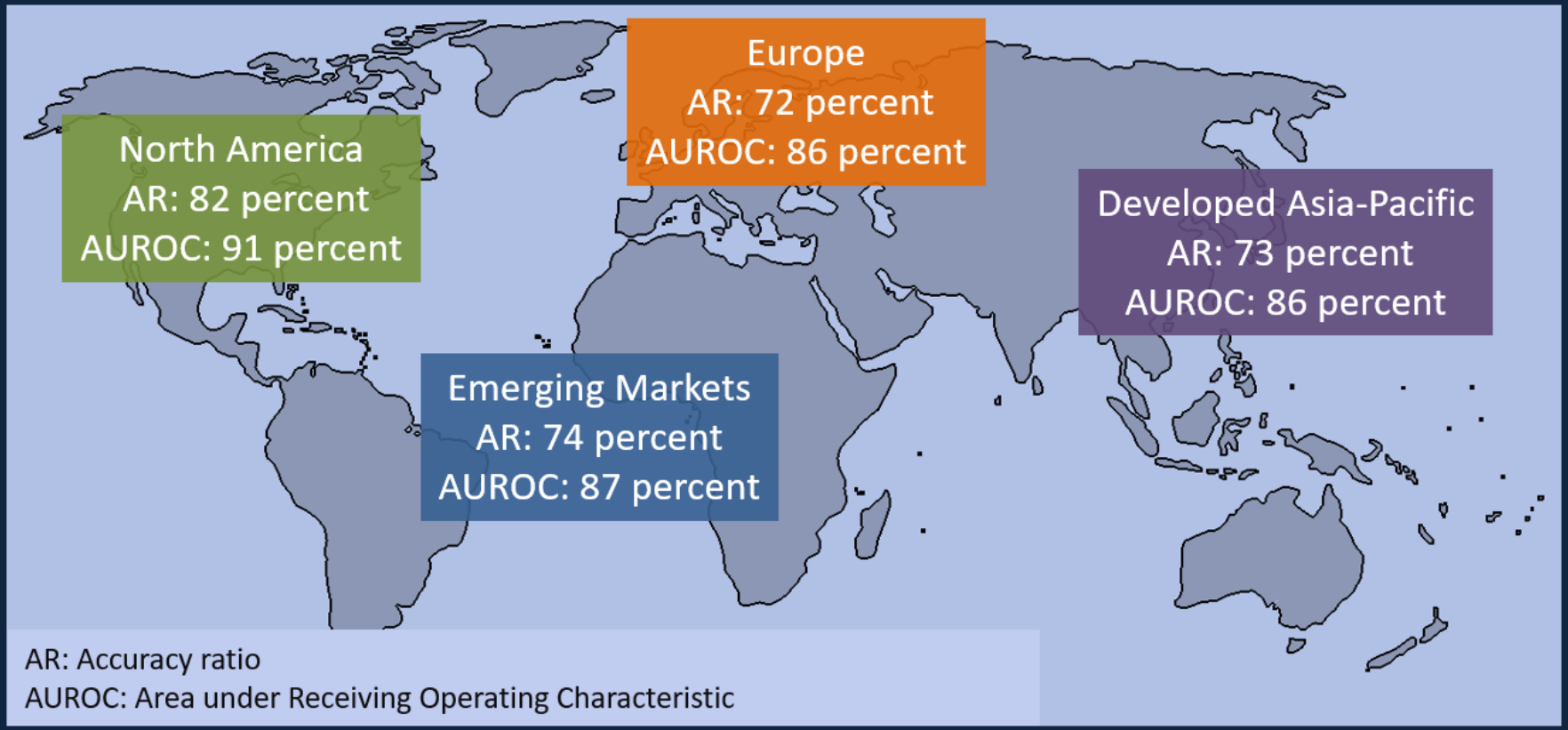
PD Model Accuracy: 1-year ahead default rates



AR: Accuracy ratio
AUROC: Area under Receiving Operating Characteristic

Bottom-up Default Analysis (BuDA)

— Methodology and Applications

Jorge A. Chan-Lau[1] **Jin-Chuan Duan**[2] **Wei Sun**[3]

[1] Institute for Capacity and Development
International Monetary Fund

[2] NUS Business School and Credit Research Initiative
National University of Singapore

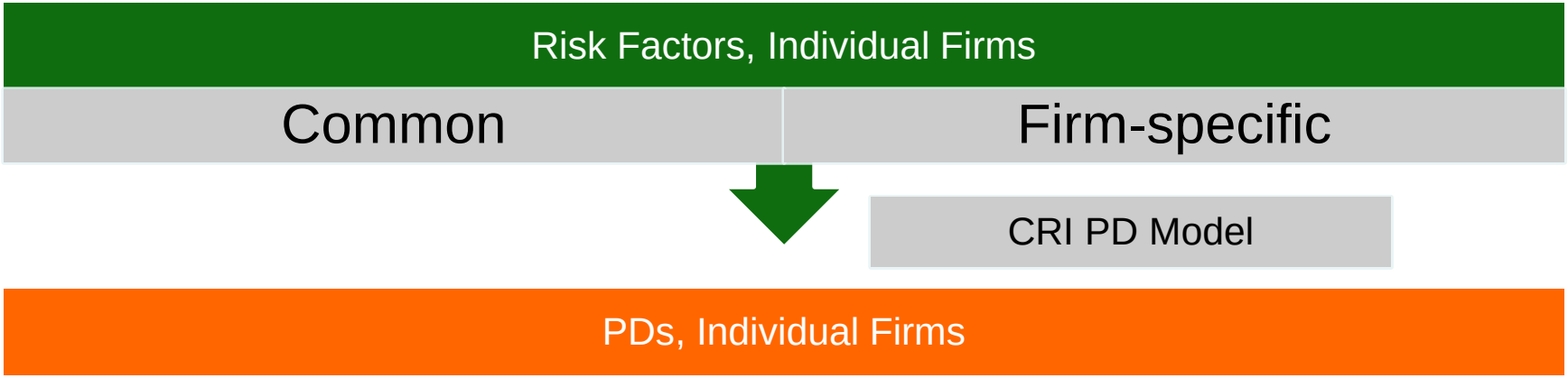
[3] Credit Research Initiative
National University of Singapore

