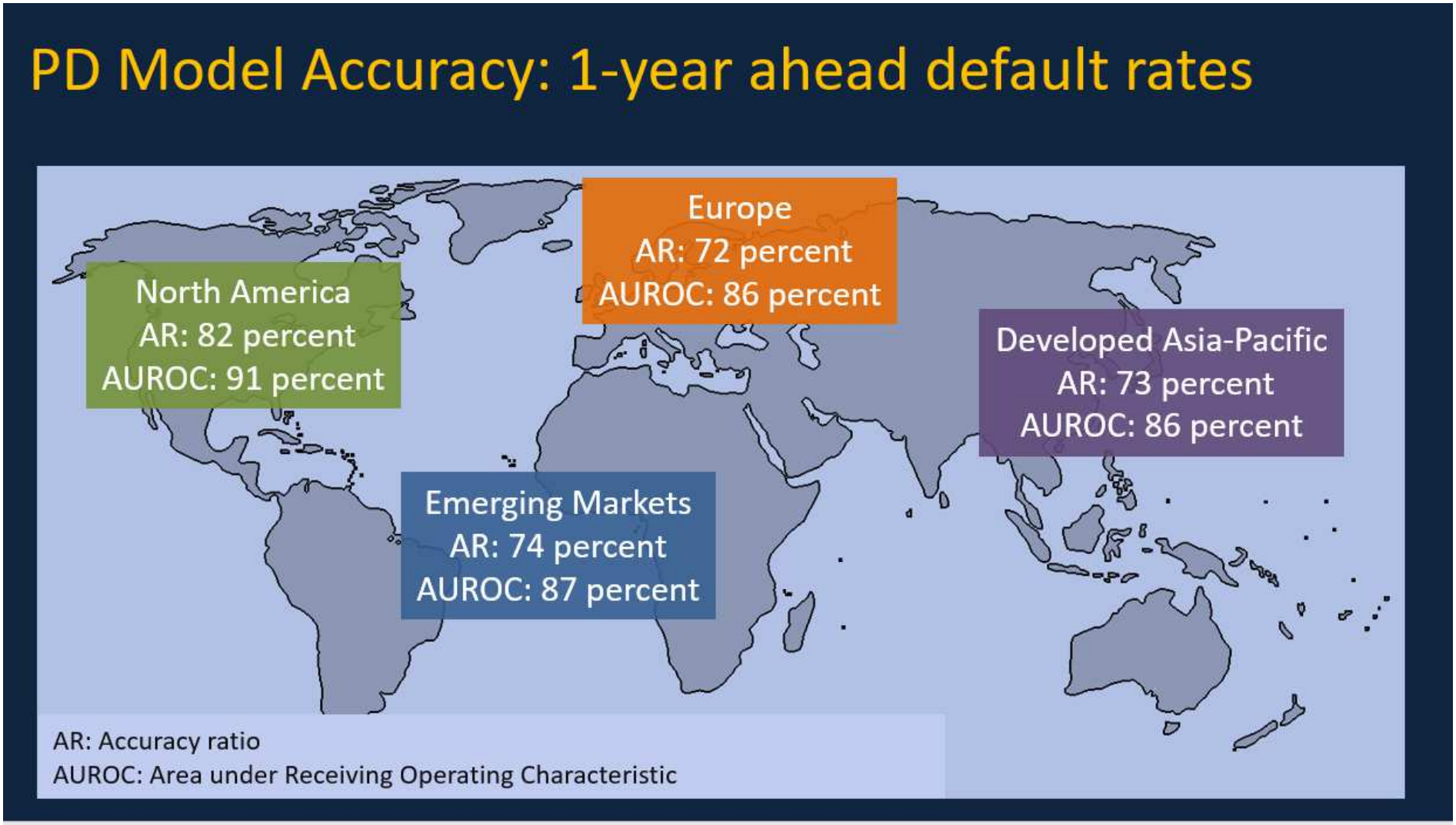
Receiver operating characteristic curve balances Type I and Type II errors

	Classification Decision	
True State	Non-default	Default
Non- default	Score > C (Correct Prediction)	Score $\leq$ C (False Alarm: Type II Error)
Default	Score >C (Miss: Type I Error)	Score $\leq$ C (Hit)

PD Model Accuracy - ROC



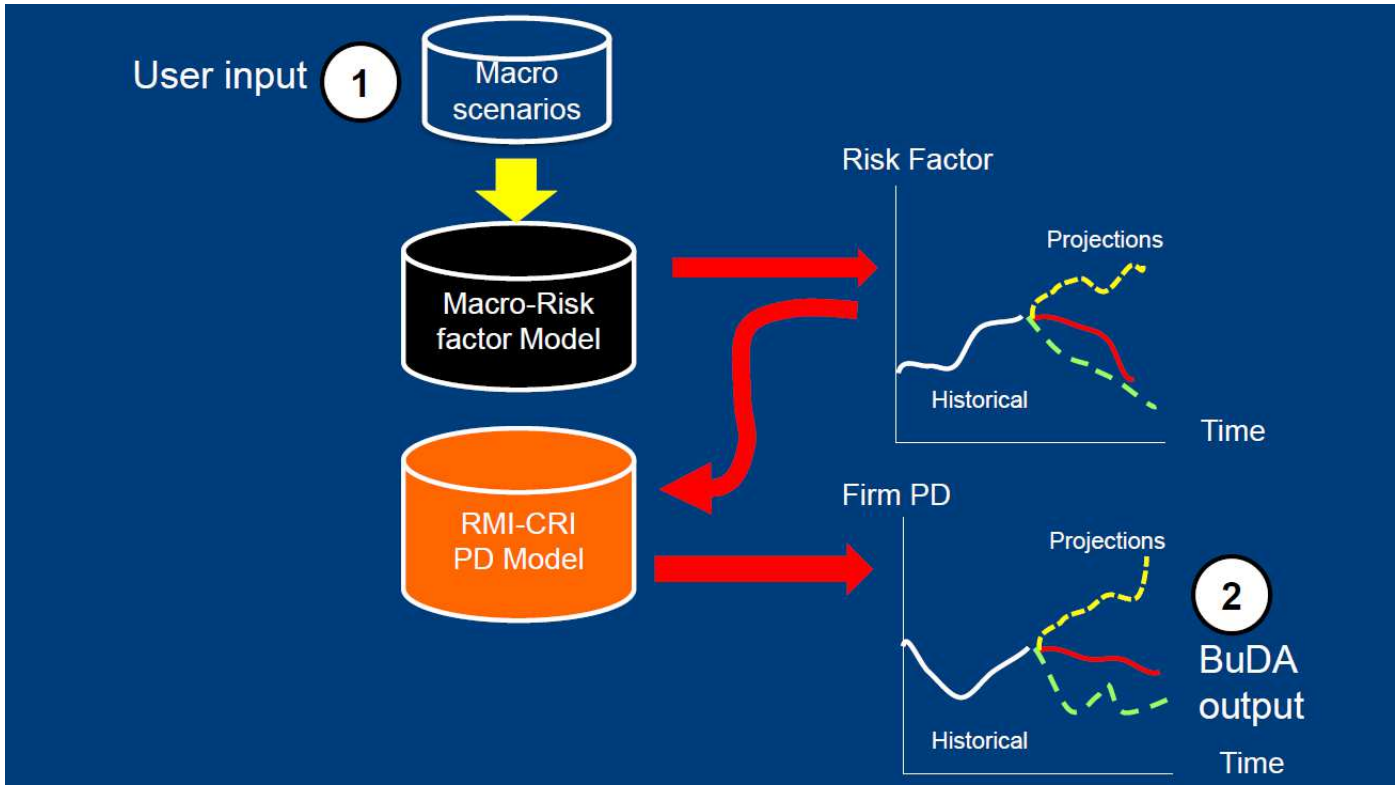
PD Model Accuracy - AR and AUROC



Risk Factor Forecasting

Scenario Analysis Building Blocks

- Recall the Scenario Analysis mechanics



Forecast Risk Factors rather than PDs Directly

- DSW model
  - Uses risk factors as predictors
  - Good performance
  - Highly non-linear
- Forecast risk factors conditional on macro-financial scenario variables rather than PDs directly
- Input risk factor forecasts in DSW model to generate scenario PDs

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1/ The level is computed as the 12-month average value of the factor.
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Forecasting Equations: Start with Industry Averages

Common risk factors

$$\Delta X_{m,t} = \beta^X_{m,0} + \sum_{k=1}^{n} \beta^X_{m,k} Z_{k,t} + \gamma^X_{m,1} X_{m,t-1} + \gamma^X_{m,2} X_{m,t-2} + \varepsilon^X_{m,t},$$

