2022

Bottom-up Default Analysis (BuDA v3.4.2)

The user manual of BuDA Toolkit

The Credit Research Initiative (CRI)
National University of Singapore

(Previous version: August 5, 2019; This version: May 26, 2022)

Credit Research Initiative
National University of Singapore

ABSTRACT

Bottom-up Default Analysis (BuDA) is a credit stress testing and scenario analysis toolkit developed by the Credit Research Initiative (CRI) team of National University of Singapore (NUS) in a collaboration with the International Monetary Fund (IMF). This toolkit is operated and supported by CRI (https://www.nuscri.org). This document provides step-by-step instructions with illustrated examples for the BuDA web application. Regulatory authorities, central banks, and commercial/investment banks may use the BuDA toolkit to conduct credit stress testing and scenario analysis and, more generally, to examine macroeconomic and financial risks. Users are recommended to understand the key concept underpinning BuDA by reading its white paper*.

CONTENT

BuDA (v1.0) was developed by Jin-Chuan Duan of the NUS-CRI team and Weimin Miao of CriAT, a former NUS-CRI team member, in collaboration with Jorge Chan-Lau of IMF. The NUS-CRI team provides the continual development and support of the BuDA platform.

*The Credit Research Initiative team (2021), Bottom-up Default Analysis (BuDA v3.4.1) White Paper, Accessible via https://nuscri.org/en/white_paper/.

Credit Research Initiative
National University of Singapore

I. Overview

There is a growing demand for practical models and tools used for analyzing the dynamics of credit risk under different macroeconomic scenarios. The Bottom-up Default Analysis (BuDA) was conceived to meet this demand. The BuDA toolkit provides an easy-to-use interactive platform for analyzing the credit risk of individual firms/sectors/economies, or user-defined portfolios under different scenarios, stressed or otherwise. BuDA has been implemented with the API (Application Programming Interface) web application which only requires users to access an internet browser. Users need not install any other programming software as the BuDA executions will use the CRI cloud-based computing resources. With this hassle-free toolkit, users can focus on scenario design and risk analysis.

The application's structure is shown in Figure 1, where users are required to specify/provide three main inputs: (1) target portfolio, (2) testing scenarios, and (3) simulation settings. BuDA allows users to build their own portfolios from any of over 85,000 listed companies in 134 economies in the CRI database. The testing scenario of interest is specified/uploaded by users, which is based on a single or multiple macroeconomic and/or financial stress variable(s).

To meet varying needs of analysts, BuDA offers several flexibilities, including a customized portfolio, user's supplied stress variables & scenarios, as well as advanced settings to modify some simulation parameters. In addition, BuDA has an inbuilt stress-variables recommender which assists users to identify a set of stress variables that are most apt for their target portfolio out of a list of close to 3000 potential stress variables. This recommender will choose a desired number of stress variables, say, 5 out of the user-specified set of potential stress variables which can be drawn from a list of close to 3000 global and economy/sector variables. This manual focuses on how to utilize the BuDA toolkit. Examples with a brief discussion of the results are provided to assist users to gain a better appreciation.

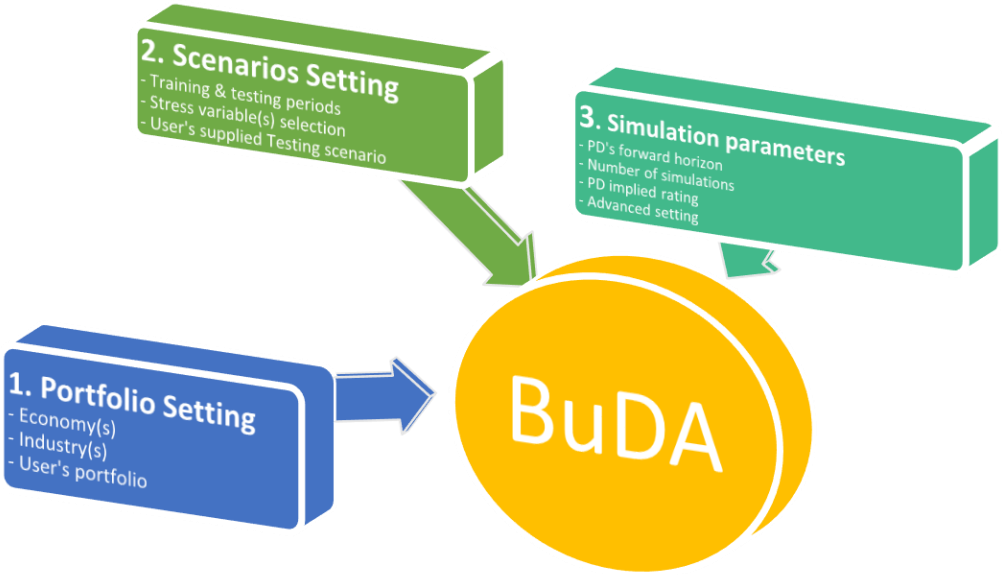


Figure 1: An overview of BuDA implementation

II. Step-by-step instructions

There are three main steps in BuDA to perform stress testing and scenario analysis. Users will be asked to specify a target portfolio, macroeconomic and financial scenarios, and simulation parameter settings, as depicted in Figure 1. The detail of each step is given in this section.

Step 1: Target Portfolio

The first step is to specify the portfolio of interest, on which the bottom-up default analysis will be conducted by aggregating the credit risks of individual firms to the portfolio level. To form the target portfolio, users may add the economies and industries from the drop-down lists. Alternatively, users may customize their own target portfolio by submitting a file.

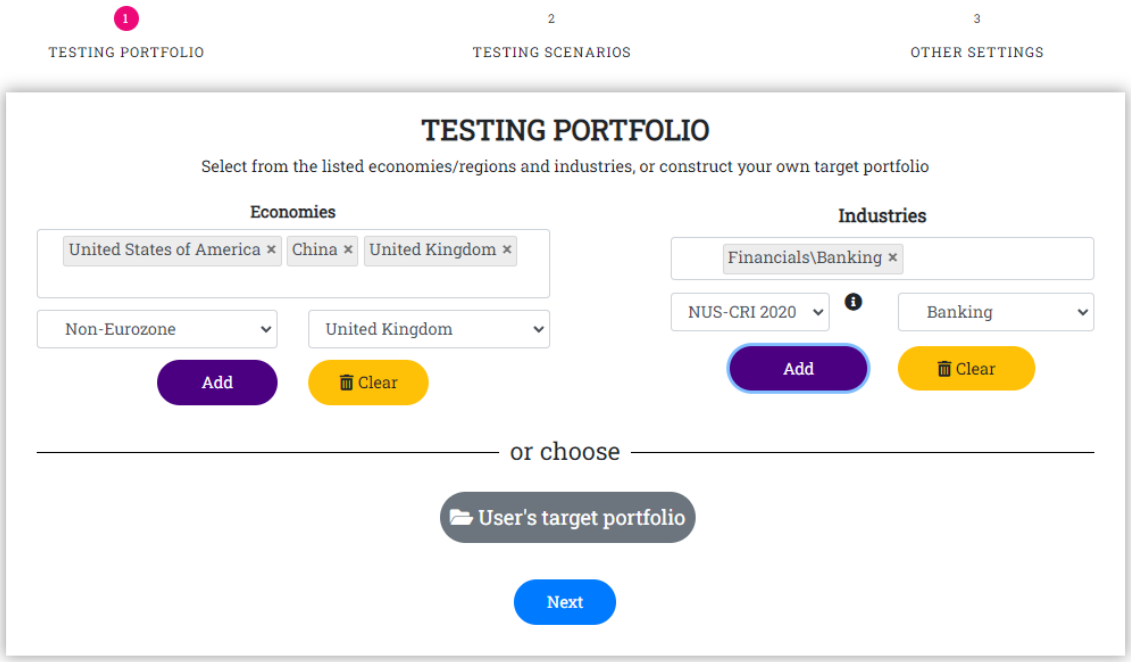


Figure 2: Testing Portfolio

For the first option, the requirements are to add both "*Economies*" and "*Industries*". These are choices based on six main geographic regions, from which users can consider to either add a specific country or simply select all economies. Users can also enter multiple economies. To complete this step, users need to add the industries of interest. BuDA provides two sets of industry classifications that group companies into 12 and 13 industries respectively, following the NUS-CRI industry classification 2007 and 2020 version. Users should choose industries under the same classification standard. Then, the target portfolio will be formed using all companies classified under the selected industries in the specified economies.

For users with their own target portfolios in mind, selecting "*User's target portfolio*" presents a way to customize the portfolio. To form a customized portfolio, users must provide an Excel file specifying the company IDs. Importantly, the list should follow the Excel template below:

	A
1	IDBB
2	305999
3	117809
4	117400
5	162324

The Excel file should contain only Bloomberg IDs (IDBBs) and the file must be saved as *.csv (Comma delimited). Once the file is successfully uploaded, BuDA will correctly identify their economies and industries and upload the data for the selected firms. The full list of the available companies with their IDBBs in the BuDA database and the template can be downloaded (optional) after clicking "*User's target portfolio*" as in Figure 2.

Step 2: Testing Scenarios

This step focuses on building the stress scenarios of interest. Users need to specify the scenarios, the testing and training data period, and the stress variable(s). The selected stress variables are common for every firm in the target portfolio regardless of their industries and economies. The users are required to upload Excel file(s) if they consider a user supplied stress testing scenario (see step 2.1) and/or stress variable(s) (see step 2.4).

Step 2.1: Stress testing scenarios

Users need to specify the nature of scenario analysis. Selecting "*Backtesting*" requires no additional file. On the other hand, opting for "User-specified scenarios" will require uploading an Excel file for their testing scenarios after finishing step 2.4 (the final step before proceeding to Other Settings).

Step 2.2 & 2.3: Testing time point & training sample period

Users are required to fill in "*Testing Time Point*", "*Training Sample Period*", see Figure 3.

- *"Testing Time Point"* is defined as an initial month prior to the testing scenario starting month. In other words, if the testing time point is denoted by *t*, *t*+1 will be the first period of the testing scenario. To put it simply, this is the time point from which users want to begin their scenario analysis.

Figure 3: Fill testing time point and training sample period

Two observations are in order:

- With the testing time point being set in Step 2.2, BuDA will automatically adjust, upon confirming the stress variables, the testing time point by checking data availability.
- Although users may select any month in the given period, the choice should be made with data availability in mind. For example, the testing time point in Figure 3 is 201806. Users need to ensure that their uploaded testing data is available from 201807 onward.

- "*Training Sample Period*" is the period that BuDA uses to estimate the stress testing regressions. There are three choices:
  - "*Till testing time point*" – the training period is defined as the period up to the specified testing time point.
  - "*Whole sample period*" – all available training data will be used as the training data.
  - "*User-specified sample period*" – users can specify any range within the available sample period.

Step 2.4: Stress variables selection

BuDA provides historical data for a list of close to 3000 potential stress variables, including the country specific macroeconomic variables, *common risk factors* (CRI-PD predictors[1] for country and industry levels), commodity prices, and other stress variables of interest. Users can select from this list by checking "*Choose from economy/variable list*" or upload their own stress variables (optional) by checking the "*User Supplied Stress-testing Variables*". Combining the provided and user's supplied variables is possible.

Users can also let BuDA recommend a desired number of stress variables, up to 10, from the provided list of potential variables that are most apt for the target portfolio. Doing so requires of checking "*Stress Variables Recommender*" and following three simple steps. These steps for using the recommender will be covered with a concrete example later in section III of this guide.

[1] The CRI-PD model has multiple predictors, including firm specifics and common risk factors. User can also use those common risk factors as the stress variables. Readers can find concrete discussions of the CRI-PD model's inputs in the BuDA White Paper.