International Monetary Fund, Washington DC, July 17-18, 2017

The BuDA Approach

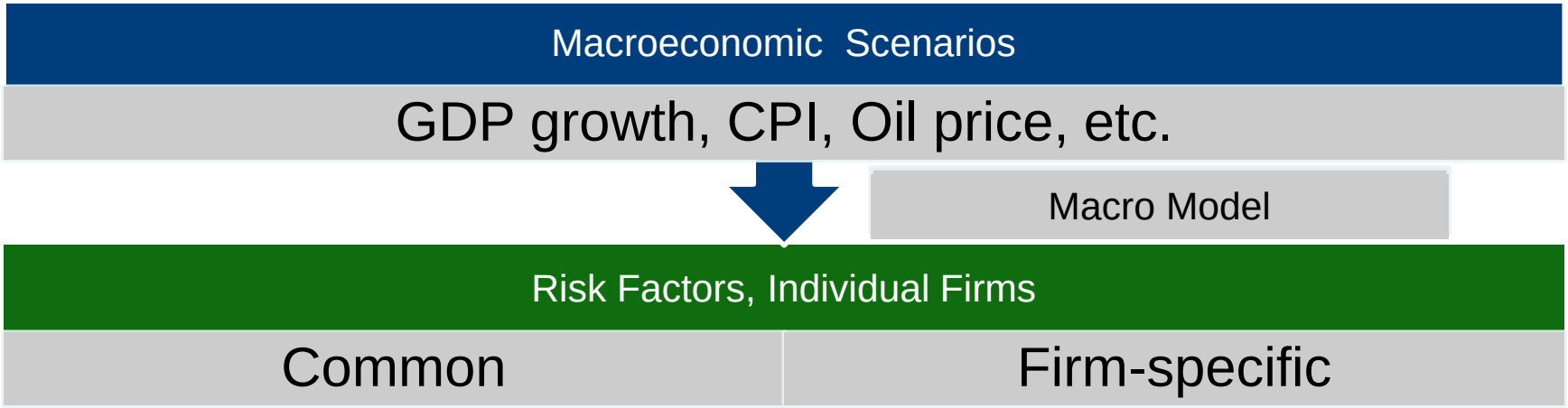
The approach has two components:

- The first is the CRI PD model that links risk factors (e.g. DTD, profitability, etc.) with PD.



The BuDA Approach

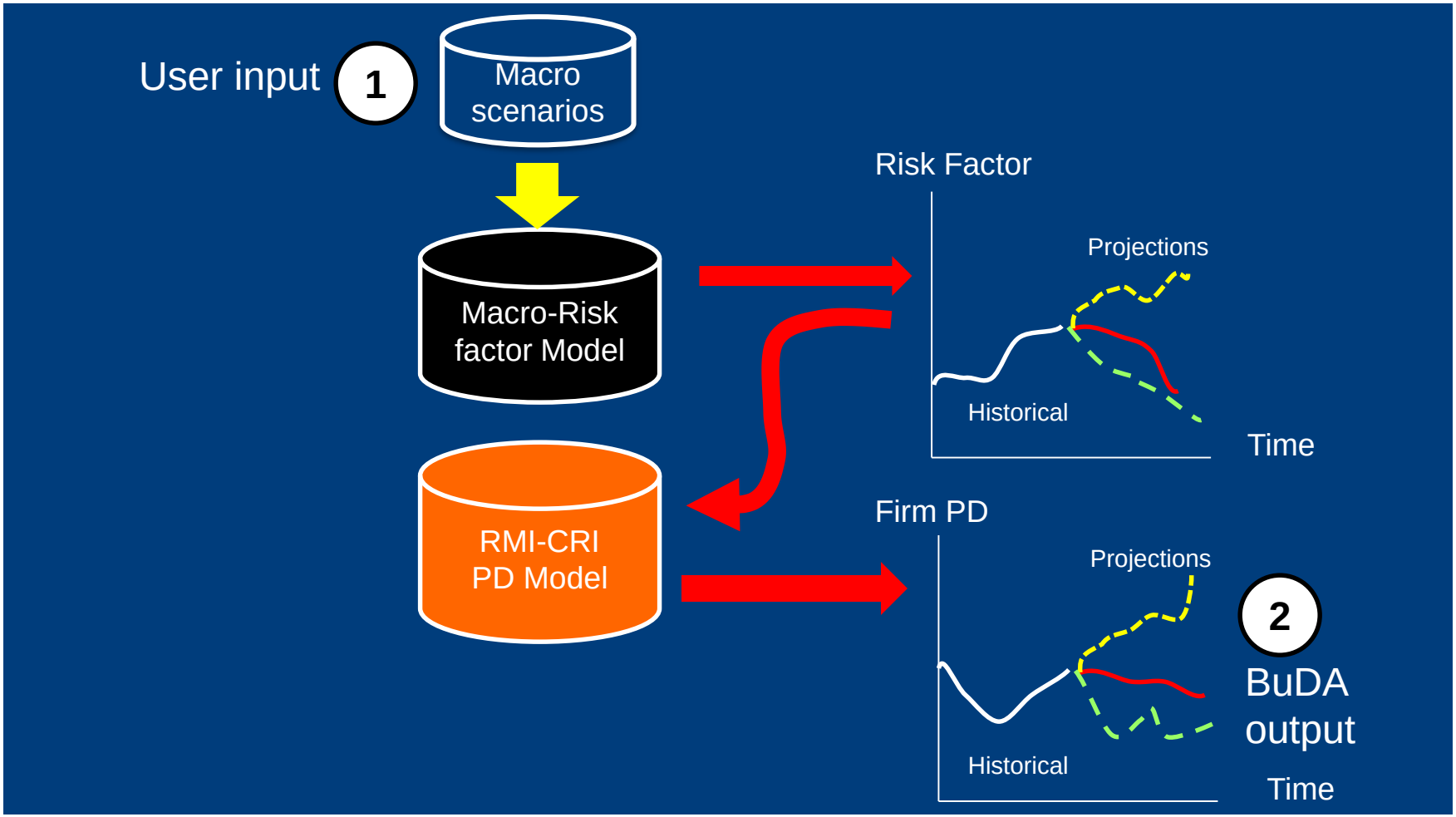
- The second is the macro-risk factor model that links macro-financial factors with PD predictors.



- Model parameters are estimated using historical data.

The BuDA Approach

Under the scenarios characterized by future paths of the stress variables (e.g. world's GDP growth drops to 2% over 2017-2019), BuDA outputs the PD projections for the specified future.



Why Not Link PD and Stress Vars Directly?

- If one has a PD model, it makes sense not to ignore the functional form (maybe non-linear) that links inputs with PD. In this case, one can still use the two-step BuDA approach to do stress testing.

- If one has default frequencies/PDs generated from an unknown model, he has no choice but to directly regress his data on the macro stress variables. In this case, the default data can be quite noisy (e.g. many zeros) or non-stationary for individual series.

The Risk Factors in the CRI PD Model

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

Macro Model for Predicting Risk Factors

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.

Why Not Regress on Y Directly?