Firm-specific risk factors

$$\Delta \bar{Y}_{i,j,t} = \beta^Y_{i,j,0} + \sum_{k=1}^{n} \beta^Y_{i,j,k} Z_{k,t} + \gamma^Y_{i,j,1} \bar{Y}_{i,j,t-1} + \gamma^Y_{i,j,2} \bar{Y}_{i,j,t-2} + \varepsilon^Y_{i,j,t},$$

X_m: common risk factors, m=1,2

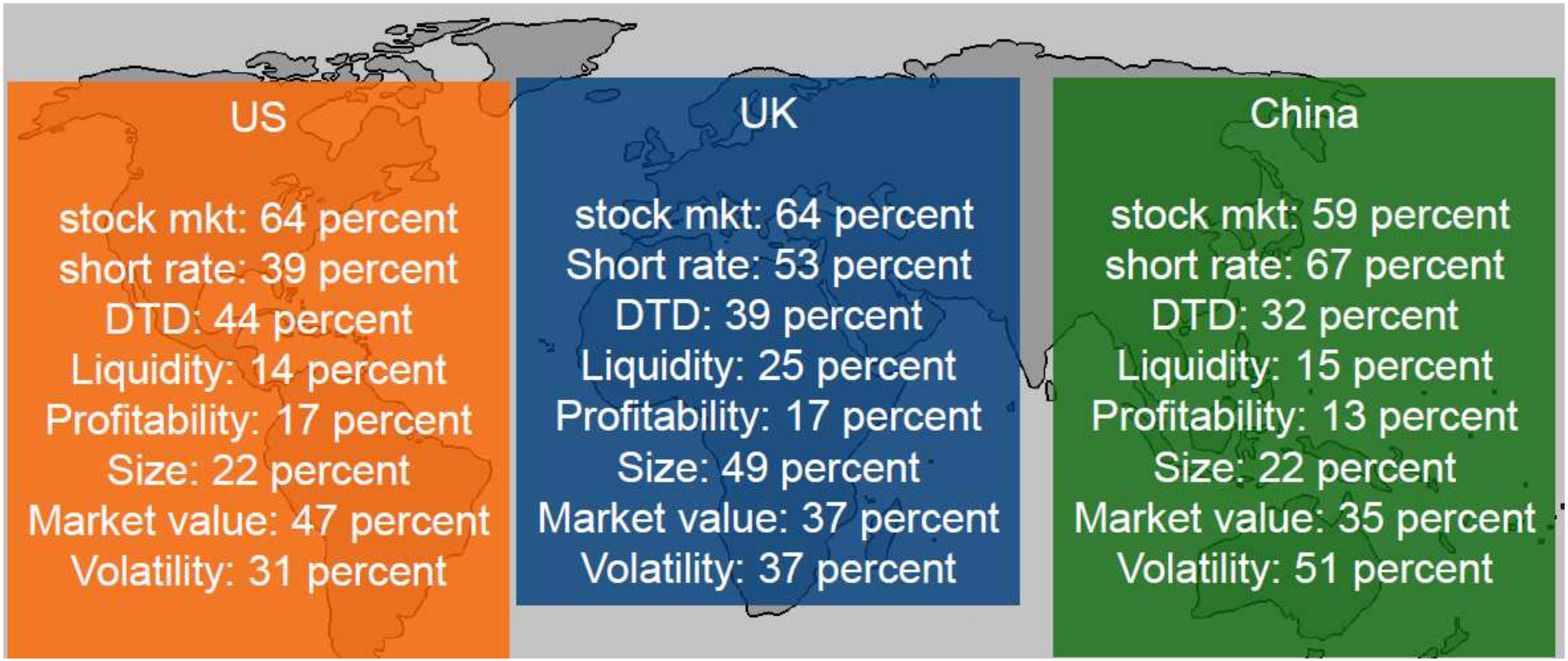
$\bar{Y}_{i,j}$: i-th country industry average of j-th firm-specific risk factor.

Z_k: k-th macroeconomic variable; may or may not contain X_m.

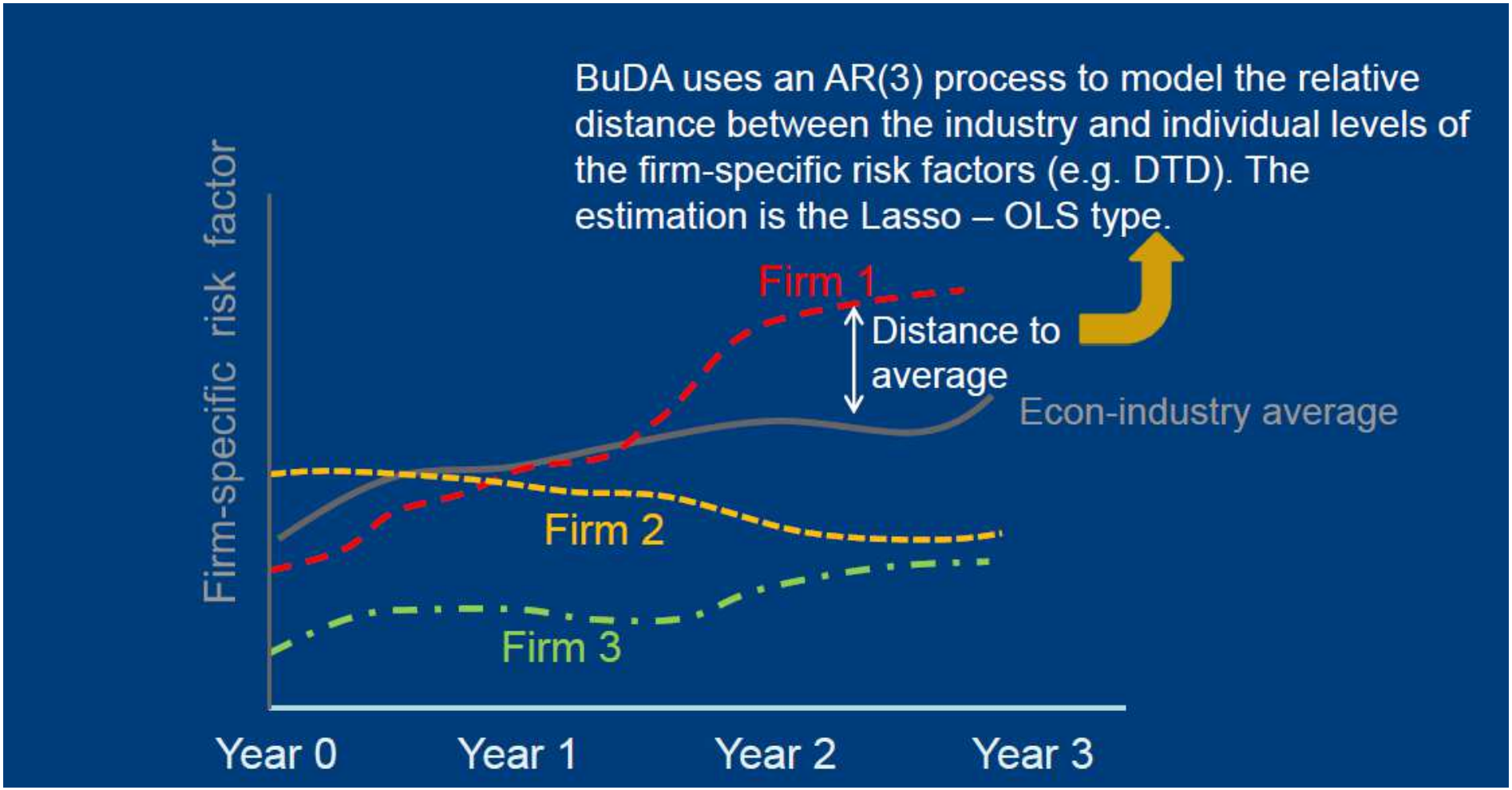
Mixed frequency problem

- Estimating forecasting equations needs dealing with mixed frequency problem
  - Stock index returns and DTD, monthly
  - Macro variables, quarterly
- Interpolate values within quarter
- Time-aggregated regression
  - Parameters less sensitive to interpolation method