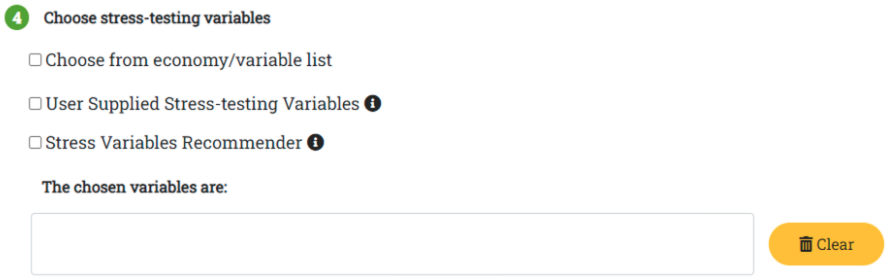


Figure 4: The selection of stress variables

Choose from Economy/Variable List

The categories of the provided variables are shown in
. Users can easily sort the macroeconomic variables and common risk factors by economy, see Table 5. If a group of economies is selected, e.g., Eurozone, the variables for its individual members will be included. Updated details of these variables, including the data sources, can be downloaded upon clicking the information sign. After confirming the selected variables, BuDA will summarize the variable selected, see Figure 10 later.

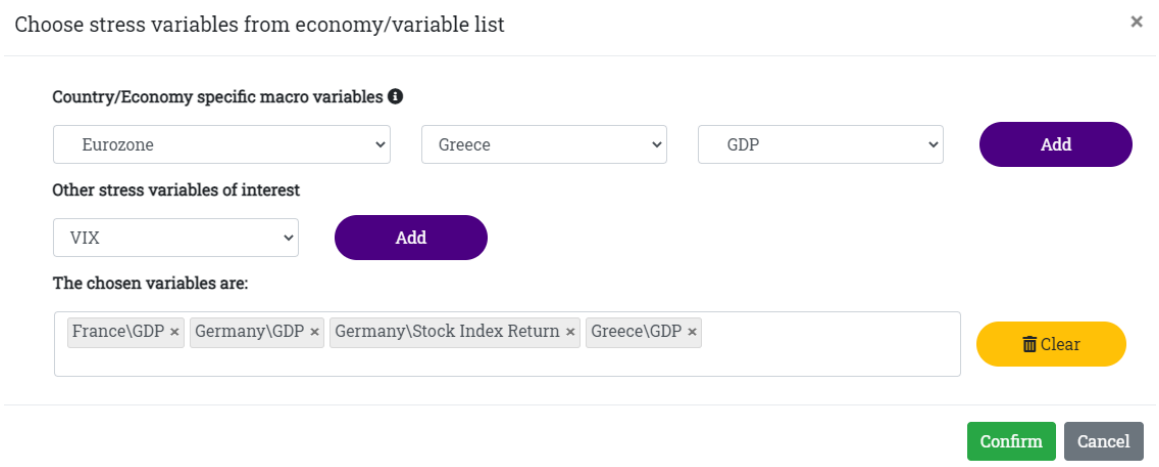


Figure 5: The selection of stress variables

Table 1: List of provided stress variables

Type	Variables	Brief Description
Country specific macro- economic variables	GDP	Real Gross Domestic Product growth rate
	UNEMP	Difference of Unemployment rate
	CPI	Percentage change of consumer price index
	NEER	Percentage change of Nominal Effective Exchange Rate
	INT	Difference of 3-month interbank rate
	HPI	House Price Index growth rate
	PPI	Percentage change of producer price index
	CAB	Difference of Current account balance
Country specific Common factors (CRI-PD predictors)	Stock return	Monthly stock return
	Interest rate	3-month interbank rate (level)
	Aggregate DTD	Aggregate distance-to-default for financial and/or non- financial industry
Other key stress variables	Commodity Prices	Percentage change of Standard and Poor's Goldman Sachs Commodity Index and over 20 individual commodities
	VIX	Percentage change of the Chicago Board Options Exchange Volatility Index
	FFI	St. Louis Federal Reserve Financial Stress Index (level)
Credit Cycle Index	CCI	Credit Cycle Index is provided by using aggregated CRI-PD. User can select the data from country to industry levels.

User-supplied Stress Testing Variables

For a user's supplied variables, it is important to provide their historical time series in an Excel file (*.csv) using the template as shown in Figure below. The overall length of the data should be at least **five** years, although using ten years or more is recommended. Apart from the historical data, users need to specify the frequency and type of each variable using the following definitions:

- *"Frequency"* (row 6), specify the value of:
  - "1" for monthly data
  - "0" for quarter-end data and fill the data in month 3, 6, 9, and 12 only
  - "-1" for year-end data and fill data in month 12 only
- "*Macro Type"* (row 10), specify the value of:
  - "1" indicates growth rate % or percentage change (e.g. GDP growth)
  - "0" indicates change in different (e.g. difference of unemployment rate)

- "-1" indicates the level value (e.g. interest rate).

	A	B	C	D	E	F	G	H	I	J	K
1	This Frequency provides the information whether the training macro-economic scenarios used are reported on a monthly basis c										
2	The value "1" means "Monthly"; "0" means "Quarterly"; and the value "-1" means "Yearly".										
3	If it is on a quarterly basis;the data should be reported in Month 3 6 9 12 while blank need be reported in other months.										
4	If it is on a yearly basis; the data should be reported in Month 12 while blank need be reported in Month 1-11										
5	Growth rate on a monthly basis should be MoM growth rate (non-annualized); on a quarterly basis should be QoQ growth rate (n										
6	Frequency		1	1							
7											
8	This Macro Type provides the information that for each country whether the training macroeconomic scenario is the change (grov										
9	The value "1" means "Change (Growth Rate %)"; the value "0" means "Change (Difference)"; the value "-1" means "Level".										
10	Macro Type		-1	1							
11											
12	year	month	FED Stress Index	Oil price return							
13	1993	12	0.198								
14	1994	1	0.179								
15	1994	2	0.365								
16	1994	3	0.509								
17	1994	4	0.643								
18	1994	5	0.745	4.73							
19	1994	6	0.781	6.30							
20	1994	7	0.704	5.93							
21	1994	8	0.672	-12.78							
22	1994	9	0.872	4.72							
23	1994	10	0.923	-1.35							
24	1994	11	0.951	1.12							
25	1994	12	0.979	-3.63							
26	1995	1	0.898	1.80							
27	1995	2	0.796	0.42							

Figure 6: User's supplied training data template

Stress Variables Recommender

This new feature helps users select a set of stress testing variables that are most apt for the target portfolio. The algorithm recommends a desired number of stress variables out of a list of close to 3000 global and economy/sector-specific variables by utilizing a cutting-edge zero-norm variable selection technique. To use this recommender, simply check "*Stress Variables Recommender*" in Figure 4, and follow the three simple steps.

In the first step, users are required to define a pool of variables from which the recommendation algorithm can choose. By default, the algorithm will select variables from the economies in the target portfolio. The categories of stress variables available are the same as in Table 1. Users can click "+" to expand each category and select/unselect the variables in that category. The total number of variables in the pool will also be displayed, see Figure 7.

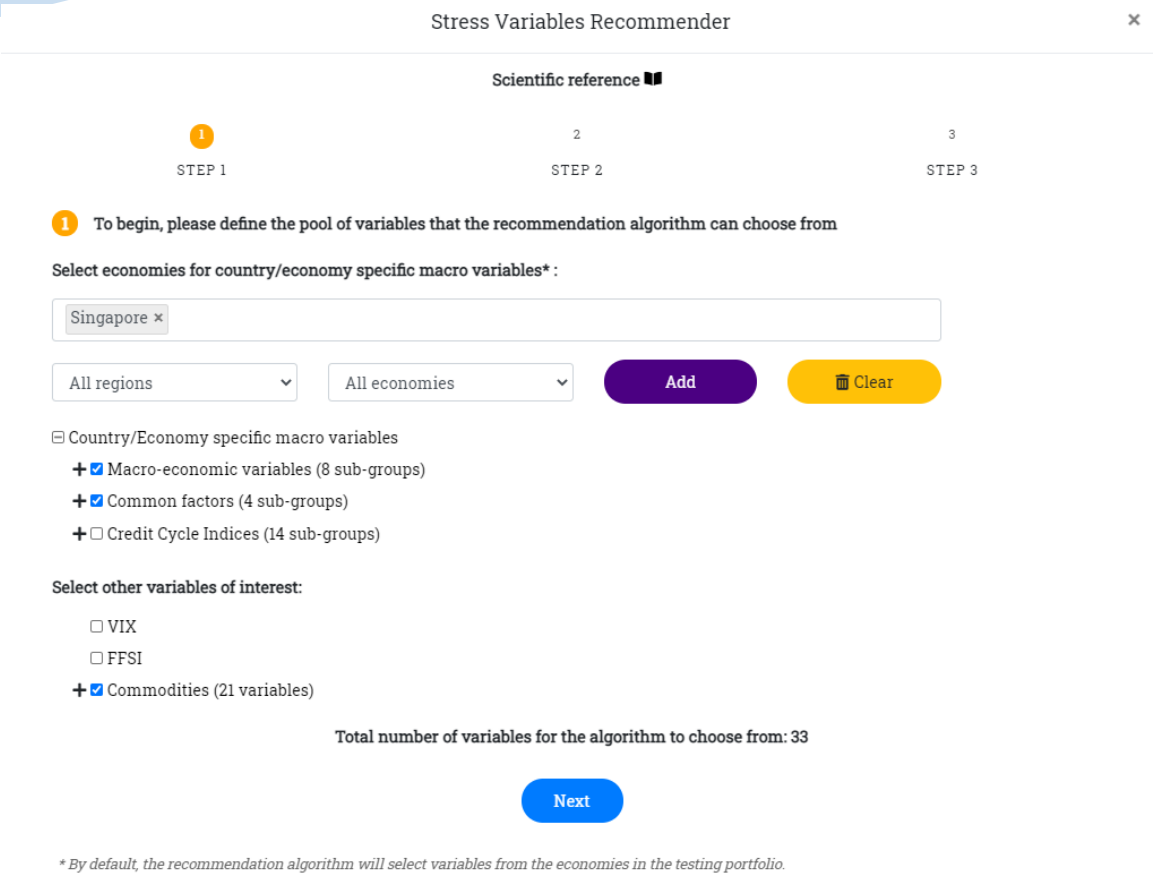


Figure 7: Definition of stress variable pool in recommender

Click "Next" to proceed to the second step, users can then fill in the desired number of stress variables that the algorithm should recommend (from 1 to 10 variables), see Figure 8.

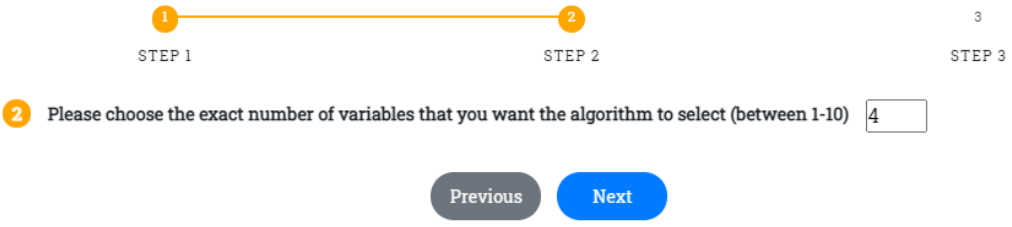


Figure 8: Choice of the number of variables to be recommended

In the third step, users can review the choices made in the previous two steps and revise the variable(s) by going back to the previous step. Users may have in mind some "must-include" stress variable(s) that are deemed critical to the task. These variables can only be entered from within the subset of stress variables defined in step 1. The "must-

include" stress variable(s), if chosen, will be forced into the recommended set of stress variables and crowd out other variables even if they do not deliver at the same level of explanatory power, see
Figure 9. Of course, this option may also be left blank. Finally, click "*Start Recommendation Algorithm*" to begin the selection. The resulting recommended variables will automatically be filled in the stress variables box in Figure 4.