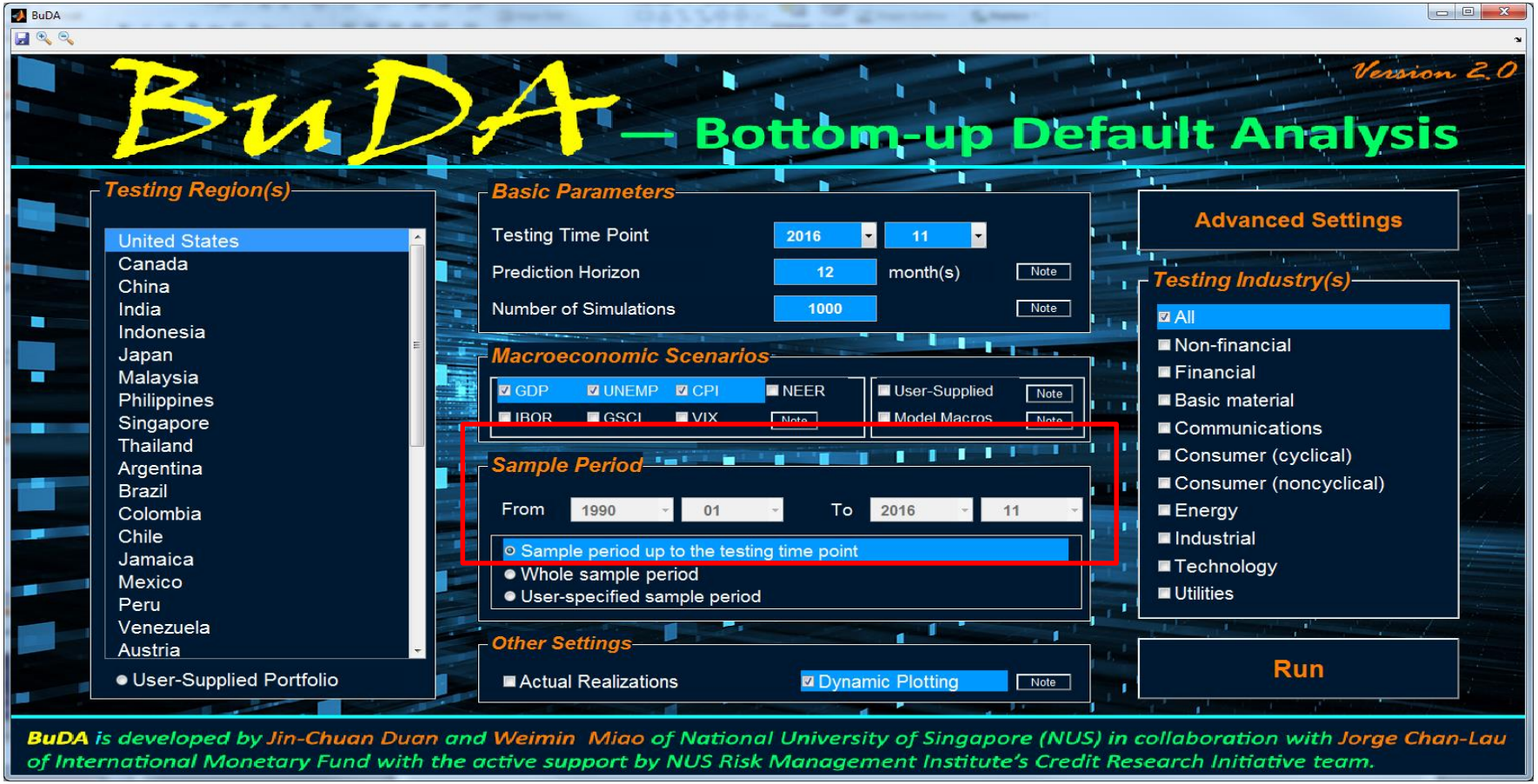
- Y, e.g. the individual DTD series, might not be stationary (e.g. in absorbing state). It is hard to model its process. The regressional results on Y are quite poor.

- Regressions on Y will result in too many regressors.

Macro Model for Predicting Risk Factors

BuDA can define the macroeconomic scenarios with:

- Any of the 7 default stress variables
- Any of the common risk factors (stock index return and 3-month interest rate) in the CRI PD model
- User-defined stress variables



Mixed Frequency Regression—Problem

- Mixed data frequency problem:

X_m(e.g. stock index return) and $\bar{Y}_{i,j}$ (e.g. DTD) are available monthly, while Z_k (e.g. GDP growth rate) is only available quarterly or even yearly.

- The Z_k series displays a choppy pattern with many values being zero.

Mixed Frequency Regression—Treatment

- Step 1: replace zeros with linearly interpolated values within a quarter/year.
- Step 2: regression in time-aggregated manner
  - Rewrite the stress testing function in vector form:

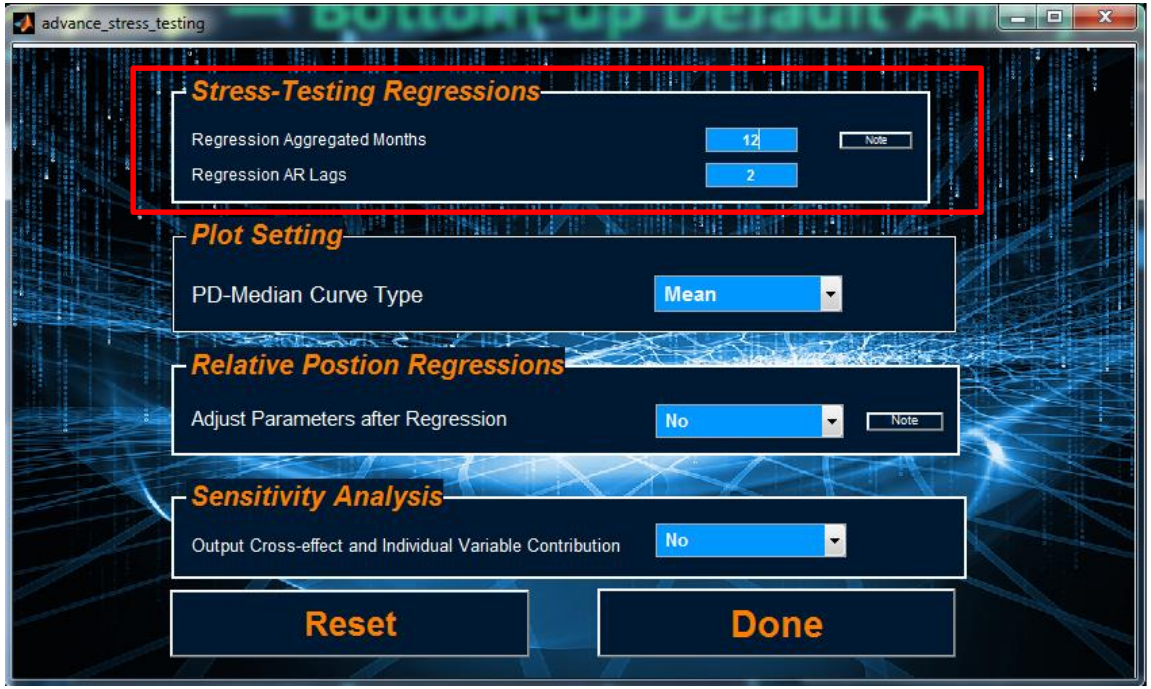
$$\begin{bmatrix} X_t \\ X_{t-1} \end{bmatrix} = \begin{bmatrix} \beta_0 \\ 0 \end{bmatrix} + \sum_{k=1}^{n} \beta_k \begin{bmatrix} Z_{k,t} \\ 0 \end{bmatrix} + \boldsymbol{A} \begin{bmatrix} X_{t-1} \\ X_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ 0 \end{bmatrix} \quad \text{with } \boldsymbol{A} = \begin{bmatrix} \gamma_1 + 1 & \gamma_2 \\ 1 & 0 \end{bmatrix}$$