Performance of macro-forecasting equations



From Industry Averages to Firm-Specific



Scenario variable contribution to PD forecast

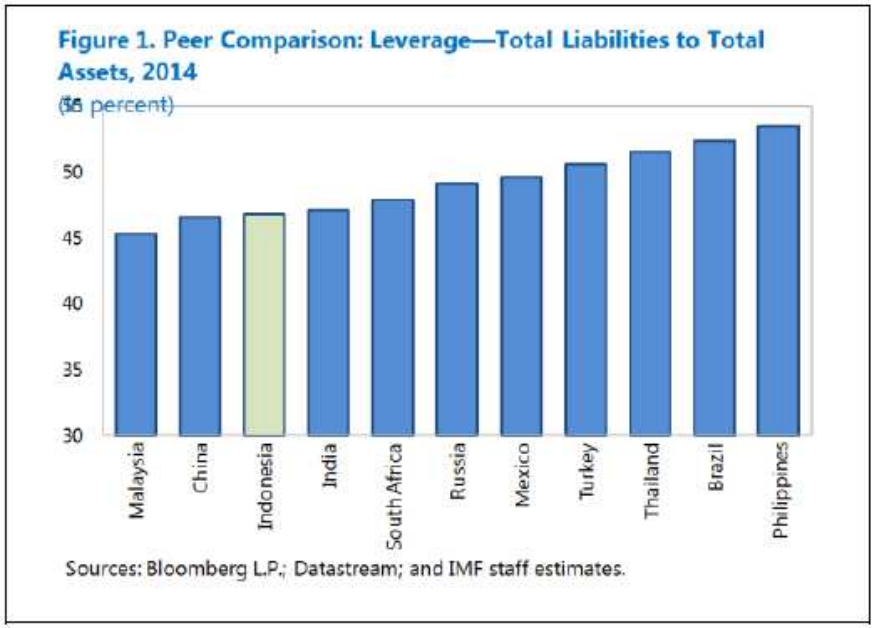
- Numerical assessment of scenario variable contribution to PD forecast
- Calculate PD_{flat} assuming scenario variables stay constant during scenario
- Calculate PD_i, stressed PD if only i-th variable changes, keep others constant
- Difference between PD_{flat} and PD_i is variable contribution
- Now calculate PD_{All}, forecast PD considering changes in all variables
- Add up all individual contributions to PD_{flat}, and substract from PD_{All}. This yields the cross effects

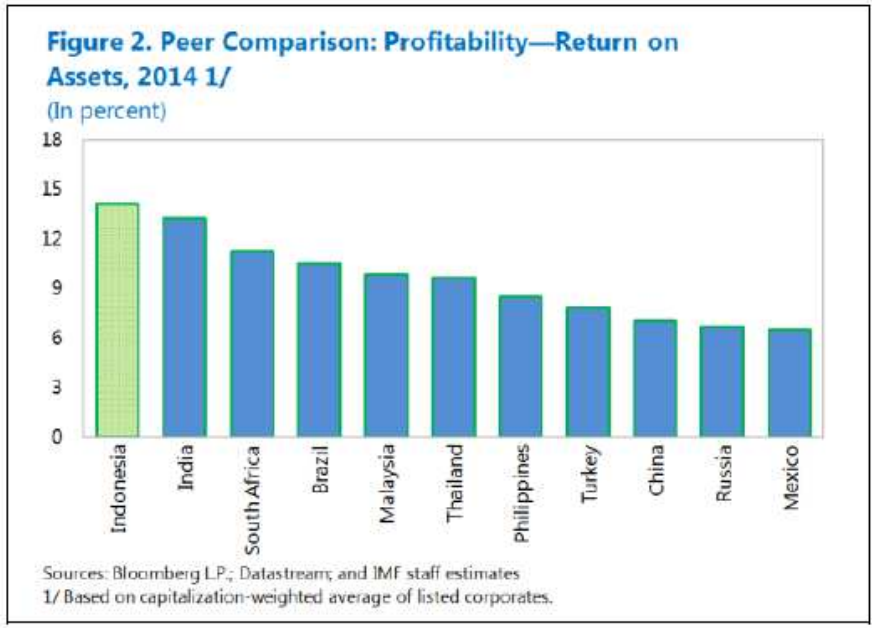
Outline

2016 Article IV Indonesia

Policy Context

- Strong corporate sector vis-a-vis peer economies

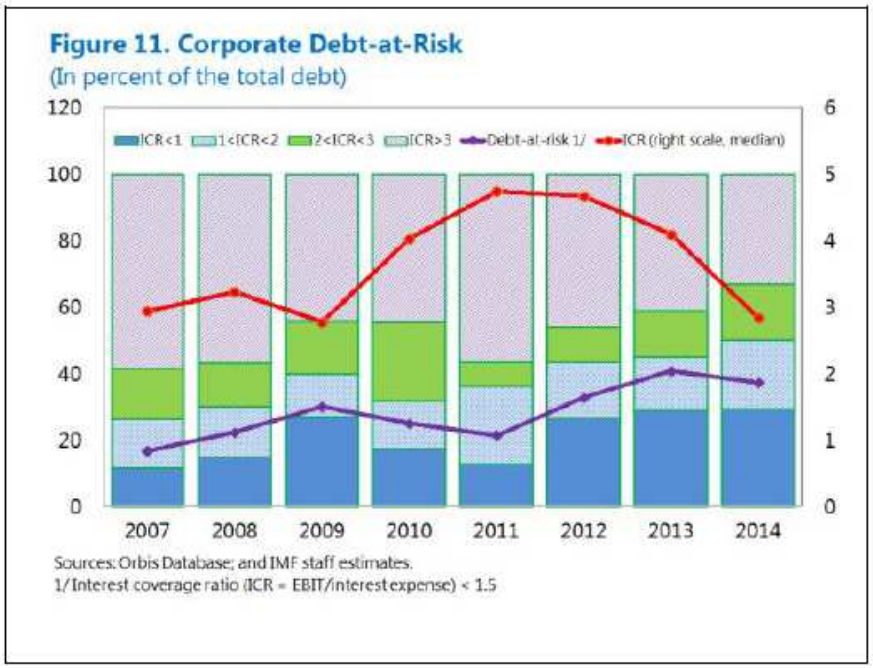


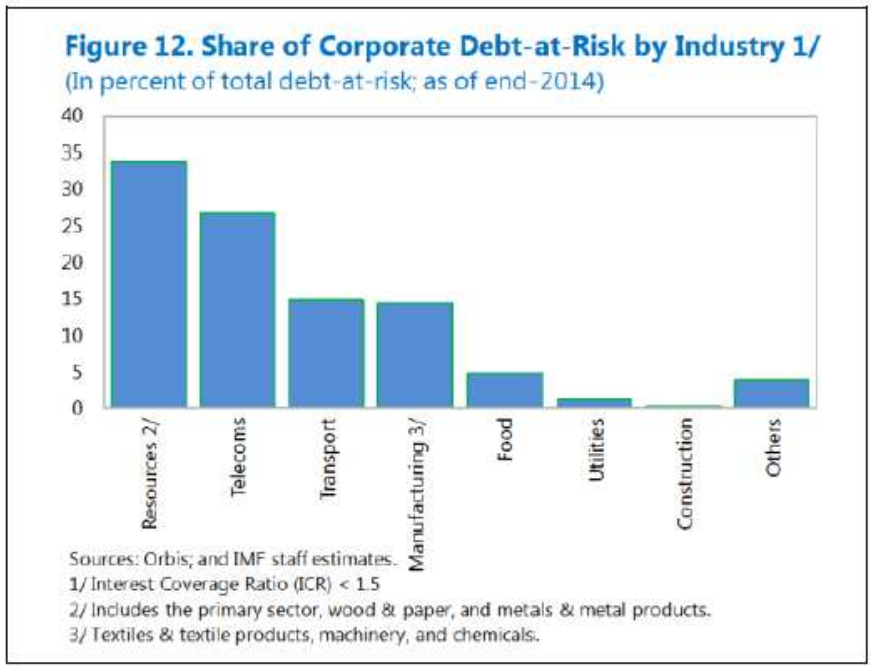


- FX debt equals 60 percent corporate debt
- Interest coverage ratio weakening to 2008 crisis levels

Policy Context

- Deteriorating corporate debt-at risk
- Headwinds
  - Commodity down cycle
  - Slowing economy





BuDA Analysis

- Complements ratio analysis with scenario analysis
- Scenario variables
  - Real GDP growth
  - Unemployment
  - CPI inflation
  - NEER
  - Short-term interest rate