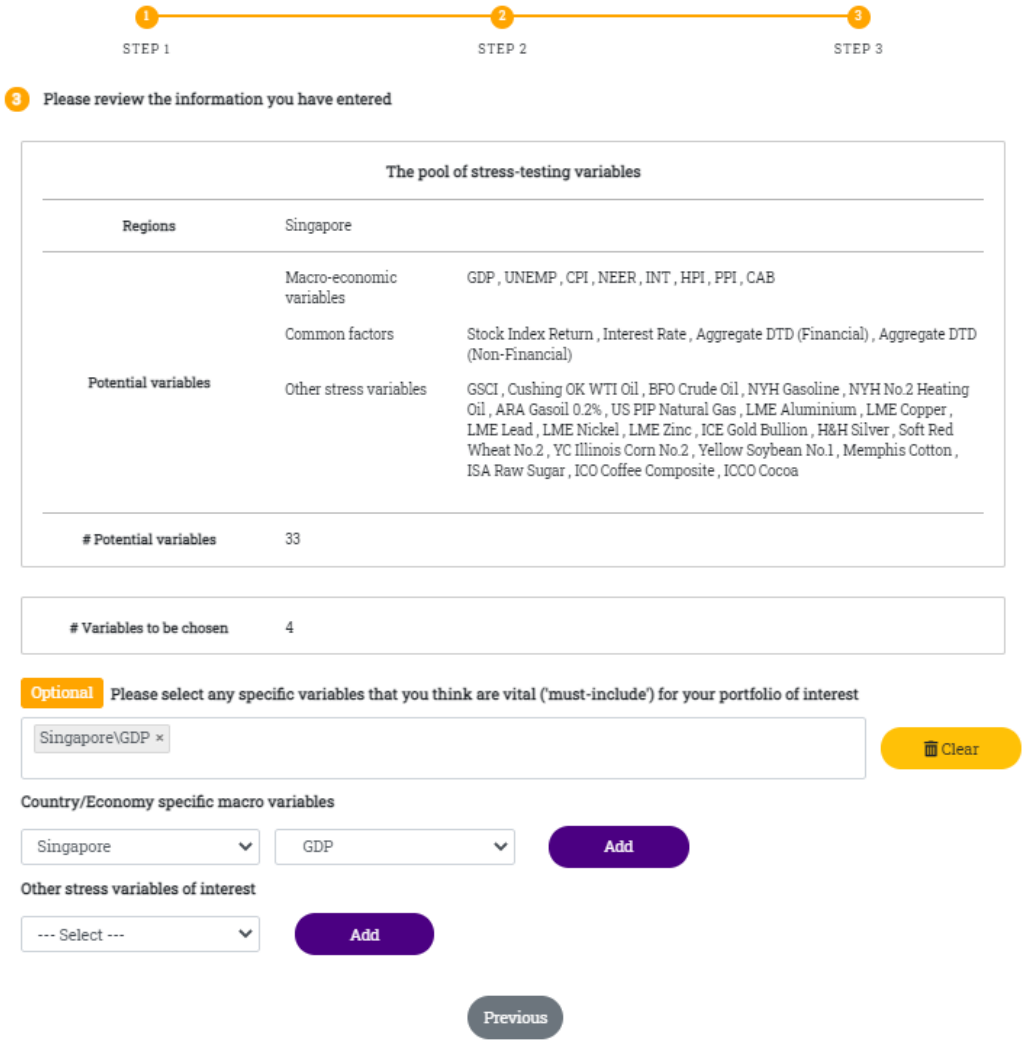


Figure 9: Selection of 'must-include' variables (optional)

After confirming the stress variables, BuDA will automatically check and report the data availability, see Figure 10. BuDA can proceed only when the overlapping period among the selected variables are larger than 5 years. Therefore, users are recommended to select a long enough training sample period to avoid model estimation difficulties.

The available data periods are :

Stress-testing variables : December, 1993 to September, 2018.

CRI PD Data : up to September 2018.

Stress-testing variable	Available Start Date	Available End Date
France GDP	1990-04	2018-09
China GDP	1990-04	2018-09
Germany GDP	1990-04	2018-09
VIX	1990-02	2018-09
FED Stress Index	1993-12	2018-09
Oil price return	1993-12	2018-09

Figure 10: Available periods of the training period checking

Uploading user specified scenarios

When "user specified scenarios" is checked, users may select "Generate scenario file" to confirm their selection, where an Excel file will be generated and downloaded. The file will be automatically customized to the selected stress variables in Step 2.4, in which users can fill in the scenarios. The variables in the provided file should match those stress variables.

Figure 11 is a generated Excel file using the stress variables previously selected. The following information should be filled in to complete the stress testing scenarios:

- *"Frequency"* (row 6) specifies the value of:
  - "1" for monthly data
  - "0" for quarter-end data and fill the data in month 3, 6, 9, and 12 only
  - "-1" for year-end data and fill data in month 12 only
  - The frequency does not need to be the same as that of the training data
- Ensure the same data type of each variable as in the training data, which is defined in Table 1 for the provided stress variables and/or the user's uploaded stress variables.
- Do not modify the generated Excel file for testing scenario, except for providing the data.
- The coverage of the provided scenario should be from the first month or the most recent quarter-end or year-end months depending on the data frequency. The unused rows can be left blank.

- Multiple scenarios can be tested simultaneously by adding more sheets into the file.
- The uploaded Excel file should be in *.xlsx format.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	(i) Please specify the frequency of each selected stress variable, where '1' for monthly data(MoM), '0' for quarter-end data(QoQ), '-1' for year-end data(YoY)												
2	(ii) Please fill the time series of the selected stress variables. The quarter-end data will be filled in months 3,6,9,12, and month 12 for the year-end data												
3	(iii) Please refer to Table 7 in BuDA White Paper for information on description of the Provided Macroeconomic Variables												
4													
5			France GDP	China GDP	Germany GDP	VIX	FED Stress Index	Oil price return					
6		frequency	0	0	0	1	1	1					
7													
8	year	month	France GDP	China GDP	Germany GDP	VIX	FED Stress Index	Oil price return					
9	2018	10											
10	2018	11											
11	2018	12	0.00	0.50	0.30	1.0	0.0	5.0					
12	2019	1				1.0	0.0	5.0					
13	2019	2				1.0	0.0	5.0					
14	2019	3	-0.25	0.25	0.30	1.0	0.0	5.0					
15	2019	4				2.0	0.1	4.0					
16	2019	5				2.0	0.2	4.0					
17	2019	6	-0.50	0.00	0.30	2.0	0.3	4.0					
18	2019	7				3.0	0.4	3.0					
19	2019	8				3.0	0.5	3.0					
20	2019	9	-0.50	0.00	0.30	3.0	0.5	3.0					
21	2019	10				4.0	0.5	2.0					
22	2019	11				4.0	0.5	2.0					
23	2019	12	-1.00	0.00	0.30	4.0	0.5	2.0					

Figure 11: The automatically generated testing scenario template

There is an additional requirement if users select to provide stock index return as one of the stress variables. Instead of providing returns, users must provide stock index values, then BuDA will calculate the returns.

Step 3: Basic Parameters and Advanced Setting

Basic Parameters

For the basic parameters, users are required to fill in "*PD Horizon*", *"Simulation Settings"*, *"Probability of Default Implied Rating"* and "*Portfolio Aggregation Setting*", (See Figure 12):

- Users can specify the PD's forward horizon, which is available from 1-month PD to 60-month PD. The information concerning the forward horizon can be found in the BuDA white paper.
- "*Number of simulations*" determines the precision of the BuDA estimate. BuDA generates simulated possible outcomes under the given scenario and compute the average of the simulated quantity of interest (e.g., the target portfolio's median PD). The number of simulations can be specified by users. A larger number of simulations will require more computing time, but the result is more accurate.

- For “Probability of Default implied Rating” (PDiR2.0), BuDA provides a graph which depicts the overall stress testing results with reference to a letter-based rating scale. These labels indicate the PD boundaries for different letter ratings. These boundaries are generated with the CRI PDiR2.0 methodology by referencing the credit migration history of a credit rating agency. Default is set to referencing the S&P ratings. Users can opt for Moody’s ratings using the dropdown menu.
- Users can also specify the aggregation method used on individual companies stressed PD, which aggregates all the simulated PD on the selected portfolio’s company number level. The default setting is choosing the mean and median. In addition, users can also aggregate by multiple quantile levels should they prefer, which may cater for a more nuanced analysis of distribution of risk in the industry under different stressed scenarios. .

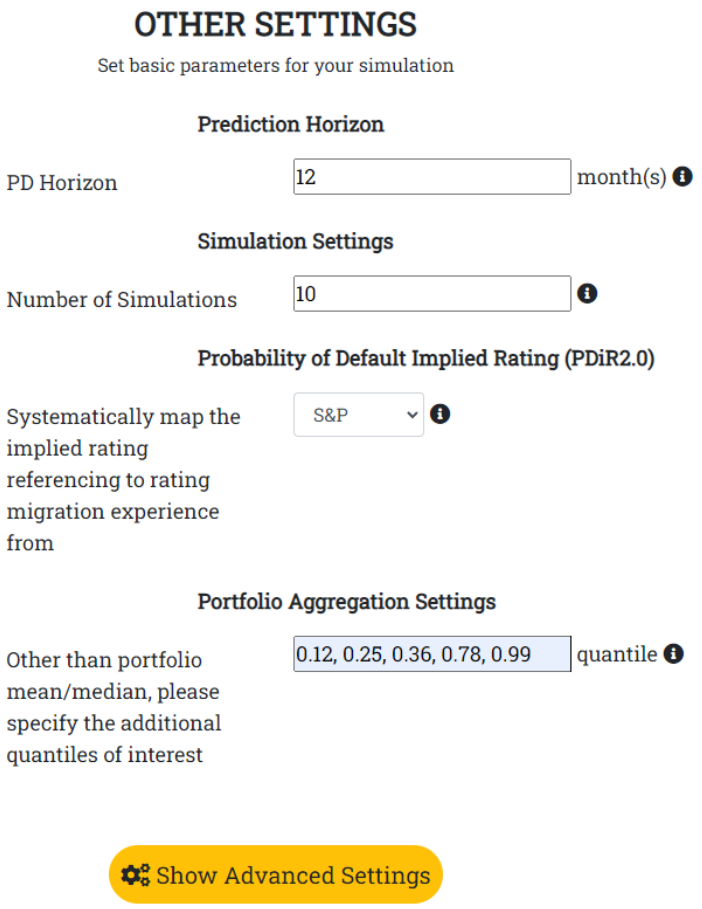


Figure 12: Basic Parameters

Advanced Setting

Users can modify some simulation parameters as shown in Figure 3, "Show *Advanced Settings*" (optional).