  - Substituting for $\begin{bmatrix} X_{t-1} \\ X_{t-2} \end{bmatrix}$ l periods gives rise to:

$$X_t = \beta_0 \sum_{p=0}^{l-1} (\boldsymbol{A}^p)_{1,1} + \sum_{k=1}^{n} \sum_{p=0}^{l-1} \beta_k (\boldsymbol{A}^p)_{1,1} Z_{k,t-p} + (\boldsymbol{A}^l)_{1,1} X_{t-l} + (\boldsymbol{A}^l)_{1,2} X_{t-l-1} + \sum_{p=0}^{l-1} (\boldsymbol{A}^p)_{1,1} \varepsilon_{t-p}$$

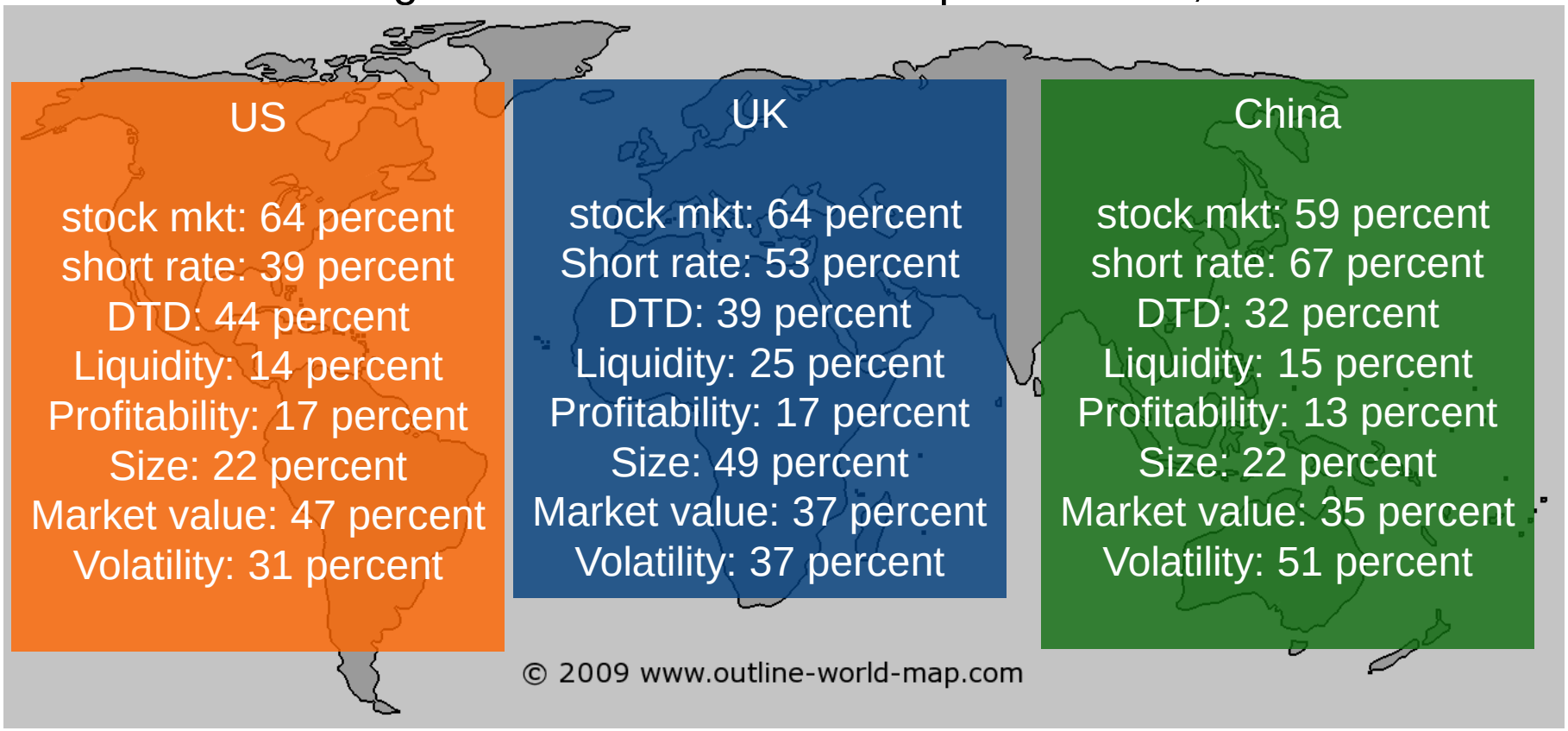
Mixed Frequency Regression—Outcome

- Parameter estimation less sensitive to how Z_k is converted to monthly data.



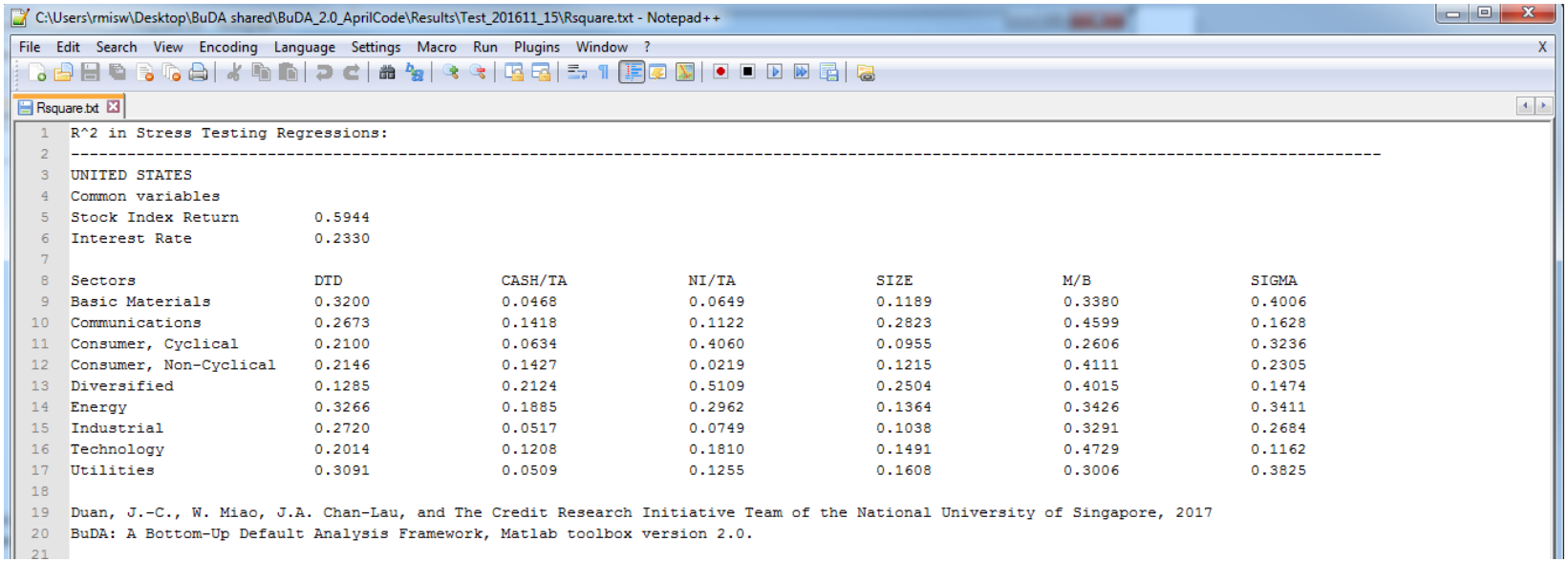
R^2 of Macro-Risk Factor Regressions

R^2 of the stress testing regression with all 7 pre-defined stress variables. Averaged across sectors. Data up to June 30, 2017.