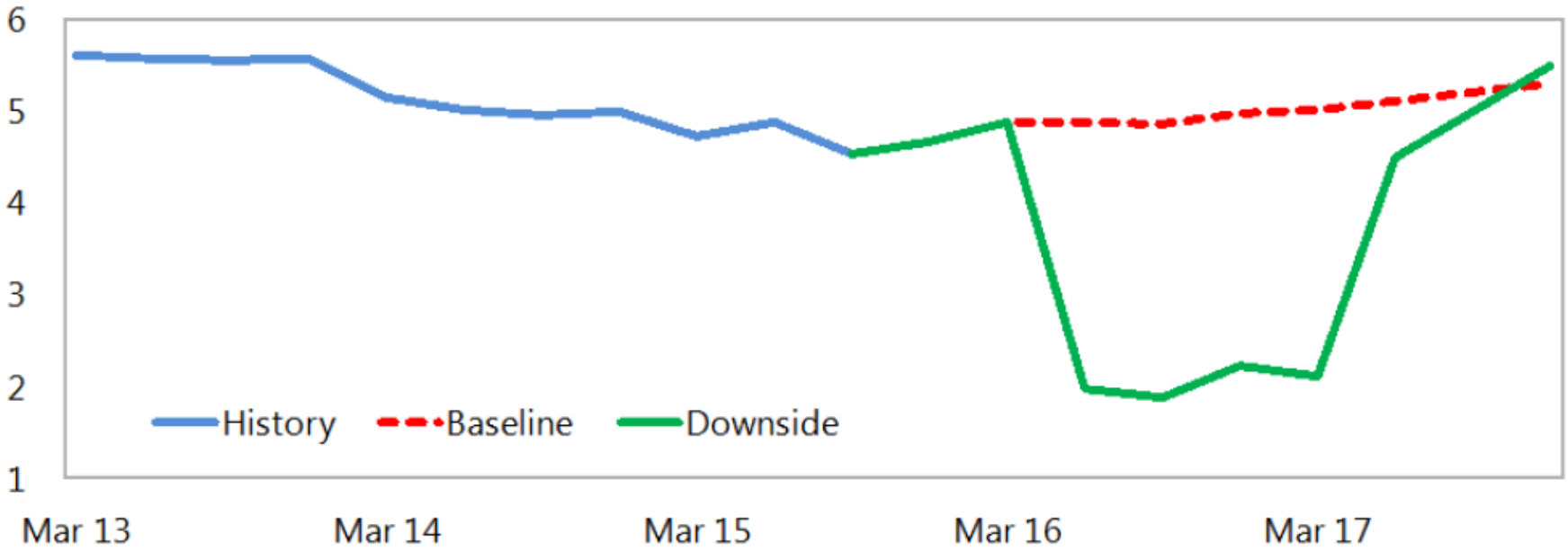
BuDA Analysis

- Baseline scenario
  - Moderate GDP growth
  - Gradual decline in unemployment
  - Falling inflation
  - Range-bound exchange rate
  - Moderate decline in interest rates
- Adverse scenario
  - Sharp drop in GDP growth + V-shaped recovery
  - Drastic jump in unemployment rate
  - Inflation surge
  - Double digit depreciation
  - Interest rate spike

BuDA Analysis

GDP Growth

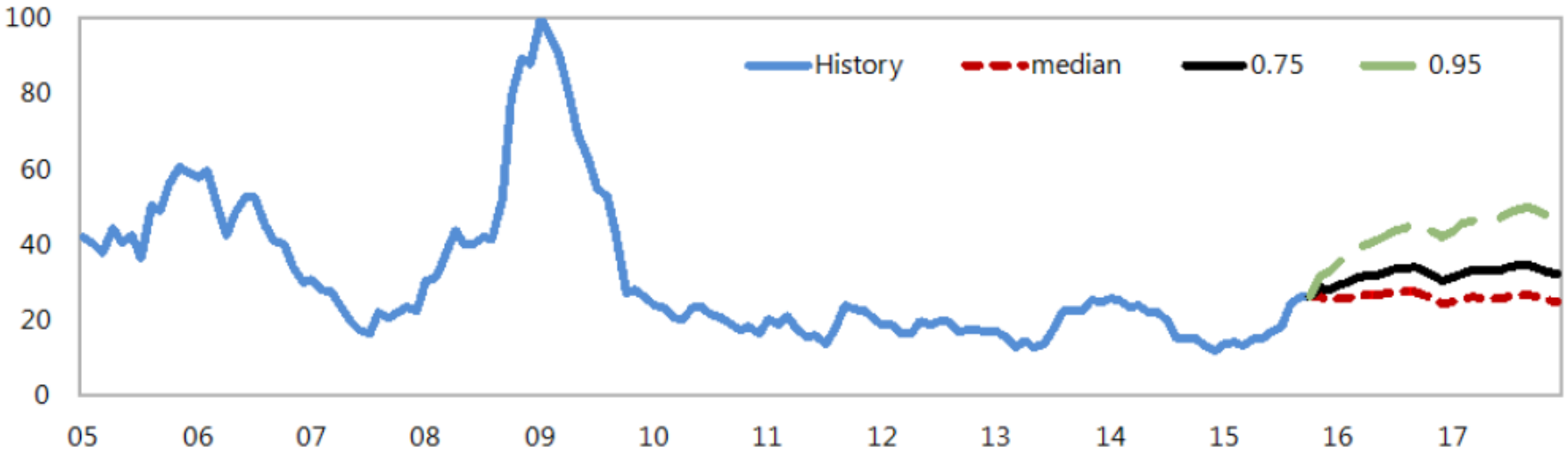
(In percent, year-on-year)



Sources: Haver Analytics Inc.; and IMF staff estimates.

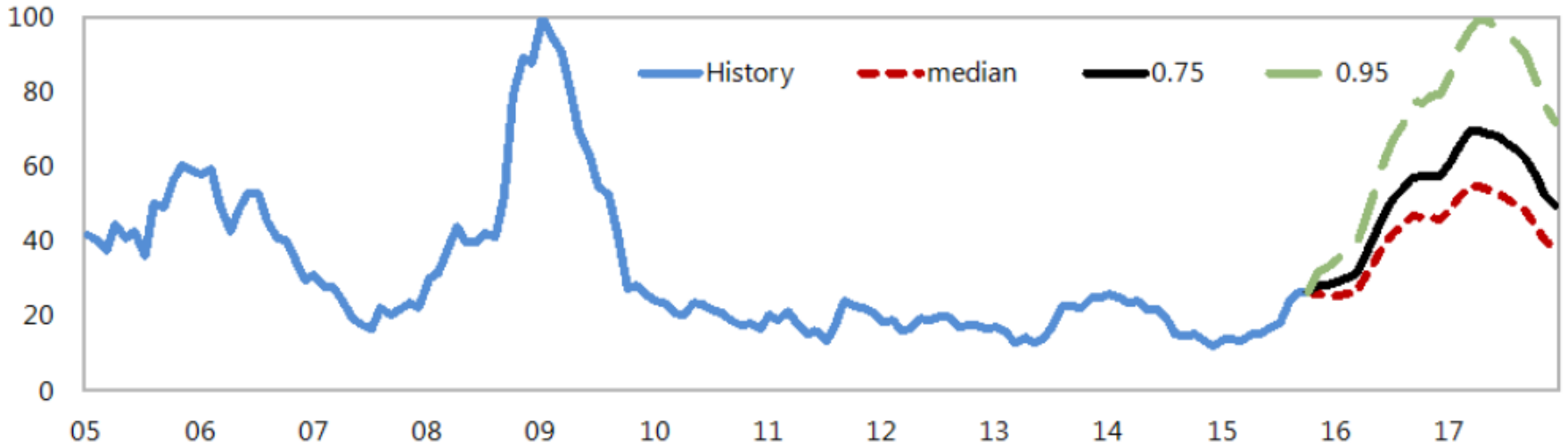
BuDA Analysis

PD Under Baseline Scenario: Mean, 75th and 95th Percentile



Sources: National University of Singapore; and IMF staff estimates.