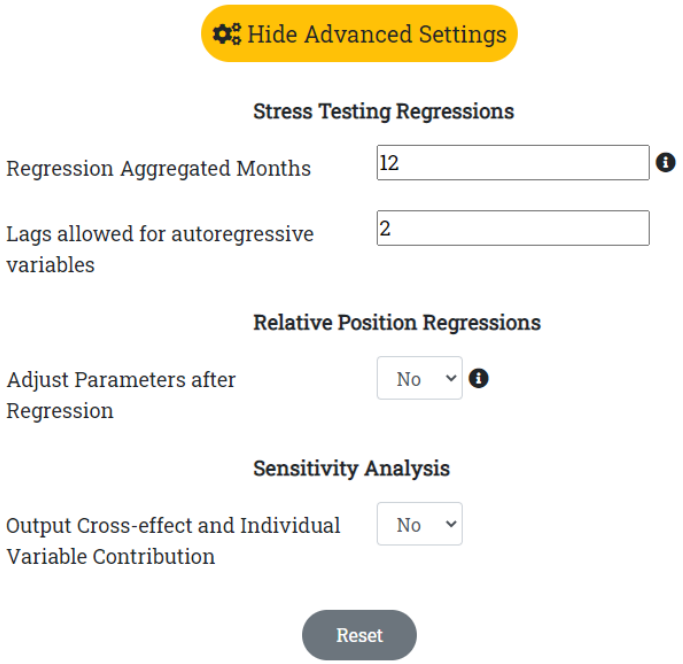


Figure 13: Advanced setting

The first option is "*Regression Aggregated Months*". Some stress variables, for example, GDP, are typically available on a quarterly frequency whereas others may be available monthly or even daily. Implementing the stress testing regressions faces a challenge of having to deal with mixed-frequency data. To address this issue, BuDA deduces the stress testing regressions to a time-aggregated form (see the BuDA White Paper for the detail). Users can specify the number of the time-aggregated months, where 12-month is the default option.

"*Lags allowed for autoregressive variables*" lets users adjust the number of lag terms deployed in the stress testing regressions, and the default is two lag terms.

"*Adjust parameter after regression*" is an option for relative-position autoregression, which is based on AR(3). Recall that the stress testing regressions are performed on the industry-averaged firm-specific variables. The relative position (individual value minus industry average) is applied to translate from the simulated future industry level to individual level (see the BuDA White Paper for the detail). This function allows users, if they see fit, to modify the estimated AR(3) parameters. If this option is selected, the Excel file, FirmParainEcon, will be automatically downloaded after the stage III estimation is

completed. The file will report the parameter estimates for each variable in the firms' relative-position autoregression. Users can modify the estimates in a way they see fit, before uploading the file as shown in Figure 14. This is useful when users have a strong intuition on the autoregression parameters[2].

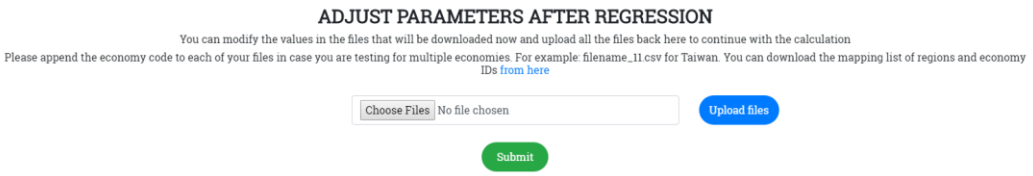


Figure 14: Adjust parameter after regression

By selecting "Yes" in the drop-down menu in the "Sensitivity Analysis" panel, users can assess the contribution of each stress variables to the stressed portfolio PD by holding other stress variables constant. The user can also see the difference between the sum of the individual effects and the gross effect when all variables are accounted for simultaneously. This difference is viewed as the cross effect.

After submitting, BuDA immediately starts the estimation where the estimation time in total and for different subcomponents will be estimated and shown, see Figure 15. Once the estimation is complete, the BuDA outputs will be automatically download as *.zip file. Users should turn off any pop-up blocker if the zip file cannot be downloaded. The discussion on the BuDA results is provided later in Section IV.

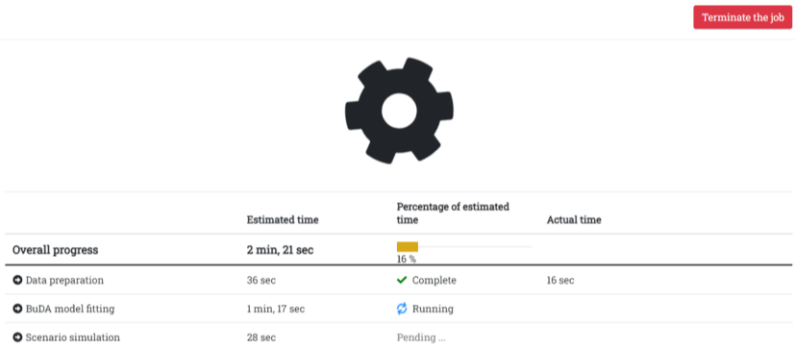


Figure 15: Estimated running time

[2] As an example, the estimation result may suggest a quick decay rate for some individual-level risk factor (measured as a relative position) and decides that more persistence is called for. The AR(3) parameters can then be revised to generate a higher level of persistence.

III. Stress-Variables Recommender: an example

This section provides an example of using BuDA's recommender function to select stress variables. This example uses the financial industry of the ASEAN-5 countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) and perform a backtesting from 2008-01 onward.

Three-step Instruction

Step 1:

To begin, define a pool of potential stress variables from which the recommendation algorithm can choose. Select economy/sector-specific stress variables and other variables of interest to define this pool. By default, the algorithm will select variables from the economies in the target portfolio, which is the ASEAN-5 financial industry in this example. Users can add or remove economies to reflect their needs. The economy/sector-specific variables are categorized into three groups. Users can click "+" to expand each category and select/unselect variables in that category. In this example, all categories are fully included. For other variables of interest, VIX and FFSI are also added to the pool, see Figure 16. In total, 132 variables are in the pool for the algorithm to choose from.

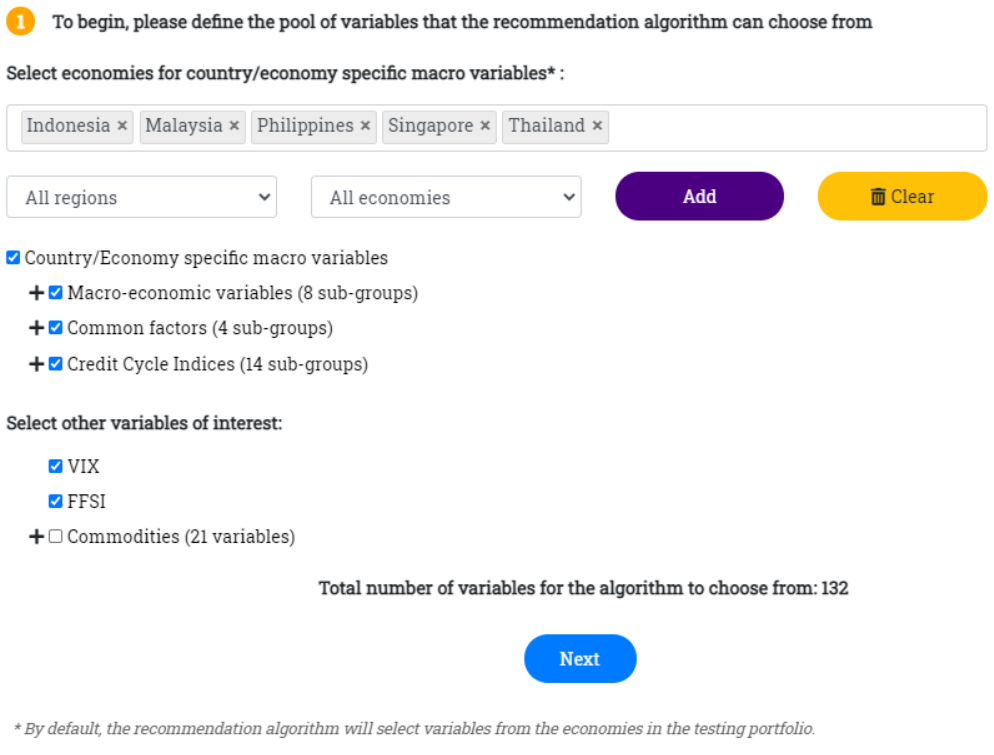


Figure 16: Defining the pool of stress variables

Step 2:

Specify the number of desired stress variables for the algorithm to select. In this example it is set to 5 variables (see Figure 17). The algorithm is set to choose up to 10 variables.

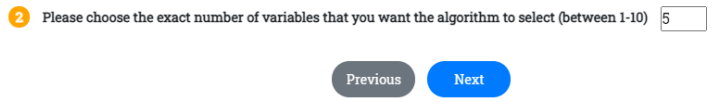


Figure 17: Specifying number of variables

Step 3:

In the final step, users can review the variables in the defined pool and the desired number of stress variables to be recommended. Additionally, users have the option to put one or more variables in the defined pool as the 'must-include' stress variables so that they will always appear in the final recommended set. In this example, Singapore GDP is the "must-include" variable. Select Singapore GDP using the selection box and click "Add". As such, the final 5 variables chosen by the algorithm will comprise Singapore GDP and 4 other stress variables to deliver the highest explanatory power, see Figure 18.

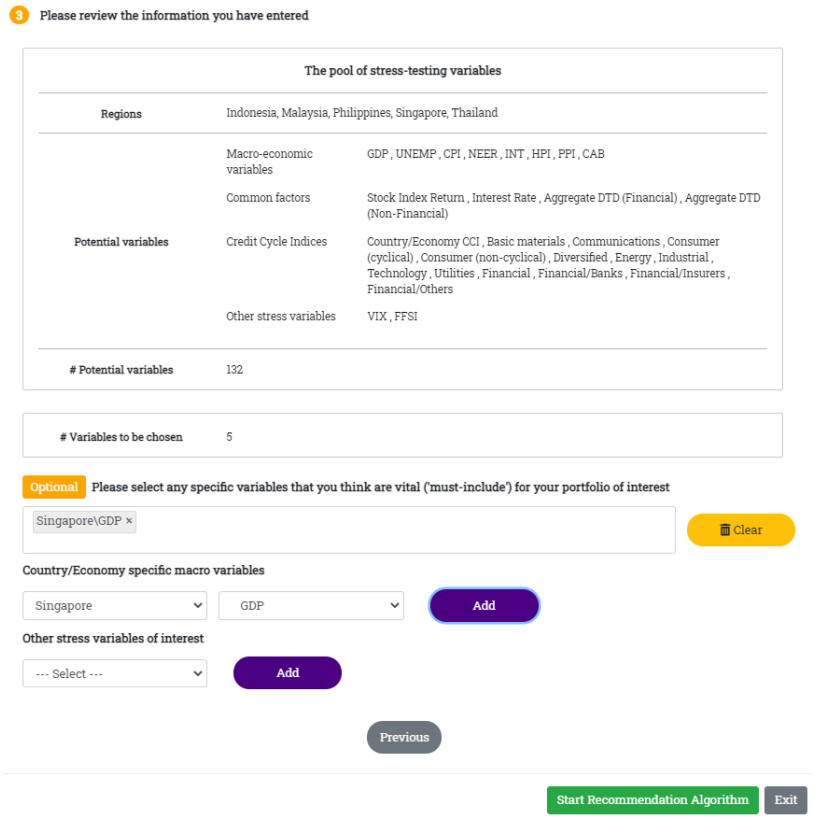


Figure 18: Reviewing the information and selecting 'must-include' variables

Now, click “Start Recommendation Algorithm” and wait for the results to be generated. During the computation, a summary about the variable selection task will be displayed for users’ reference.

Results

The recommended 5 variables are automatically filled in the stress variables box in Step 2.4 (see Figure 19), namely, the “must-include” Singapore GDP, Indonesia Aggregate DTD (Financial), Malaysia Interest Rate, Thailand Interest Rate, and Thailand Aggregate DTD (Financial).