R^2 of Macro-Risk Factor Regressions

"Rsquare.txt" in the "Results" folder displays the goodness-of-fit for the stress testing regressions.



C:\Users\rmisw\Desktop\BuDA shared\BuDA_2.0_AprilCode\Results\Test_201611_15\Rsquare.txt - Notepad++

File Edit Search View Encoding Language Settings Macro Run Plugins Window ?

Rsquare.txt

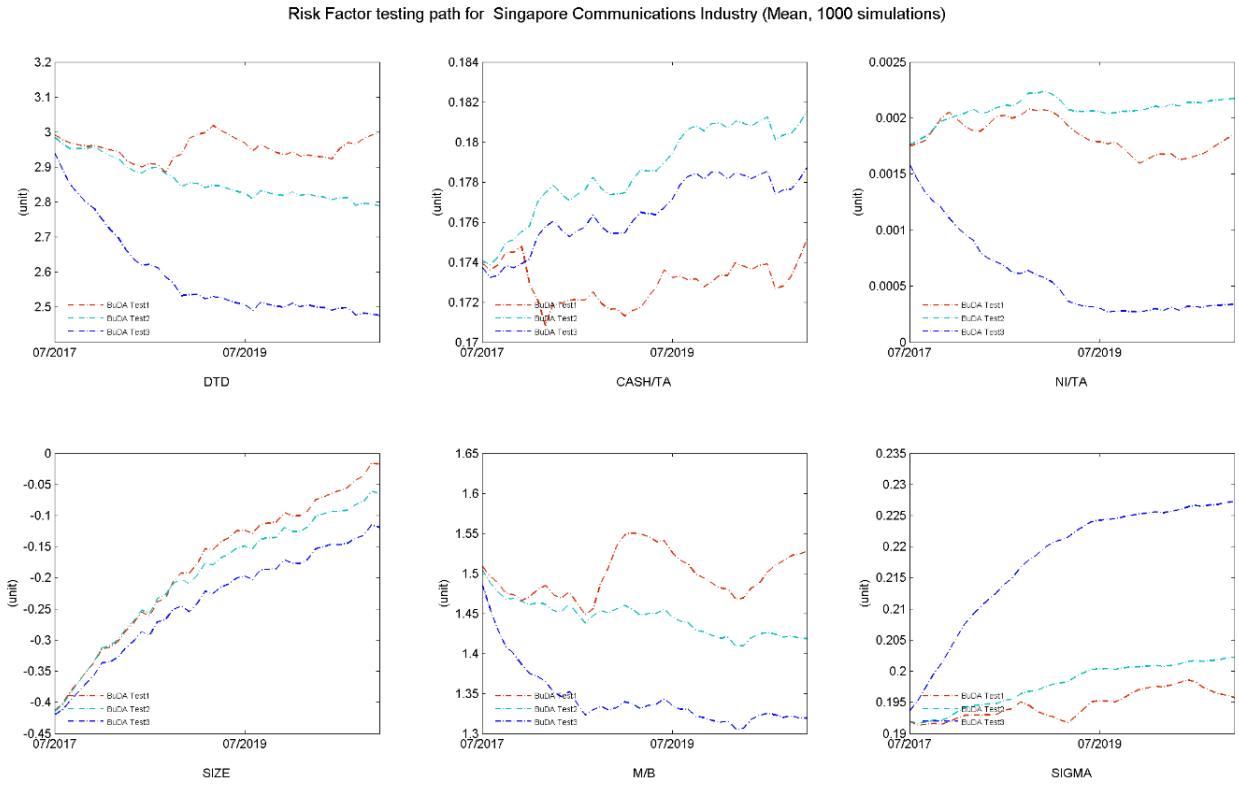
```
R^2 in Stress Testing Regressions:
-------------------------------------------------------------------------------------------------------------------------------------------
UNITED STATES
Common variables
Stock Index Return        0.5944
Interest Rate             0.2330

Sectors                   DTD              CASH/TA          NI/TA            SIZE             M/B              SIGMA
Basic Materials           0.3200           0.0468           0.0649           0.1189           0.3380           0.4006
Communications            0.2673           0.1418           0.1122           0.2823           0.4599           0.1628
Consumer, Cyclical        0.2100           0.0634           0.4060           0.0955           0.2606           0.3236
Consumer, Non-Cyclical    0.2146           0.1427           0.0219           0.1215           0.4111           0.2305
Diversified               0.1285           0.2124           0.5109           0.2504           0.4015           0.1474
Energy                    0.3266           0.1885           0.2962           0.1364           0.3426           0.3411
Industrial                0.2720           0.0517           0.0749           0.1038           0.3291           0.2684
Technology                0.2014           0.1208           0.1810           0.1491           0.4729           0.1162
Utilities                 0.3091           0.0509           0.1255           0.1608           0.3006           0.3825

Duan, J.-C., W. Miao, J.A. Chan-Lau, and The Credit Research Initiative Team of the National University of Singapore, 2017
BuDA: A Bottom-Up Default Analysis Framework, Matlab toolbox version 2.0.
```