PD Under Downside Scenario: Mean, 75th and 95th Percentile



2016 Article IV Canada

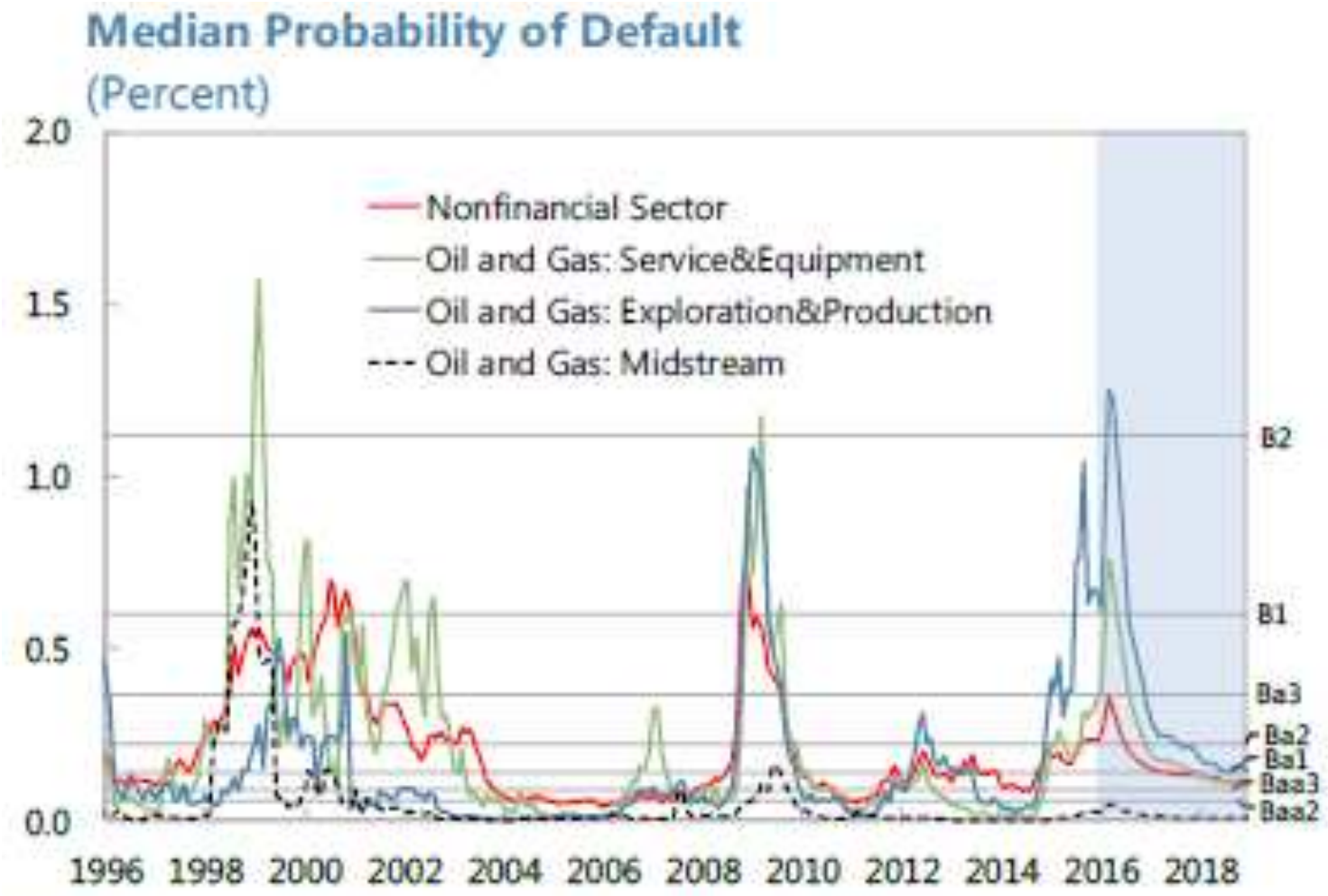
Policy Context

- Rebound of real GDP growth
- Rising unemployment
- Sustained decline in oil prices
- Substantial bank exposure to oil and gas sector
  - Direct and indirect exposure = 13 -15 percent total loans
  - Rising loan delinquencies

BuDA Analysis

- Country desk baseline scenario
- 108 oil and gas companies, of which
  - 72 exploration and production

BuDA Analysis



Sources: IMF staff estimates based on BuDA and Moody's rating grades.

BuDA Analysis

1/ Changes compared to the scenario where the values of the macrovariables are fixed at their December 2015 levels.
2/ Include domestic GDP and unemployment.
3/ Include US growth, short-term and long-term interest rates.
Sources: IMF staff estimates based on BuDA.

2016 Article IV UAE

Policy Context

- Well capitalized, resilient banking system
- Liquidity buffers adequate but declining
- Headwinds ahead
  - Lower oil prices
  - Higher short-term interest rates
  - Non-oil GDP

BuDA Analysis

- Complements panel data analysis of liquidity buffers
- Analysis includes
  - 17 banks
  - 57 non-financial corporates
- 5-year scenarios
- Scenario variables
  - Oil price
  - real non-oil GDP
  - CPI inflation
  - EIBOR interbank rate

BuDA Analysis

Baseline Scenario

- Oil price down to USD 45 bbl, recovers to USD 60 bbl
- Non-oil GDP down to 2.4 percent, improves to 4 percent
- Inflation down to 2.8 percent,rises to 3.6 percent
- EIBOR moves with LIBOR

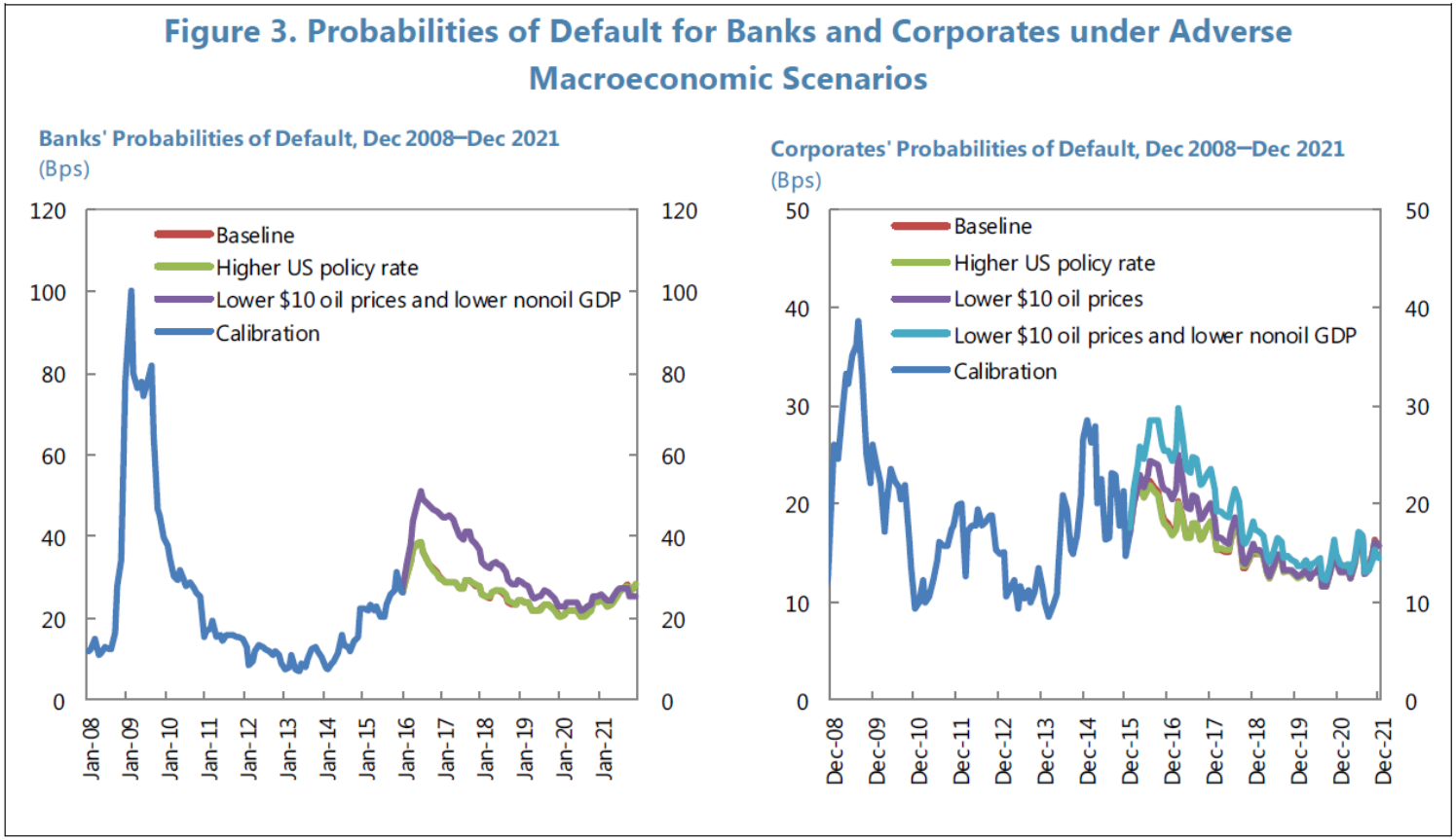
Oil price shock

- Oil price down by USD 10 bbl during 5 years
- Non-oil GDP declines by 1.7 percent
- Stable inflation
- EIBOR moves with LIBOR