Figure 19: Recommended variables

Next, click “*Confirm*” to check the sample period for each variable and then click “*Next*” to go to the final step. This example uses all default values for other settings. So, click “*Submit*” to start the analysis. Download the results when they are ready.

The file *12mthPDMedian_PDiR2.0 (Mean).png* shows that using the 5 recommended stress variables yields a good result in terms of matching the stressed portfolio PDs with the actual PDs from 2018-01 onward, see Figure 20.

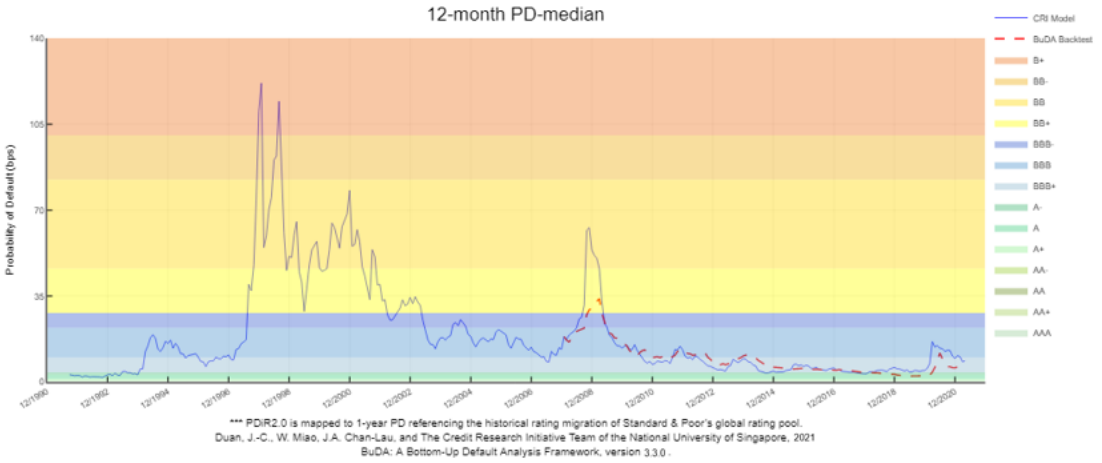


Figure 20: Backtesting result of ASEAN-5 financial industry

IV. BuDA Implementation: an example

This section explains from start to finish the BuDA stress testing analysis as well as the interpretation of the BuDA results. The example is the Energy Industry of the United States of America and deploys two stress variables: (1) Cushing OK WTI Oil spot price (WTI Crude) provided in the BuDA database and (2) the US GDP on a quarterly basis. The second variable in this example is purposely treated as a user-supplied stress variable and its time series is extracted from the US Federal Reserve Database even though the US GDP series is also available in the BuDA database.

Figure 21 shows the backtesting results where the testing time point is 2010-01 and the training data is the whole sample period. This section first provides a guidance for specifying the user inputs and then turns to the description of the BuDA results.

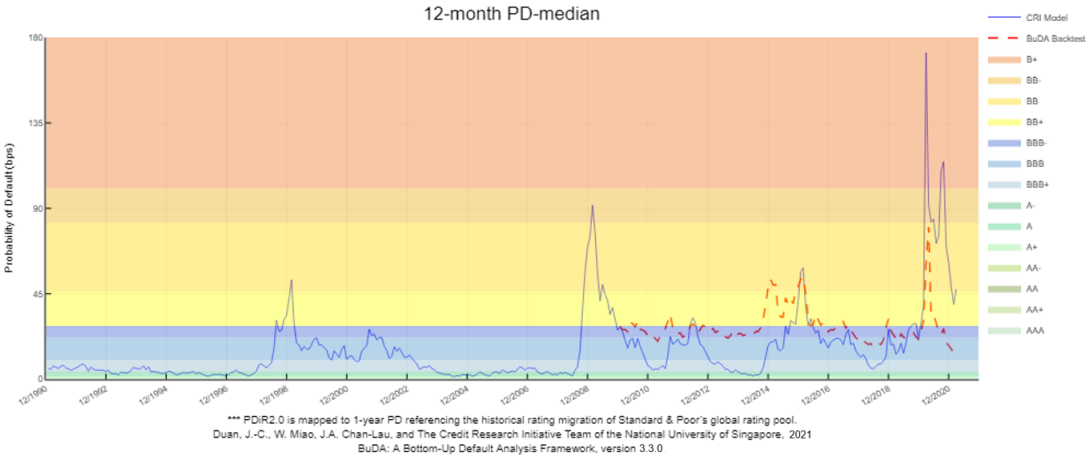


Figure 21: Backtesting result of US energy industry

Three-step Instruction

Step 1:

Rather than selecting the country and industry, the target portfolio for this illustration purpose comprises all energy firms in the US identified by their IDBBs (Bloomberg IDs) in an Excel file. When "User's target portfolio" is selected, a window, "*Upload portfolio*", pops up. The Excel file in Figure 22 contains the IDBBs of these firms and the file is saved as *.csv before uploaded.

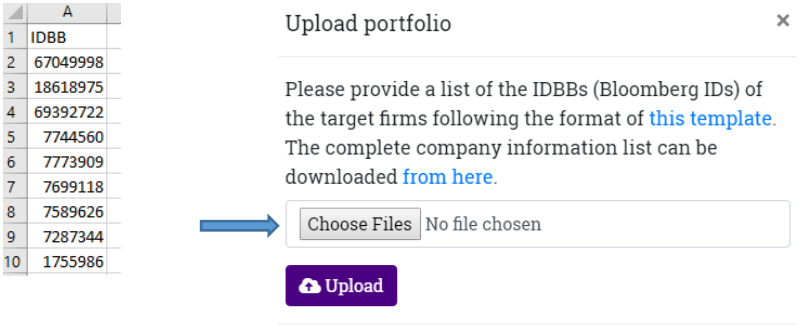


Figure 22: Case Study Step 1

Once the provided portfolio is successfully uploaded, the Economies and Industries boxes are updated as "*United States of America*" and "*Energy*", see Figure 23.

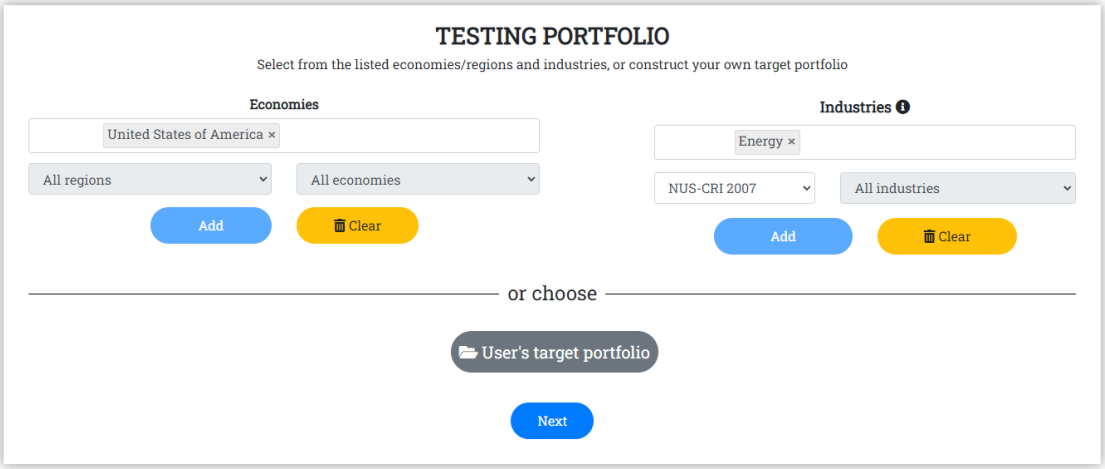


Figure 23: Provided portfolio is successfully updated

Step 2:

Select 'User-specified scenarios'. Furthermore, choose the testing time point as 2021-02 and the training period to be "*Till testing time point*". Since WTI Crude spot price is provided by BuDA, click "*Choose from economy/variable list*" to select it from "*Other stress variables of Interest*". In addition, US GDP is intended for inclusion through *"User Supplied Stress Variable"*. To upload the US GDP data, users follow the instructions for preparing the training and testing data.

Training data preparation for user's supplied stress variables

- To upload the US GDP data, simply tick the *"User Supplied Stress Variable"* check box to upload the data set.
- For monthly US GDP data, "*Frequency*" is specified as "1", and "*Macro Type*" as "1", in C8 and C12 in Figure 24, respectively.
- In this example, data are assigned for each month from 1993-01 to 2021-04.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	US																	
2																		
3	This Frequency provides the information whether the training macro-economic scenarios used are reported on a monthly basis or a quarterly basis or a yearly basis.																	
4	The value "1" means "Monthly"; "0" means "Quarterly"; and the value "-1" means "Yearly".																	
5	If it is on a quarterly basis;the data should be reported in Month 3 6 9 12 while blank need be reported in other months.																	
6	If it is on a yearly basis; the data should be reported in Month 12 while blank need be reported in Month 1-11																	
7	Growth rate on a monthly basis should be MoM growth rate (non-annualized); on a quarterly basis should be QoQ growth rate (non-annualized); on a yearly basis should be YoY growth rate.																	
8	Frequency		1															
9																		
10	This Macro Type provides the information that for each country whether the training macroeconomic scenario is the change (growth rate/difference) or the level.																	
11	The value "1" means "Change (Growth Rate %)"; the value "0" means "Change (Difference)"; the value "-1" means "Level".																	
12	Macro Type		1															
13																		
14	year	month	US_GDP															
15	1993	1	0.055962															
16	1993	2	0.055962															
17	1993	3	0.055962															
18	1993	4	0.193447															
19	1993	5	0.193447															
20	1993	6	0.193447															
21	1993	7	0.158941															
22	1993	8	0.158941															
23	1993	9	0.158941															
24	1993	10	0.451306															
25	1993	11	0.451306															
26	1993	12	0.451306															
27	1994	1	0.322678															
28	1994	2	0.322678															
29	1994	3	0.322678															
30	1994	4	0.449444															
31	1994	5	0.449444															
32	1994	6	0.449444															
33	1994	7	0.194579															
34	1994	8	0.194579															
35	1994	9	0.194579															
36	1994	10	0.380424															
37	1994	11	0.380424															
38	1994	12	0.380424															
39	1995	1	0.117884															

macro_train_template

Figure 24: US GDP Historic growth rate

Figure 25 shows the available training sample period for the selected stress variables: WTI Crude spot price and US GDP.