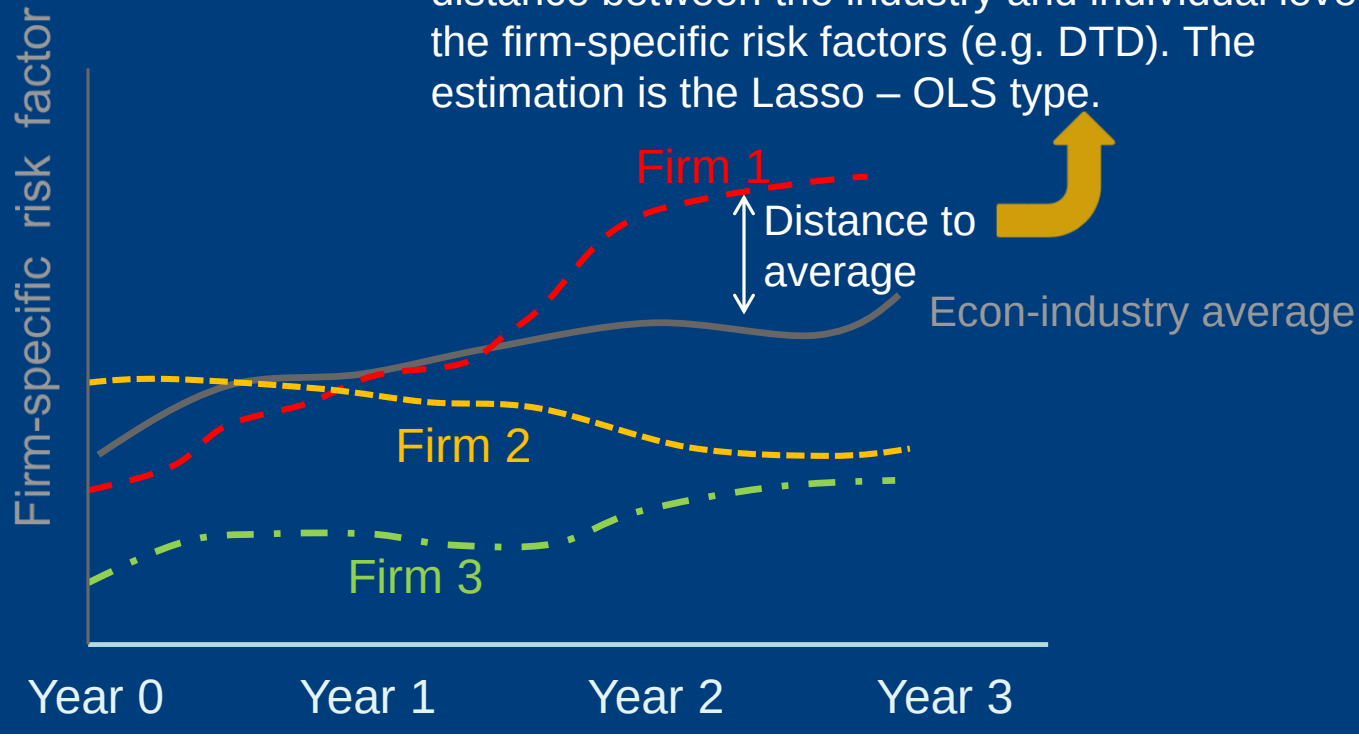
Risk Factor Analysis

The BuDA can also export the evolution of the default covariates under various scenarios.



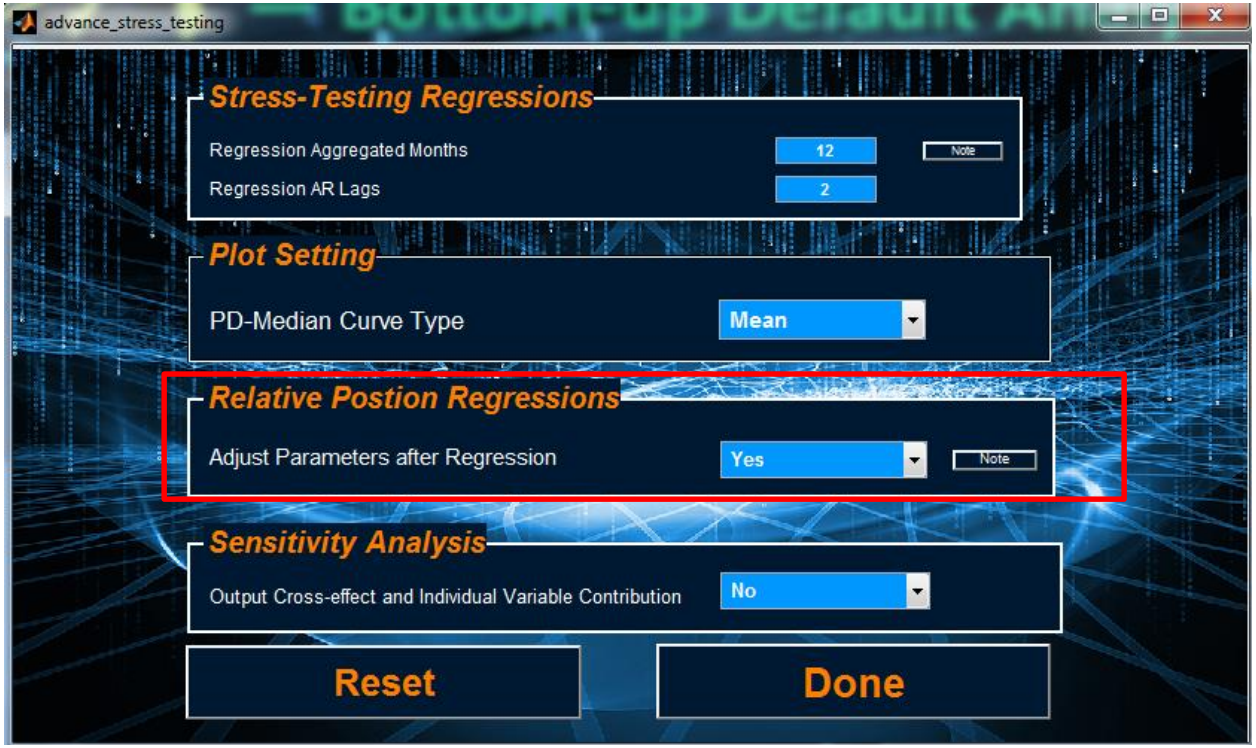
From $\bar{Y}$ to Y: An AR(3) Process

BuDA uses an AR(3) process to model the relative distance between the industry and individual levels of the firm-specific risk factors (e.g. DTD). The estimation is the Lasso – OLS type.



From $\bar{Y}$ to Y: An AR(3) Process

If 'Yes' is chosen in the "Relative Position Regressions" panel, the regression will run twice. User can adjust the coefficients in the second run if she has a better specification for the parameters.