Interest rate shock

- EIBOR increases by 100 bps

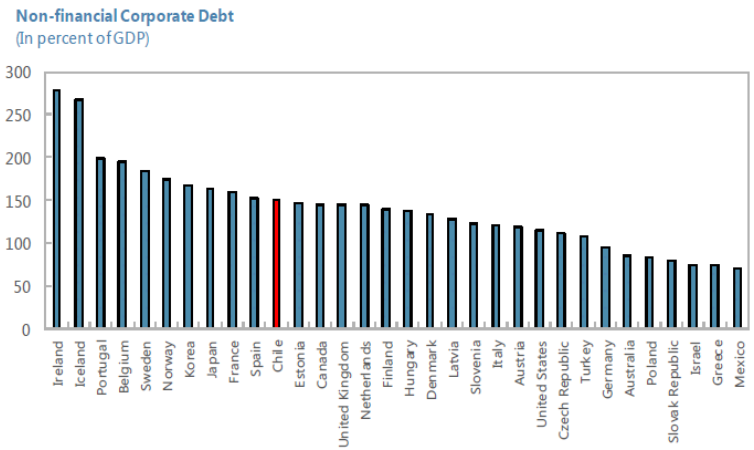
BuDA Analysis

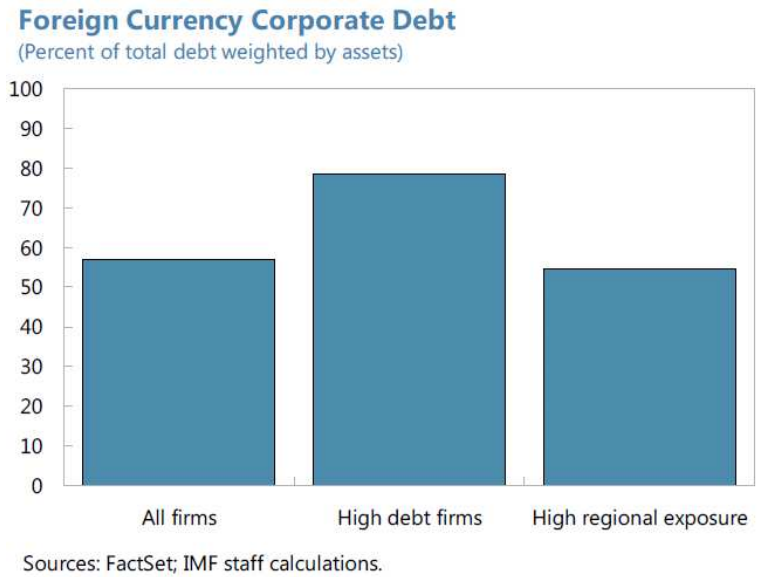


2016 Article IV Chile

Policy Context

- Corporate debt high vis-a-vis peers
- FX debt higher for highly levered non-financial firms
- High regional exposure of corporate sector





BuDA Analysis

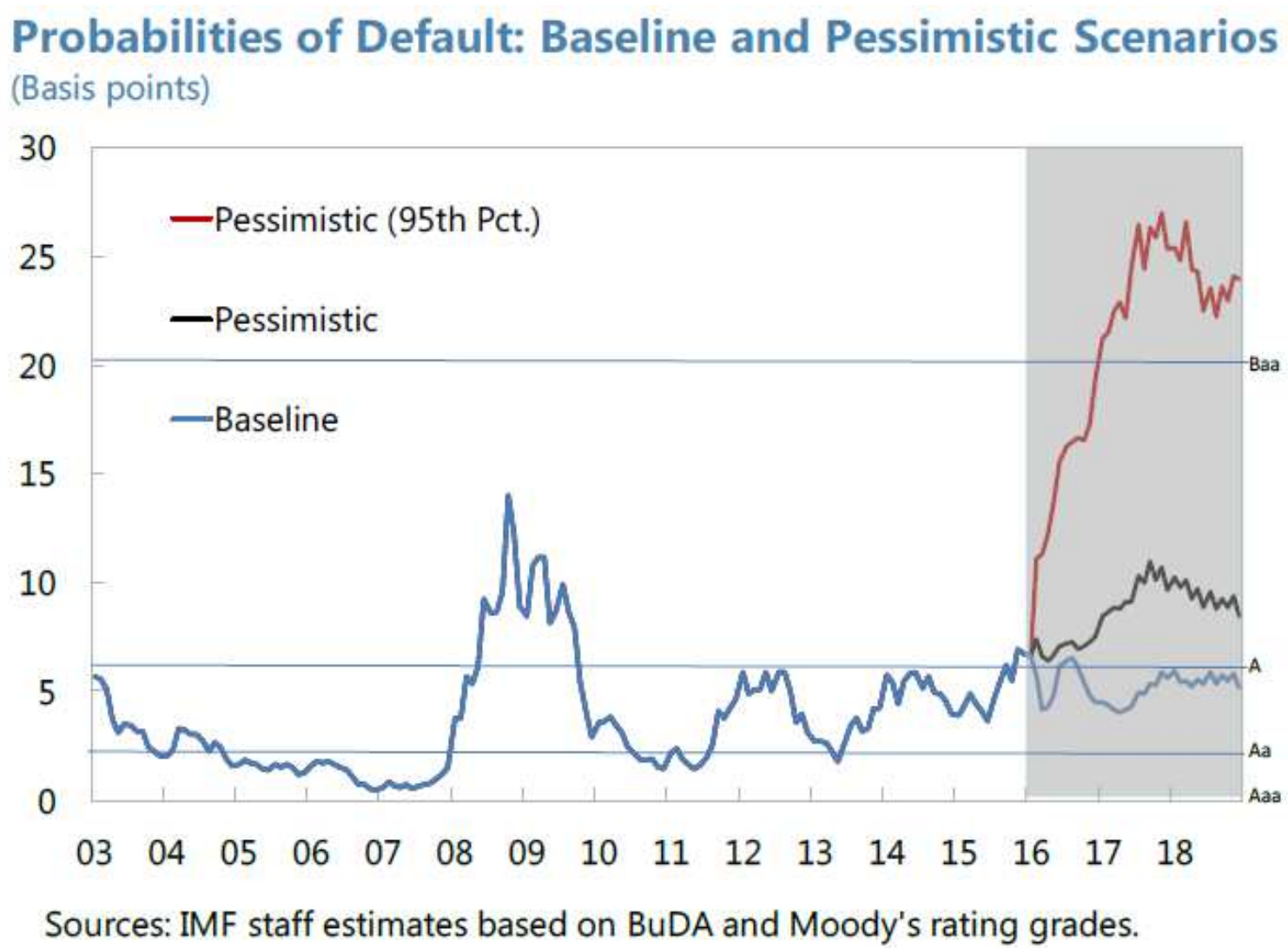
- Multiapproach analysis
  - Balance sheet analysis
  - Network analysis
  - BuDA Analysis

BuDA Analysis

Scenarios

- Baseline
  - Country desk projections
  - GDP growth
  - Unemployment
  - CPI Inflation
- Pessimistic
  - Growth slowdown by 5 percent
- Regional Downturn
  - Growth slowdown by 5 percent partner countries
  - Elasticity pass-through 0.3