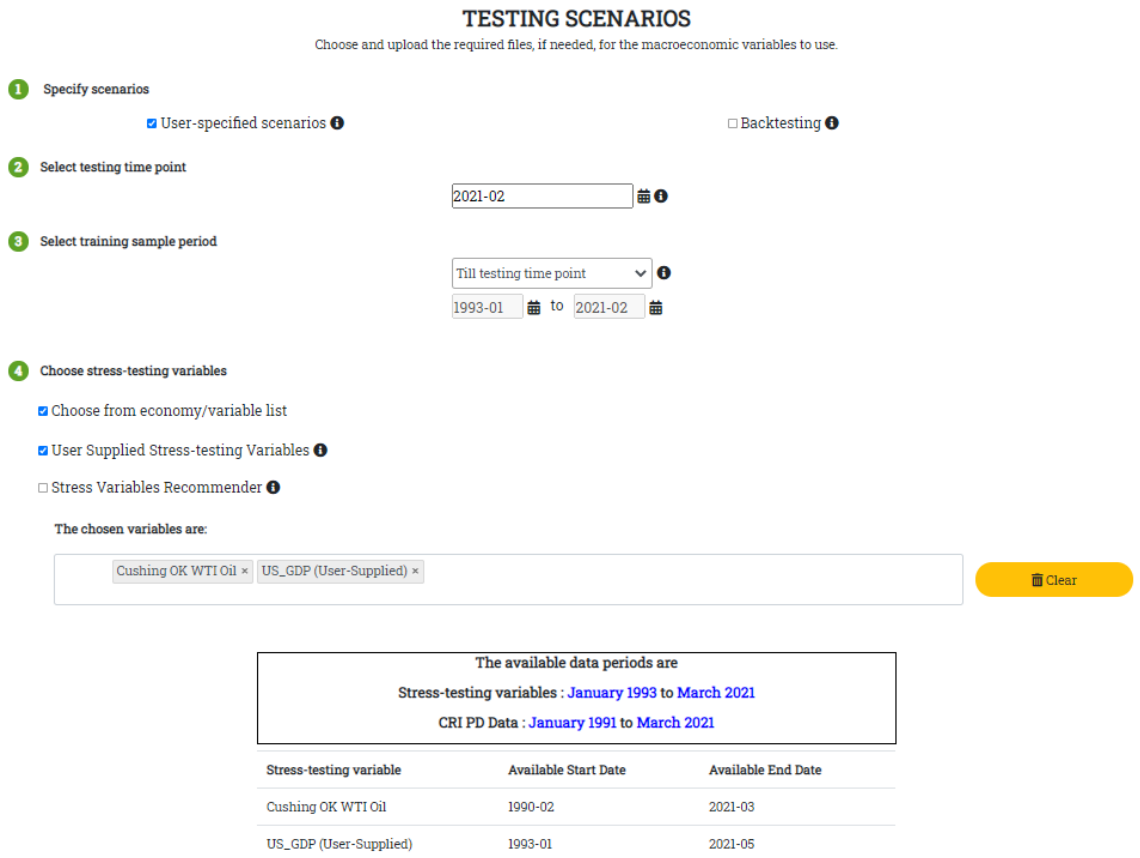


Figure 25: Available training period of uploaded training data

Testing data preparation

After confirming the stress variables, select "*Generate testing scenario file*". A customized template corresponding to the user's chosen variables will be downloaded. Do not modify or re-use the template as it might create inconsistency and cause an error.

In this example, there are three scenarios of interest (adverse, current and improving), which are determined by the WTI Crude spot price and US GDP growth rate as shown in Figure 26. Each scenario should be specified in separate sheets of a single Excel file. By default, the provided template accommodates two scenarios. Users can add a new sheet by copying "*Scenario 2*" and creating "*Scenario 3*".

It is important to specify the correct data frequency in the first sheet. “1” is filled in for this example as monthly data are used (see cell C6 in adverse scenario 1, Figure 26).

Upload the filled template to BuDA and click “confirm”.

Note: that the frequency of the testing data does not need to be the same as the training data. All three of the sheets must have the identical length and variable names.

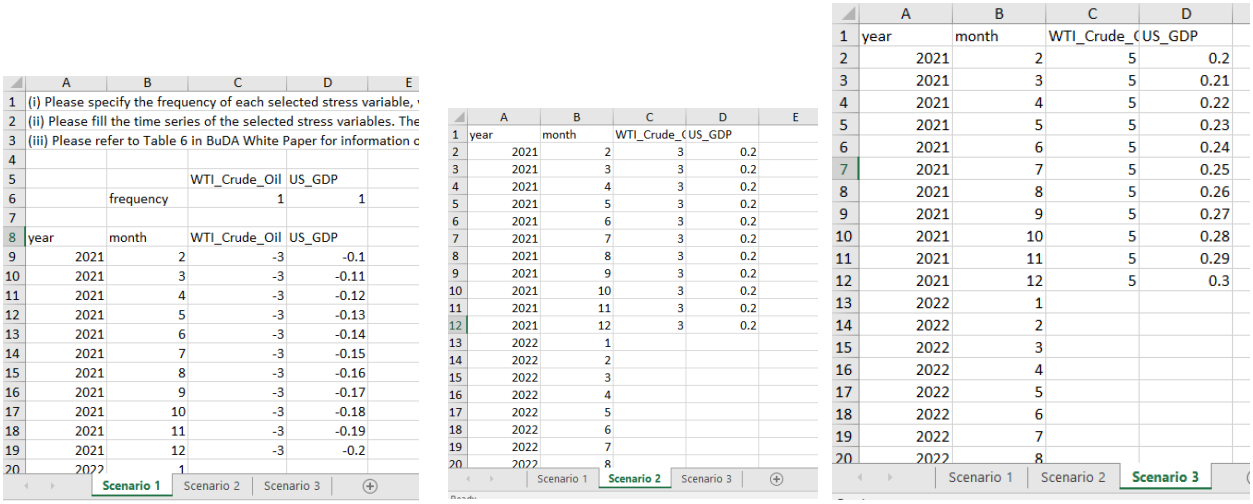


Figure 26: Stress Scenarios on WTI Crude and US GDP

Step 3:

The default setting of BuDA is to use 1-year PD values, thus the PD horizon is set for 12 months. PD Horizon can be set anywhere between 1 and 60 months. Users can also set the PDiR2.0 ratings to be mapped to S&P or Moody’s.

Click “*Submit*”. It may take several minutes to half-an-hour to complete the various BuDA computation tasks. The estimated times for different BuDA steps will be shown and the overall progress will also be reported on the screen.

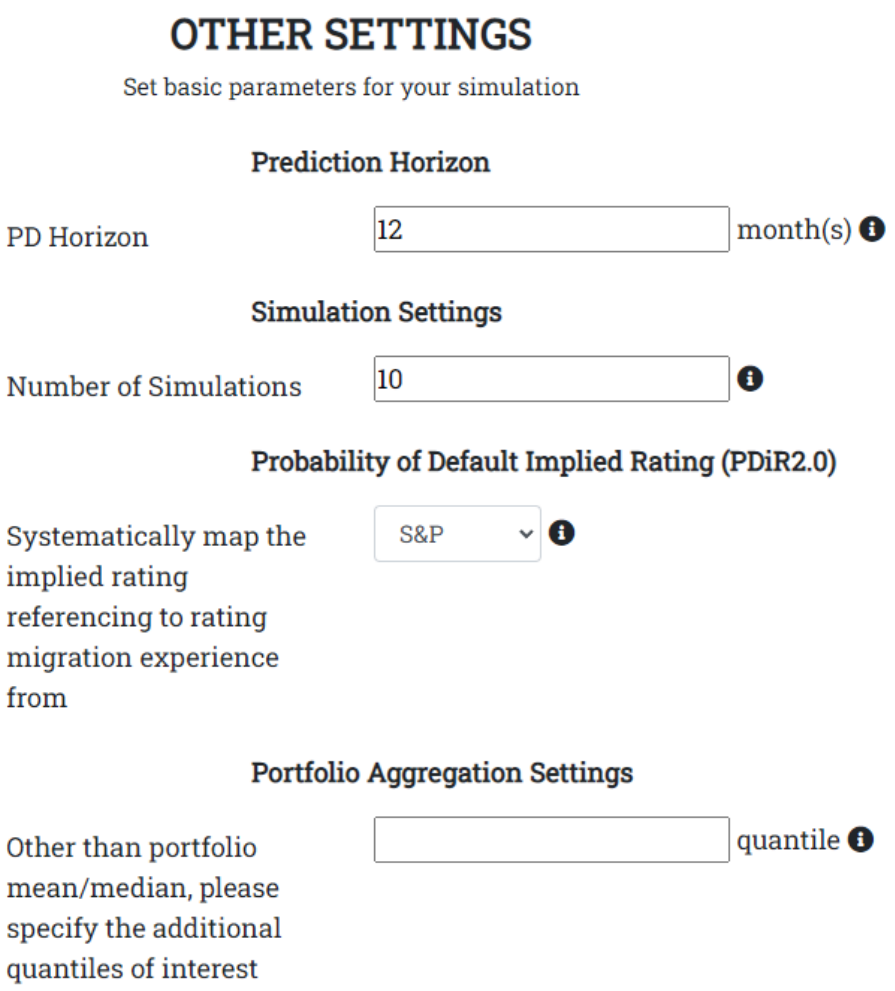
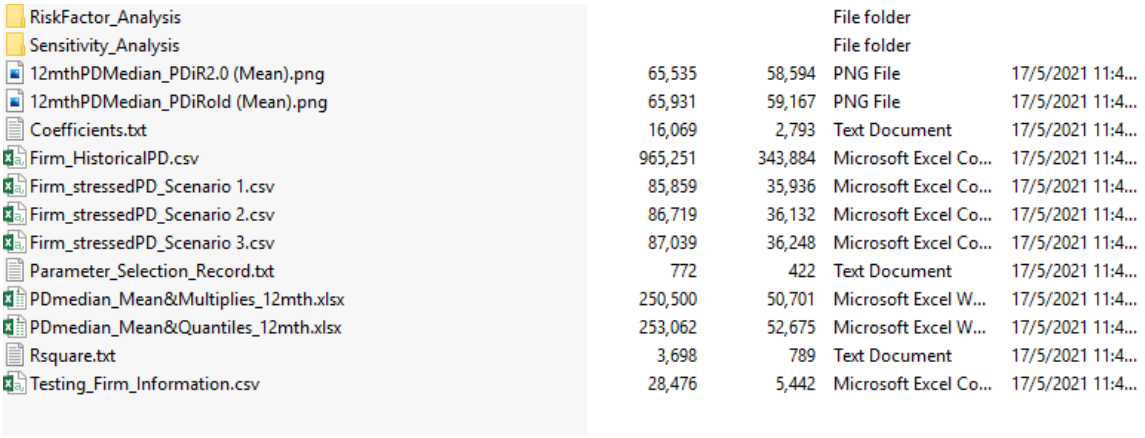


Figure 27: Case Study Step 3

Results

Once the computation is complete, BuDA will automatically download the outputs in a *.zip file. The following section will cover the detail of the BuDA results, as seen in Figure 28.



RiskFactor_Analysis			File folder	
Sensitivity_Analysis			File folder	
12mthPDMedian_PDiR2.0 (Mean).png	65,535	58,594	PNG File	17/5/2021 11:4...
12mthPDMedian_PDiRold (Mean).png	65,931	59,167	PNG File	17/5/2021 11:4...
Coefficients.txt	16,069	2,793	Text Document	17/5/2021 11:4...
Firm_HistoricalPD.csv	965,251	343,884	Microsoft Excel Co...	17/5/2021 11:4...
Firm_stressedPD_Scenario 1.csv	85,859	35,936	Microsoft Excel Co...	17/5/2021 11:4...
Firm_stressedPD_Scenario 2.csv	86,719	36,132	Microsoft Excel Co...	17/5/2021 11:4...
Firm_stressedPD_Scenario 3.csv	87,039	36,248	Microsoft Excel Co...	17/5/2021 11:4...
Parameter_Selection_Record.txt	772	422	Text Document	17/5/2021 11:4...
PDmedian_Mean&Multiplies_12mth.xlsx	250,500	50,701	Microsoft Excel W...	17/5/2021 11:4...
PDmedian_Mean&Quantiles_12mth.xlsx	253,062	52,675	Microsoft Excel W...	17/5/2021 11:4...
Rsquare.txt	3,698	789	Text Document	17/5/2021 11:4...
Testing_Firm_Information.csv	28,476	5,442	Microsoft Excel Co...	17/5/2021 11:4...