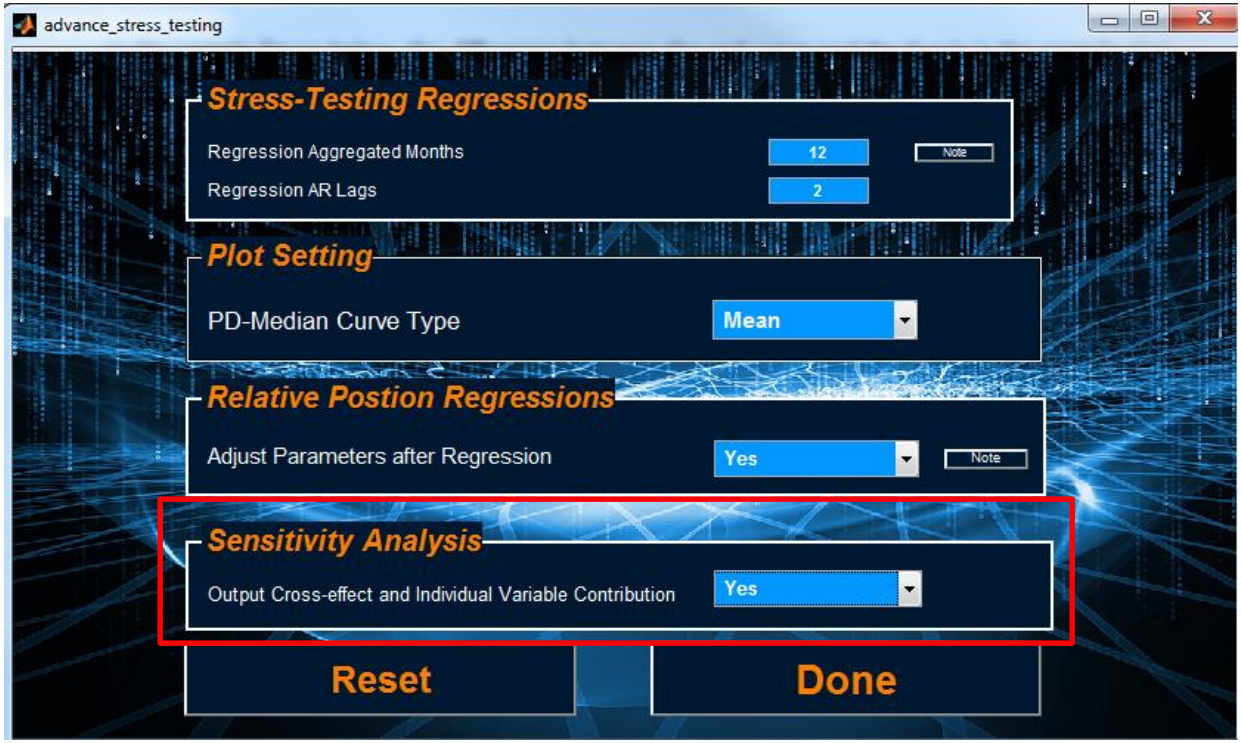
Prescribing Macro Scenarios

- It is crucial that the multiple stress variables defining a scenario are internally consistent.

- It is a good idea to rely on a macroeconometric model or structural vector autoregression to produce future paths of the stress variables.

Sensitivity Analysis

User can select “Yes” in the “Sensitivity Analysis” panel in order to assess the individual contribution to the PD of each stress variable.



Sensitivity Analysis

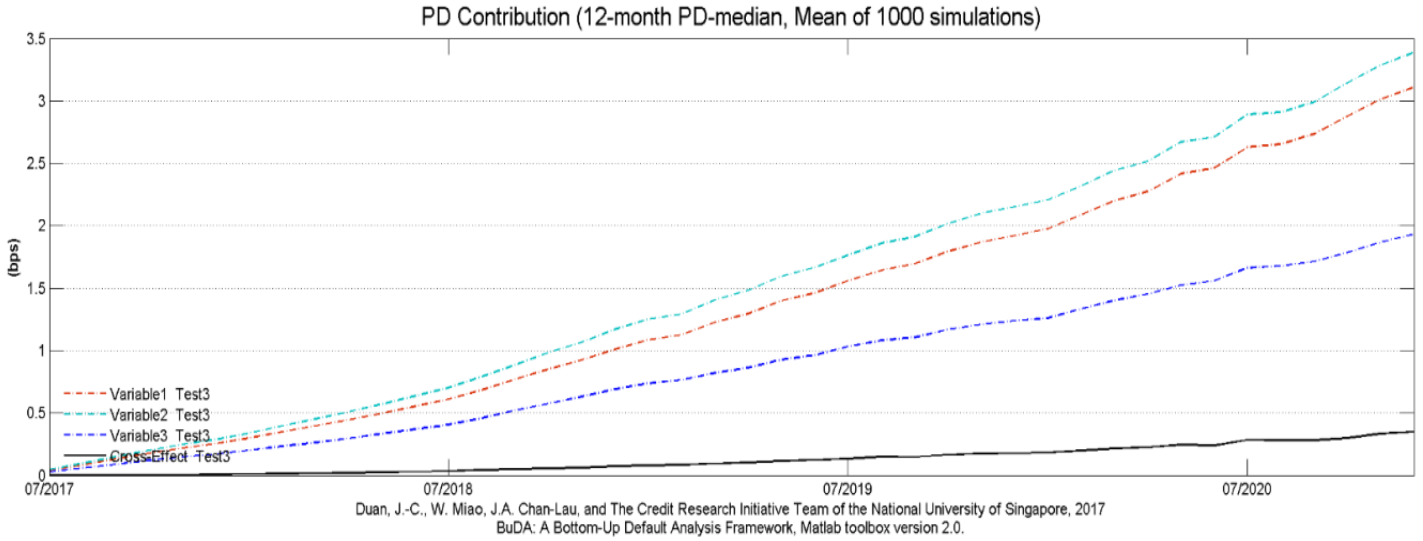
PD_{flat}: PD in the "zero-change" scenario, where the state of economy stays the same for the years to come, e.g. the GDP is fixed for the next five years.

PD_i: the stressed PD when only the i-th variable (among many) follows the presumed trajectory into the future, while others stay constant. i=1, 2, …, n.

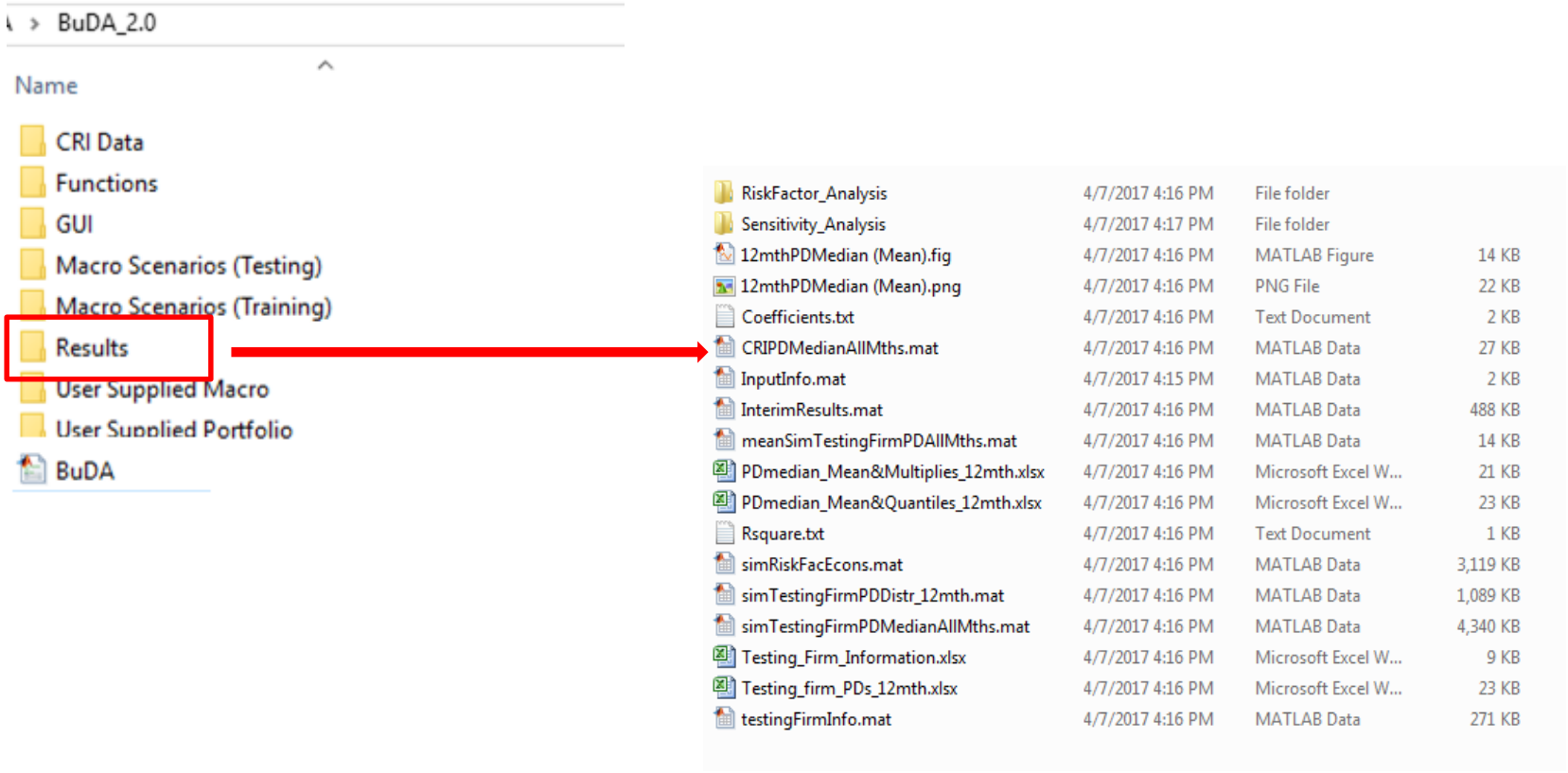
PD_{All}: the stressed PD when all stress variables are considered simultaneously.