BuDA Analysis



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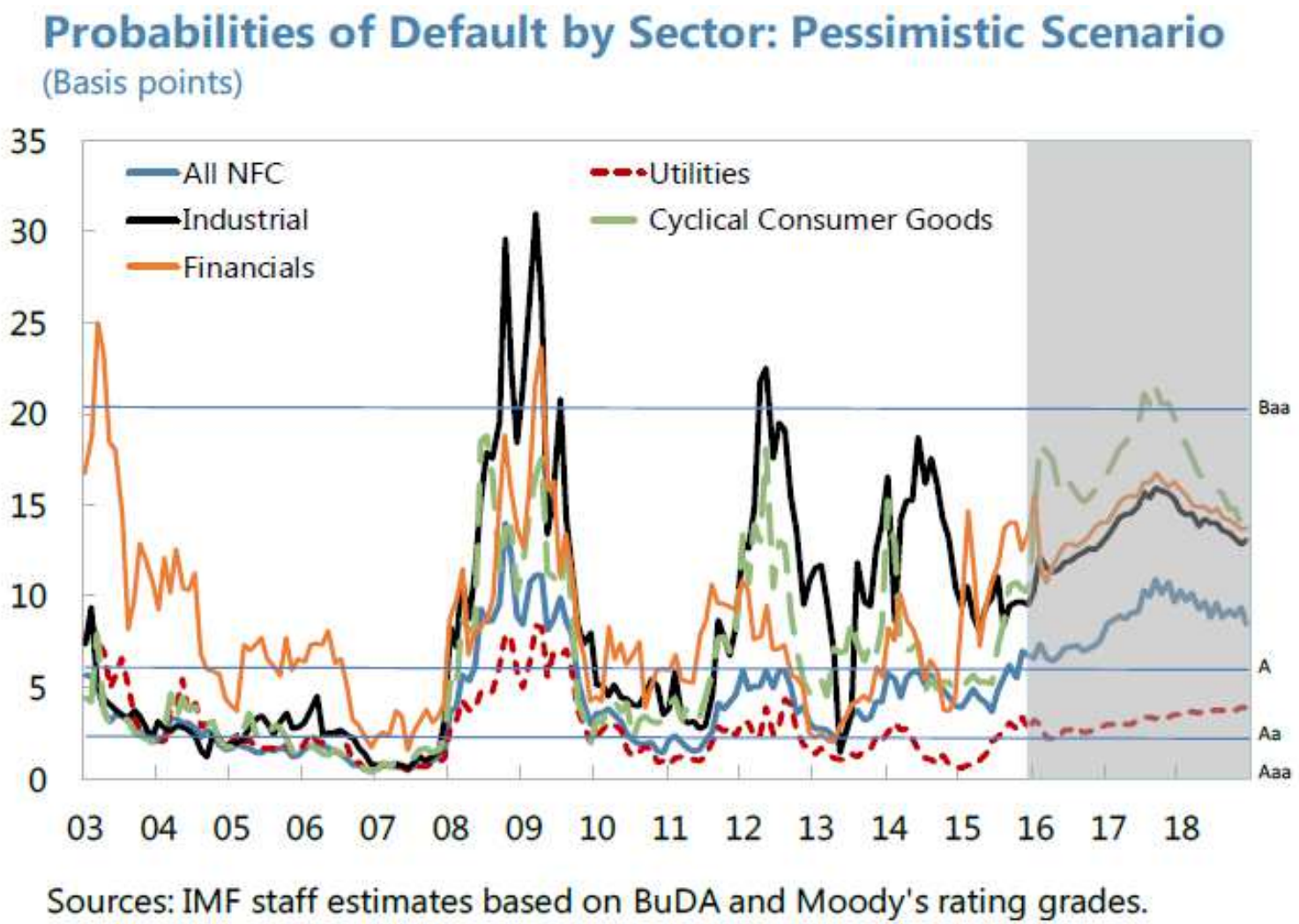
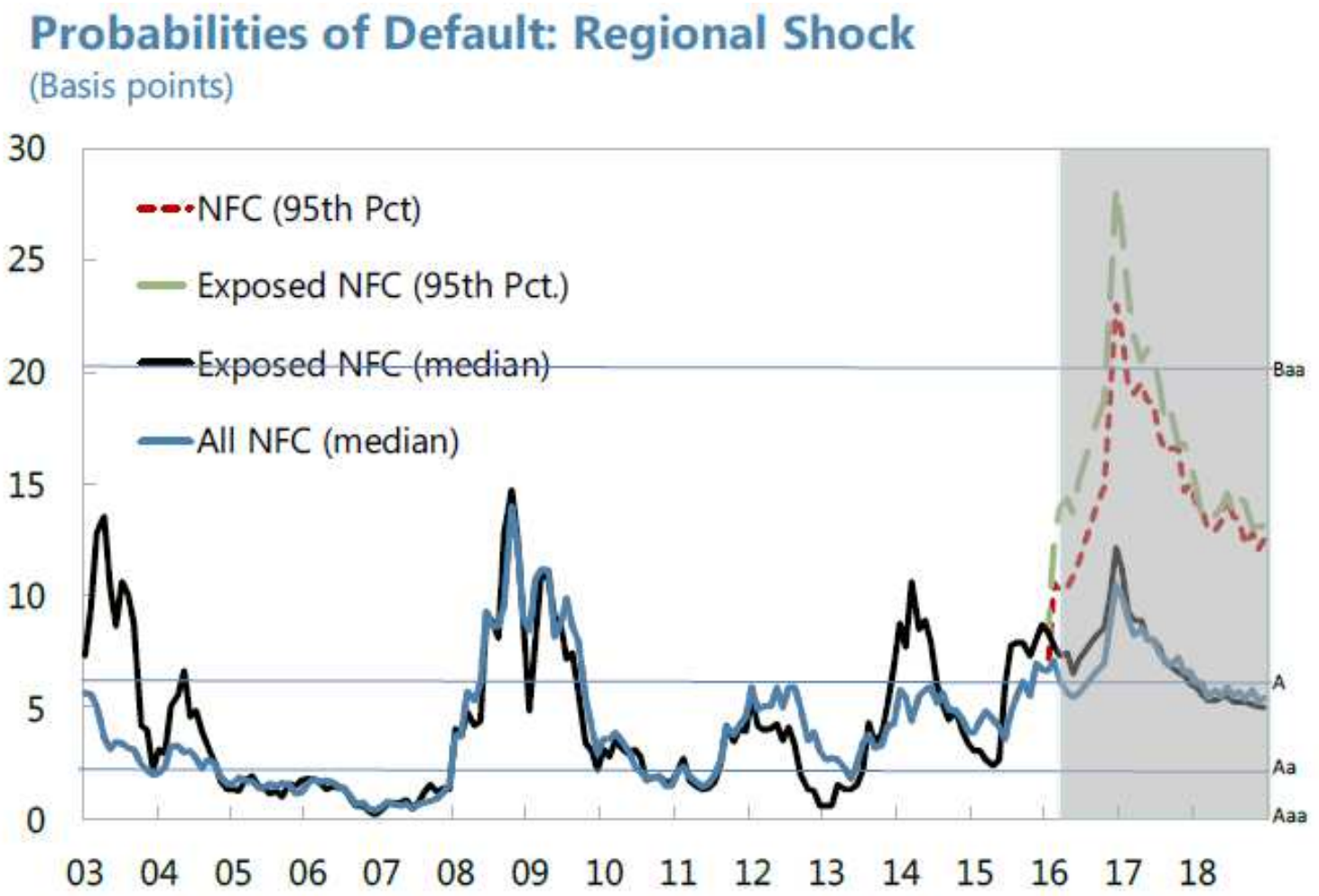


BuDA Analysis



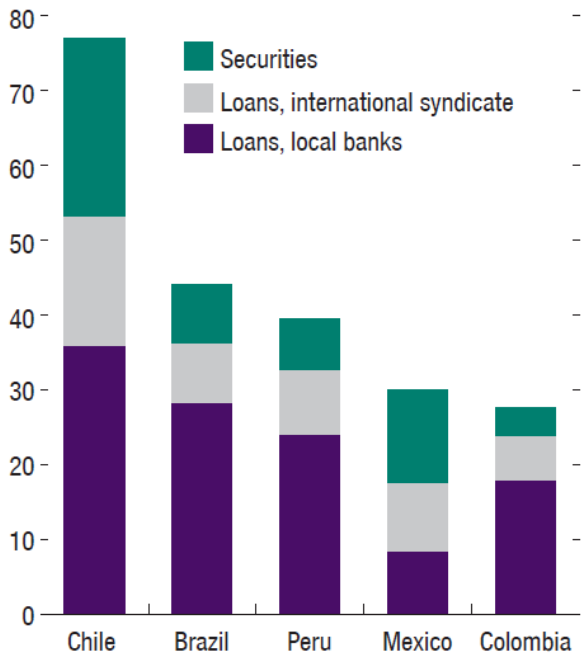
Sources: IMF staff estimates based on BuDA and Moody's rating grades.

2016 WHD Regional Economic Outlook

Policy Context

- Macro deterioration in the region
- Declining commodity prices
- High levels of corporate debt
- Potential increase in corporate solvency risk
- Spillovers from corporates to banks

Figure 3.1.1. Nonfinancial Corporate Debt by Instrument
(Percent of GDP, 2014)



Sources: Bank for International Settlements; Dealogic; IMF, International Financial Statistics database; and IMF staff calculations.