Figure 28: BuDA results

(i) *Parameter_Selection_Record.txt*

This file provides a summary of the user's request, including the selected economies, industry, and stress variables. It also indicates the testing time point and training period. Users may keep this file as a reference.

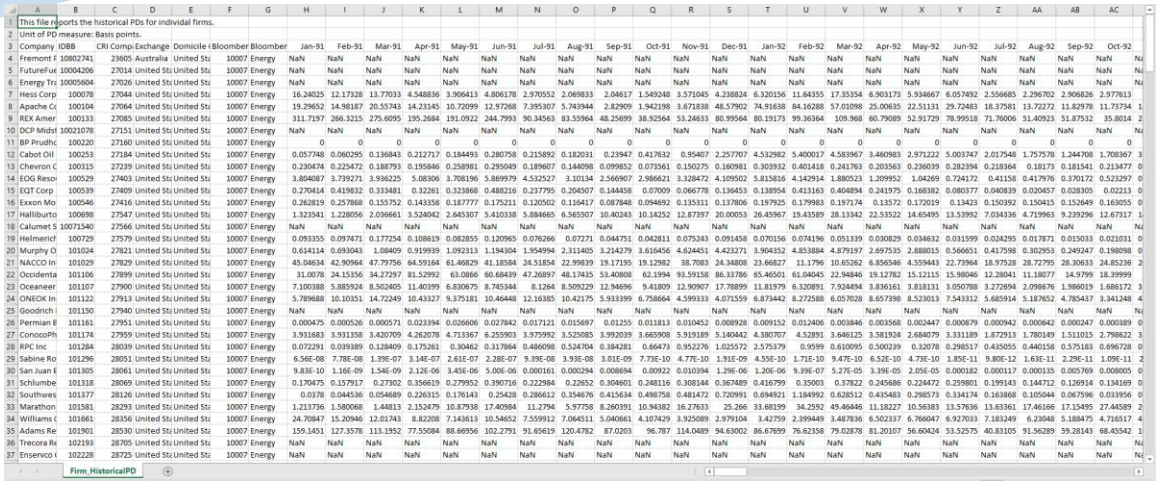
```
================================================================================
This file records the basic parameters you have selected for this test.
================================================================================

Testing Regions: United States of America
Testing Industries: Diversified, Energy
Macro Variables: WTI_Crude_Oil, US_GDP
Scenarios: Scenario 1, Scenario 2, Scenario 3
Testing Time Point: 202102
Training Sample Period: 199301 to 202102
PD Horizon: 12
Number of Simulations: 1000
```

Figure 29: Parameters Selection Record

(ii) *Testing_Firm_information.csv, Testing_Firm_information_Historical.csv*

These two files report the information on individual firms included in the portfolio. "*Testing_Firm_information_Historical.csv*" also reports the historical PDs of each firm in the sample. Users may notice several missing PDs, as those companies may not exist in that data period. They may have already defaulted, exited the market for reasons other than default, or have not been listed in a stock exchange yet.



This file reports the historical PDs for individual firms.
Unit of PD measure: Basis points.

Company	IDBB	CRI Comp	Exchange	Domicile	Bloomber	Bloomber	Jan-91	Feb-91	Mar-91	Apr-91	May-91	Jun-91	Jul-91	Aug-91	Sep-91	Oct-91	Nov-91	Dec-91	Jan-92	Feb-92	Mar-92	Apr-92	May-92	Jun-92	Jul-92	Aug-92	Sep-92	Oct-92
Fremont E	10802741	23605	Australia	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
FutureFue	10004206	27014	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
Energy Tra	10005604	27026	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
Hess Corp	100078	27044	United Sta	United Sta	10007	Energy	16.24025	12.17328	13.77033	4.548836	3.906413	4.806178	2.970552	2.069833	2.04617	1.549248	3.571045	4.238824	6.320156	11.64355	17.35354	6.903173	5.934667	6.057492	2.556685	2.296702	2.906826	2.977613
Apache Cc	100104	27064	United Sta	United Sta	10007	Energy	19.29652	14.98187	20.55743	14.23145	10.72099	12.97268	7.395307	5.743944	2.82909	1.942198	3.671838	48.57902	74.91638	84.16288	57.01098	25.00635	22.51131	29.72483	18.37581	13.72272	11.82978	11.73734
REX Amer	100133	27085	United Sta	United Sta	10007	Energy	311.7197	266.3215	275.6095	195.2684	191.0922	244.7993	90.34563	83.55964	48.25699	38.92564	53.24633	80.99564	80.19173	99.36364	109.968	60.79089	52.91729	78.99518	71.76006	51.40923	51.87532	35.8014
DCP Midst	10021078	27151	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
BP Prudhc	100220	27160	United Sta	United Sta	10007	Energy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabot Oil	100253	27184	United Sta	United Sta	10007	Energy	0.057748	0.060295	0.136843	0.212717	0.184493	0.280758	0.215892	0.182031	0.23947	0.417632	0.95407	2.257707	4.532982	5.400017	4.583967	3.460983	2.971222	5.003747	2.017548	1.757578	1.244708	1.708367
Chevron C	100315	27239	United Sta	United Sta	10007	Energy	0.230474	0.225472	0.188793	0.195846	0.258981	0.295049	0.189607	0.144098	0.099852	0.073561	0.150275	0.160981	0.303932	0.401418	0.241763	0.203563	0.236039	0.282394	0.218364	0.18173	0.181541	0.213477
EOG Resoi	100529	27403	United Sta	United Sta	10007	Energy	3.804087	3.739271	3.936225	5.08306	3.708196	5.869579	4.532527	3.10134	2.566907	2.986621	3.328472	4.109502	5.815816	4.142914	1.880523	1.209952	1.04269	0.724172	0.41158	0.417976	0.370172	0.523297
EQT Corp	100539	27409	United Sta	United Sta	10007	Energy	0.270414	0.419832	0.333481	0.32261	0.323868	0.488216	0.237795	0.204507	0.144458	0.07009	0.066778	0.136453	0.138954	0.413163	0.404894	0.241975	0.168382	0.080377	0.040839	0.020457	0.028305	0.02213
Exxon Mo	100546	27416	United Sta	United Sta	10007	Energy	0.262819	0.257868	0.155752	0.143358	0.187777	0.175211	0.120502	0.116417	0.087848	0.094692	0.135311	0.137806	0.197525	0.179983	0.197174	0.13572	0.172019	0.13423	0.150392	0.150415	0.152649	0.163855
Halliburto	100698	27547	United Sta	United Sta	10007	Energy	1.323541	1.228056	2.036661	3.524042	2.645307	5.410338	5.884665	6.565507	10.40243	10.14252	12.87397	20.00053	26.45967	19.43589	28.13342	22.53522	14.65495	13.53992	7.034336	4.719963	9.239296	12.67317
Calumet S	10071540	27566	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
Helmerich	100729	27579	United Sta	United Sta	10007	Energy	0.093355	0.097471	0.177254	0.108619	0.082855	0.120965	0.076266	0.07271	0.044751	0.042811	0.075243	0.091458	0.070156	0.074196	0.051339	0.030829	0.034632	0.031599	0.024295	0.017871	0.015033	0.021031
Murphy O	101024	27821	United Sta	United Sta	10007	Energy	0.614114	0.693043	1.08409	0.919939	1.092313	1.194304	1.954994	2.311405	3.214279	3.616456	4.624451	4.423271	3.904352	4.853884	4.879197	2.697535	2.888015	0.566651	0.417598	0.302953	0.249247	0.198098
NACCO In	101029	27829	United Sta	United Sta	10007	Energy	45.04634	42.90964	47.79756	64.59164	61.46829	41.18584	24.51854	22.99839	19.17195	19.12982	38.7083	24.34808	23.66827	11.1796	10.65262	6.856546	4.559443	22.73964	18.97528	28.72795	28.30633	24.85236
Occidenta	101106	27899	United Sta	United Sta	10007	Energy	31.00788	24.15356	34.27297	81.52992	63.0866	60.68439	47.26897	48.17435	53.40808	62.1994	93.59158	86.33786	65.46501	61.04045	22.94846	19.12782	15.12115	15.98046	12.28041	11.18077	14.9799	18.39999
Oceaneer	101107	27900	United Sta	United Sta	10007	Energy	7.100388	5.885924	8.502405	11.40399	6.830675	8.745344	8.1264	8.509229	12.94696	9.41809	12.90907	17.78899	11.81379	6.320891	7.924494	3.836161	1.818131	3.050788	3.272694	2.098676	1.986019	1.686172
ONEOK In	101122	27913	United Sta	United Sta	10007	Energy	5.789688	10.10351	14.72249	10.43327	9.375181	10.46448	12.16385	10.42175	5.933399	6.758664	4.599333	4.071559	6.873442	8.272588	6.057028	8.657398	8.523013	7.543312	5.685914	5.187652	4.785437	3.341248
Goodrich	101150	27940	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
Permian E	101161	27951	United Sta	United Sta	10007	Energy	0.000475	0.000526	0.000571	0.023394	0.026606	0.027842	0.017121	0.015697	0.01255	0.011813	0.010452	0.008928	0.009152	0.012406	0.003846	0.003568	0.002447	0.000879	0.000942	0.000642	0.000247	0.000389
ConocoPh	101174	27959	United Sta	United Sta	10007	Energy	3.931683	3.931358	3.420709	4.262078	4.713367	6.255903	3.975992	3.525085	3.992039	3.665908	5.919189	5.140442	4.380707	4.52891	3.646125	3.581924	2.684079	3.331189	1.872913	1.780149	1.511015	2.798622
RPC Inc	101284	28039	United Sta	United Sta	10007	Energy	0.072291	0.039389	0.128409	0.175261	0.30462	0.317864	0.486098	0.524704	0.384281	0.66473	0.952276	1.025572	2.575379	0.9599	0.610095	0.500239	0.32078	0.298517	0.415055	0.440158	0.575183	0.696728
Sabine Ro	101296	28051	United Sta	United Sta	10007	Energy	6.56E-08	7.78E-08	1.39E-07	3.14E-07	2.61E-07	2.28E-07	9.39E-08	3.93E-08	3.01E-09	7.73E-10	4.77E-10	1.91E-09	4.55E-10	1.71E-10	9.47E-10	6.52E-10	4.73E-10	1.85E-11	9.80E-12	1.63E-11	2.29E-11	1.09E-11
San Juan E	101305	28061	United Sta	United Sta	10007	Energy	9.83E-10	1.16E-09	1.54E-09	2.12E-06	3.45E-06	5.00E-06	0.000161	0.000294	0.008694	0.00922	0.010394	1.29E-06	1.20E-06	9.39E-07	5.27E-05	3.39E-05	2.05E-05	0.000182	0.000117	0.000135	0.005769	0.008005
Schlumbe	101318	28069	United Sta	United Sta	10007	Energy	0.170475	0.157917	0.27302	0.356619	0.279952	0.390716	0.222984	0.22652	0.304601	0.248116	0.308144	0.367489	0.416799	0.35003	0.37822	0.245686	0.224472	0.259801	0.199143	0.144712	0.126914	0.134169
Southwes	101377	28126	United Sta	United Sta	10007	Energy	0.0378	0.044536	0.054689	0.226315	0.176143	0.25428	0.286612	0.354676	0.415634	0.498758	0.481472	0.720991	0.694921	1.184992	0.628512	0.435483	0.298573	0.334174	0.163868	0.105044	0.067596	0.033956
Marathon	101581	28293	United Sta	United Sta	10007	Energy	1.213736	1.580068	1.44813	2.152479	10.87938	17.40984	11.2794	5.97758	8.260391	10.94382	16.27633	25.266	33.68199	34.2592	49.46446	11.18227	10.56383	13.57636	13.63361	17.46166	17.15495	27.44589
Williams (	101661	28356	United Sta	United Sta	10007	Energy	24.70847	15.20946	12.01743	8.82208	7.143613	10.54652	7.559912	7.064511	5.040661	4.107429	3.925089	2.979104	3.42759	2.399449	3.487836	6.502337	6.766047	6.927033	7.183249	6.23048	5.188475	4.716517
Adams Re	101901	28530	United Sta	United Sta	10007	Energy	159.1451	127.3578	113.1952	77.55084	88.66956	102.2791	91.65619	120.4782	87.0203	96.787	114.0489	94.63002	86.67699	76.62358	79.02878	81.20107	56.60424	53.52575	40.83105	91.56289	59.28143	68.45542
Trecora Re	102193	28705	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na
Enservco (	102228	28725	United Sta	United Sta	10007	Energy	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	Na

Firm_HistoricalPD

Figure 30: Testing Firm Information

(iii) *Coefficients.txt and Rsquare.txt*

"*Coefficients.txt*" reports the parameter estimates, along with their standard errors. The results in Figure 31 show that the WTI Crude spot price has positive effects on the stock index return and aggregate DTD values, which are in line with the intuition.