Sensitivity Analysis

- Distance between red curve and X-axis: $PD_1 - PD_{flat}$
- Distance between green curve and X-axis: $PD_1 + PD_2 - 2PD_{flat}$
- Distance between blue curve and X-axis: $PD_1 + PD_2 + PD_3 - 3PD_{flat}$
- Cross effect: $PD_1 + PD_2 + PD_3 - 2PD_{flat} - PD_{All}$



Program and Data Structure



Some Useful Datasets in the 'Results' folder

Testing_Firm_Information.xlsx

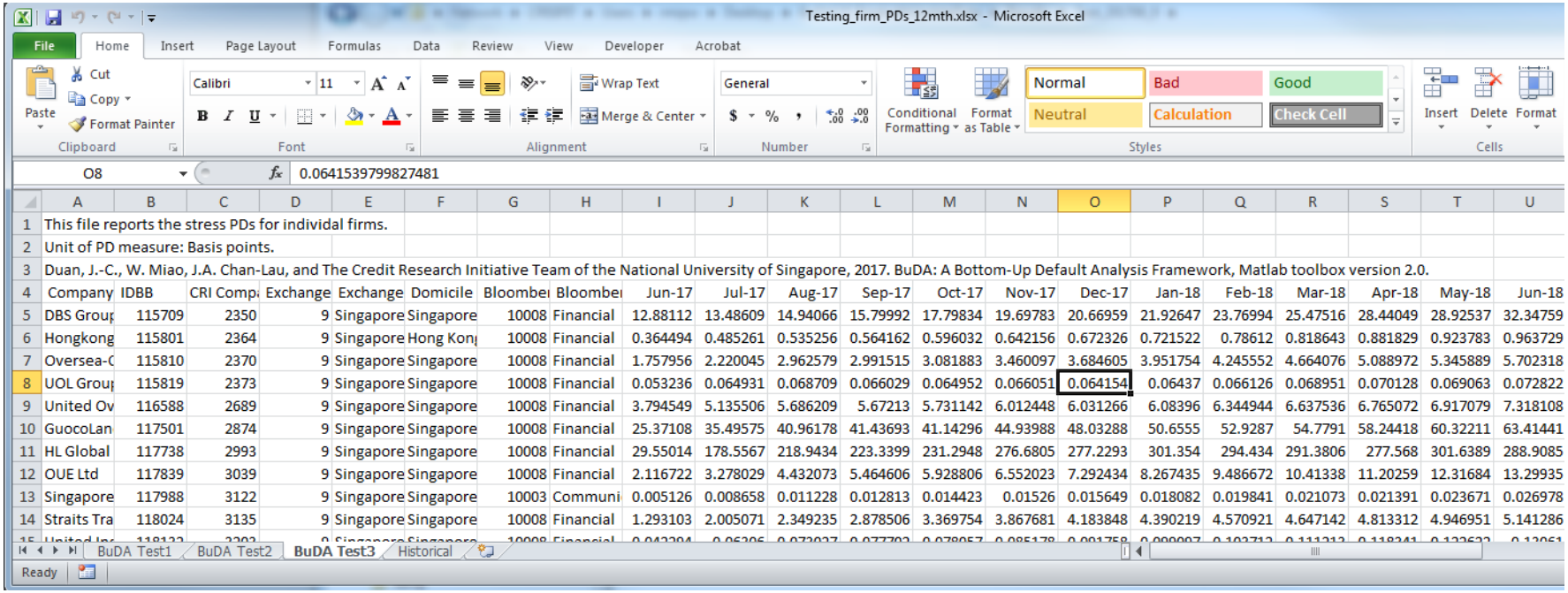
Profile information for all testing firms.

	A	B	C	D	E	F	G	H
1	Company Name	IDBB	CRI Company ID	Exchange Country Code	Exchange Country	Domicile Country	Bloomber Industry Code	Bloomberg Industry
2	Creative Technology Ltd/Singapore	103117	18	9	Singapore	Singapore	10013	Technology
3	GL Ltd	113174	426	9	Singapore	Singapore	10004	Consumer Cyclical
4	DBS Group Holdings Ltd	115709	2350	9	Singapore	Singapore	10008	Financial
5	Dairy Farm International Holdings Ltd	115780	2354	9	Singapore	Hong Kong	10005	Consumer Non-cyclical
6	Mandarin Oriental International Ltd	115796	2359	9	Singapore	Hong Kong	10004	Consumer Cyclical
7	Jardine Strategic Holdings Ltd	115798	2361	9	Singapore	Hong Kong	10006	Diversified
8	Hongkong Land Holdings Ltd	115801	2364	9	Singapore	Hong Kong	10008	Financial
9	Singapore Airlines Ltd	115808	2368	9	Singapore	Singapore	10004	Consumer Cyclical
10	Oversea-Chinese Banking Corp Ltd	115810	2370	9	Singapore	Singapore	10008	Financial
11	UOL Group Ltd	115819	2373	9	Singapore	Singapore	10008	Financial
12	Haw Par Corp Ltd	116382	2491	9	Singapore	Singapore	10006	Diversified
13	Jardine Matheson Holdings Ltd	116423	2532	9	Singapore	Hong Kong	10006	Diversified
14	United Overseas Bank Ltd	116588	2689	9	Singapore	Singapore	10008	Financial
15	Keppel Corp Ltd	116942	2735	9	Singapore	Singapore	10006	Diversified

Some Useful Datasets in the 'Results' folder

Testing_firm_PDs_**mth.xlsx

Historical month-end PDs for all testing firms in "Historical" tab and projected PDs under various scenarios in "BuDA Test*" tabs.



** denotes the prediction horizon for the output PD, e.g. 12 month (1 year).