BuDA Analysis

Scenarios

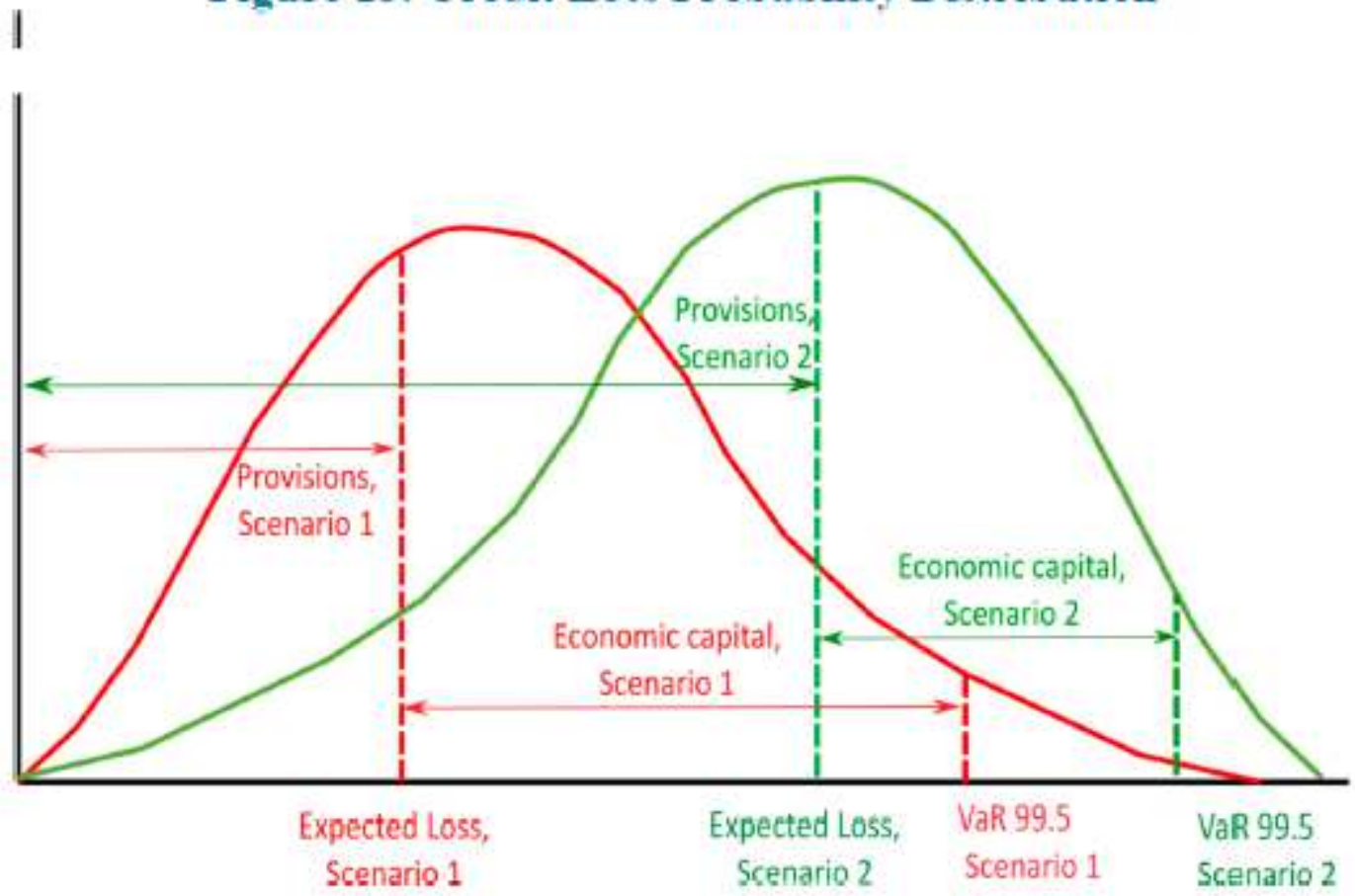
- Based on desk baseline projections
- Domestic variables
  - Real GDP growth
  - Nominal exchange rate
- External variables
  - Commodity prices (oil and metals)
  - Aggregate demand conditions in advanced economies
  - External borrowing costs

BuDA Analysis

Bank Provisions and Capital

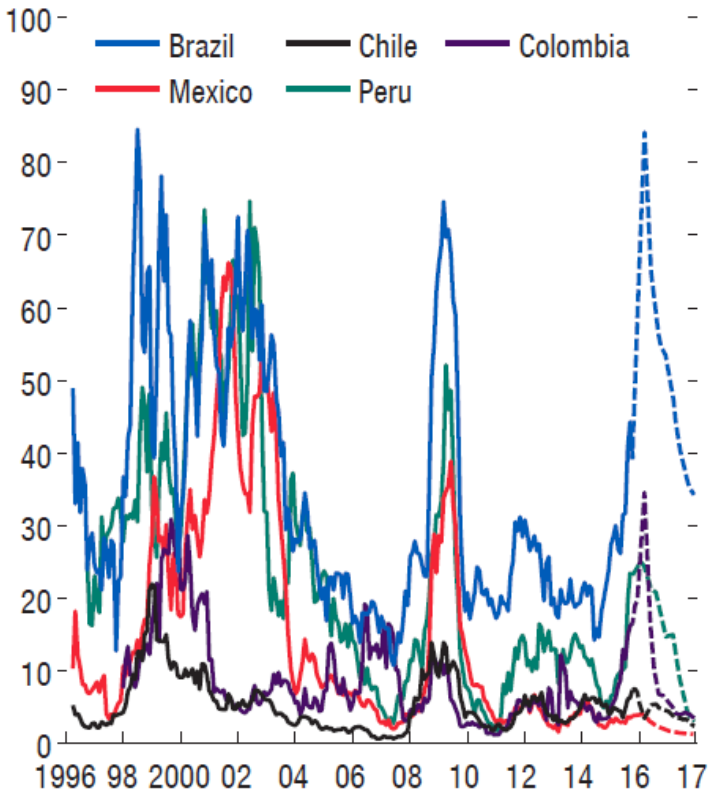
- Assumes homogeneous corporate loan portfolio
- Models loss distribution using single factor model

Figure 13. Credit Loss Probability Distribution



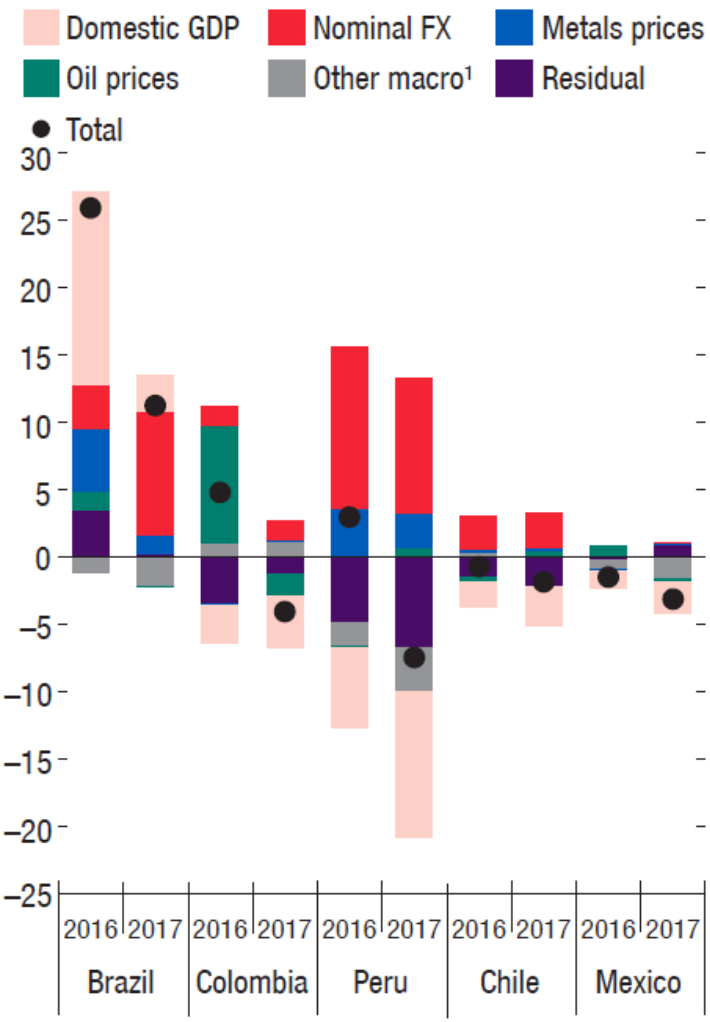
BuDA Analysis

Figure 3.1.3. Probabilities of Default in the Nonfinancial Corporate Sector
(Median probability across firms in each country, basis points)



Sources: Credit Research Initiative at the Risk Management Institute (National University of Singapore), and IMF staff calculations.

Figure 3.1.4. Contributions to Changes in Projected Corporate Probabilities of Default
(Median probability of default, basis points)



BuDA Analysis

Table 3.1.1 LA5: Required Provisions and Economic Capital
(Percent of GDP)

	Provisions		Economic Capital	
	2015[1]	2016–17[2]	2015[1]	2016–17[2]
Brazil	1.3	2.2	3.7	5.1
Chile	1.4	1.1	7.6	6.1
Colombia	1.2	1.3	4.7	4.1
Mexico	0.4	0.3	2.3	1.7
Peru	0.6	0.8	4.4	5.5

Source: IMF staff calculations.
Note: LA5 = Brazil, Chile, Colombia, Mexico, and Peru.
[1]Provisions (capital), as of October 2015, against corporate loans, estimated as total provisions (capital) multiplied by the ratio of commercial to total loans.
[2]Average.

Outline

Conclusions

- Effective surveillance requires capturing macro-financial linkages
- BuDA uses a bottom-up approach which
  - Brings timely market information and balance-sheet data together
  - Uses modern default risk models
  - Allows for the specification of flexible macro-financial scenarios
  - Enables scenario analysis and stress tests at individual firm level
- BuDA supports bilateral and multilateral financial surveillance
- BuDA is a stand-alone Matlab open-source program
  - Welcomes users' cooperation for further improving the platform
  - Available upon request, please email us at `jchanlau@imf.org` (Chan-Lau) and `bizdjc@nus.edu.sg` (Duan)

Thank You

References

- Credit Research Initiative, NUS. 2017. NUS-RMI Credit Research Initiative Technical Report.
- Duan, J.C., Miao, W., Chan-Lau, J.A. 2017. Bottom-Up Default Analysis (BuDA) User Manual. Version 2.0
- Duan, J.-C., Miao, W., Wang, T. 2015. Stress Testing with a Bottom-Up Corporate Default Prediction Model. RMI Working Paper
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