Coefficients in Stress Testing Regressions:

UNITEDSTATESOFAMERICA
Common variables

	Stock Index Return	Interest Rate	Aggregate DTD Fin	Aggregate DTD nonFin
Intercept	4.47e-03	-1.34e-02	5.95e-02	1.06e-01
	(3.81e-03)	(4.71e-03)	(2.14e-02)	(2.27e-02)
WTI_Crude_Oil	1.45e-03	1.66e-03	4.65e-03	5.39e-03
	(3.04e-04)	(3.99e-04)	(8.78e-04)	(7.30e-04)
US_GDP	1.83e-02	2.73e-02	5.06e-02	3.93e-02
	(7.78e-03)	(9.93e-03)	(2.27e-02)	(1.85e-02)
Lag 1	-4.03e-02	5.57e-02	4.62e-02	1.51e-01
	(5.31e-02)	(2.60e-02)	(4.68e-02)	(4.58e-02)
Lag 2	-6.14e-02	-7.00e-02	-7.11e-02	-1.84e-01
	(5.39e-02)	(2.90e-02)	(4.93e-02)	(4.89e-02)

Figure 31: Coefficients.txt

In addition, the R-squares[3] of all stress testing regressions are reported in "Rsquare.txt". Results in Figure 32 show that WTI Crude spot price and US GDP growth rate together have the highest explanatory power for Stock Index Return among the common risk

[3] The R-squares are calculated in the normal way instead of that in Duan et al (2012). In addition, when there are insufficient data (less than 5 firms or less than 3 years of data) in the specific economy-sector, the aggregation group-sector mean is used as a substitution. For details, please refer to BuDA White Paper v3.3.2 page 27.

factors. For the sector-average firm-specific variables, the R-square for M/B is the highest for Energy sector.

```
--------------------------------------------------------------------------------------------------------------------------------
UNITEDSTATESOFAMERICA
Common variables
Stock Index Return          0.5058
Interest Rate               0.2316
Aggregate DTD Fin           0.1620
Aggregate DTD nonFin        0.2596

Firm-specific variables (Sector mean)
Sectors                     DTD             CA/CL           NI/TA           SIZE            M/B
Diversified                 0.2575          0.1806          -0.0773         0.1606          0.3146
(Replaced by group sector average as not enough data in the sector)
Energy                      0.4520          0.3021          0.2763          0.3981          0.4562

--------------------------------------------------------------------------------------------------------------------------------
```

Figure 32: Rsquare.txt

(iv) *Firm_stressedPD_Scenario 1, Scenario 2, and Scenario 3.csv*

These files report the 12-month stressed PDs of each firm (individual level) for each stressed scenario. Please refer to the BuDA white paper for further details on how the stressed PDs are computed. "*Firm_stressedPD_Scenario 1.csv*" contains the BuDA results which are the stressed PDs under Scenario 1 (Adverse WTI Crude Oil spot price and US GDP growth rate) and displayed in Figure 33.

This file reports the stress PDs for individual firms.
Unit of PD measure: Basis points.
Please cite the BuDA results in the following way:
Duan, J.-C., W. Miao, J.A. Chan-Lau, and The Credit Research Initiative Team of the National University of Singapore, 2021. BuDA: A Bottom-Up Default Analysis Framework, version 3.3.0.

Company	IDBB	CRI Comp	Exchange	Domicile (	Bloomber	Bloomber	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
Fremont F	10802741	23605	Australia	United Sta	10007	Energy	122.8611	158.0925	190.6477	202.2277	222.6275	255.0128	287.8698	297.2366	290.0542	288.173	292.8699
FutureFue	10004206	27014	United Sta	United Sta	10007	Energy	1.783623	2.740675	3.772684	4.475175	4.820871	4.581873	4.761068	5.045903	5.388272	5.517491	5.775184
Energy Tra	10005604	27026	United Sta	United Sta	10007	Energy	118.6762	152.9492	174.3888	195.9597	228.1243	245.7368	274.3555	310.7431	322.3857	334.6031	354.7217
Hess Corp	100078	27044	United Sta	United Sta	10007	Energy	43.64163	49.41768	47.67508	51.06073	52.32923	56.42221	59.64386	66.8048	74.55788	83.11202	86.27947
REX Amer	100133	27085	United Sta	United Sta	10007	Energy	7.542284	12.00427	17.35716	23.32444	32.18888	43.38055	56.21932	81.17503	88.39172	109.1897	134.3316
DCP Midst	10021078	27151	United Sta	United Sta	10007	Energy	86.79962	97.19196	107.0486	120.0941	139.6103	158.0194	172.5097	187.4678	206.479	219.5129	235.5402
BP Prudho	100220	27160	United Sta	United Sta	10007	Energy	2.393531	1.600349	1.285467	1.483039	1.985415	2.210228	2.089163	2.01408	2.21298	1.963503	1.775257
Cabot Oil	100253	27184	United Sta	United Sta	10007	Energy	6.602343	6.717797	6.052518	5.690866	5.845816	5.950327	6.281221	7.124905	7.767722	8.406605	8.707624
Chevron C	100315	27239	United Sta	United Sta	10007	Energy	24.95404	37.86579	75.80555	117.5004	162.2655	209.6402	277.5381	348.1382	361.3147	454.7769	499.7736
EOG Reso	100529	27403	United Sta	United Sta	10007	Energy	31.63771	36.37159	39.52311	43.72233	48.13735	52.43326	58.20429	68.87399	79.5599	94.79434	110.0192
EQT Corp	100539	27409	United Sta	United Sta	10007	Energy	68.90571	89.34453	105.2091	109.2242	113.925	119.296	125.1413	148.4281	159.8213	163.027	165.188
Exxon Mo	100546	27416	United Sta	United Sta	10007	Energy	22.1269	24.43382	35.02087	50.60882	65.52885	83.8052	108.4959	144.4539	179.2362	219.481	272.3099
Halliburto	100698	27547	United Sta	United Sta	10007	Energy	55.11362	50.6325	57.38073	67.6983	76.07609	80.60649	87.70337	98.16227	106.3744	112.6044	118.5511
Calumet S	10071540	27566	United Sta	United Sta	10007	Energy	80.02655	74.11446	78.95053	92.95904	109.6391	120.0061	128.6662	142.5917	151.9819	166.2633	178.0239
Helmerich	100729	27579	United Sta	United Sta	10007	Energy	39.85655	48.91403	61.11287	70.03287	80.66621	95.79209	111.4403	125.3544	139.9541	155.6855	169.2528
Murphy O	101024	27821	United Sta	United Sta	10007	Energy	150.2499	170.2359	160.7212	166.2717	163.2531	174.505	176.0627	191.316	205.4951	216.1369	229.748
NACCO In	101029	27829	United Sta	United Sta	10007	Energy	31.12977	38.97503	45.0098	52.48098	62.20729	71.49052	84.37981	100.5315	119.1575	140.2195	163.5537
Occidenta	101106	27899	United Sta	United Sta	10007	Energy	215.1188	327.6193	411.188	485.9467	556.0662	586.8673	673.1134	767.344	918.3785	934.2331	1013.278
Oceaneer	101107	27900	United Sta	United Sta	10007	Energy	73.88017	89.73585	104.701	116.1512	132.5065	145.4379	160.8247	184.0052	207.2844	224.5771	235.5438
ONEOK In	101122	27913	United Sta	United Sta	10007	Energy	90.25203	207.7665	432.1028	643.2683	830.9583	1015.951	1098.32	1174.969	1200.438	1272.271	1334.509
Goodrich I	101150	27940	United Sta	United Sta	10007	Energy	74.84823	65.06254	48.76308	45.03629	53.13501	63.27709	69.33399	73.2644	76.04172	79.04066	82.0198
Permian E	101161	27951	United Sta	United Sta	10007	Energy	0.338402	0.315824	0.267446	0.24273	0.219931	0.212314	0.223776	0.248784	0.269943	0.292275	0.3157
ConocoPh	101174	27959	United Sta	United Sta	10007	Energy	25.52673	24.45428	27.9509	33.21203	39.67875	49.07248	59.18456	74.1548	92.85883	113.3641	136.876
RPC Inc	101284	28039	United Sta	United Sta	10007	Energy	8.975341	12.10374	16.03621	18.09141	19.83629	21.91511	24.09204	27.21695	30.25508	32.10497	34.11786
Sabine Ro	101296	28051	United Sta	United Sta	10007	Energy	0.002047	0.002827	0.003556	0.0044	0.005626	0.005479	0.006125	0.004965	0.006066	0.005867	0.008498
San Juan E	101305	28061	United Sta	United Sta	10007	Energy	0.027626	0.064368	0.073439	0.078272	0.083372	0.088569	0.096662	0.10859	0.112945	0.123216	0.126794
Schlumbe	101318	28069	United Sta	United Sta	10007	Energy	68.71239	89.71554	106.5254	123.1815	145.2318	163.5409	184.4801	215.8327	243.7571	261.3708	277.9221
Southwes	101377	28126	United Sta	United Sta	10007	Energy	155.9872	223.7263	275.9651	309.0002	337.1308	366.0621	397.6917	445.1567	475.528	494.2666	530.3697
Marathon	101581	28293	United Sta	United Sta	10007	Energy	48.72839	58.16944	63.70472	72.4157	82.20909	92.10082	103.2325	118.4717	132.0519	143.6622	147.086
Williams (	101661	28356	United Sta	United Sta	10007	Energy	34.4819	42.538	46.83064	56.98829	53.3333	52.27887	52.64097	58.2205	64.22803	67.93616	84.29464
Adams Re	101901	28530	United Sta	United Sta	10007	Energy	21.49739	20.24204	20.20609	21.10066	21.39146	21.50021	22.3035	24.08825	25.20348	27.20076	28.93571
Trecora Re	102193	28705	United Sta	United Sta	10007	Energy	26.00781	24.95942	22.43596	20.47524	20.6033	21.38728	23.78959	26.98281	28.86215	30.9912	31.77388
Enservco (	102228	28725	United Sta	United Sta	10007	Energy	58.24226	91.82914	118.1506	168.0271	216.8853	258.6732	313.9387	363.5026	412.9307	442.0126	479.6187
Abraxas P	102316	28778	United Sta	United Sta	10007	Energy	454.3084	507.5184	478.579	500.7736	531.4654	547.8015	563.3219	616.8109	700.5189	786.3895	876.0345

Firm_stressedPD_Scenario 1

Figure 33: Testing_firm_PDs_12mth_Test1.csv

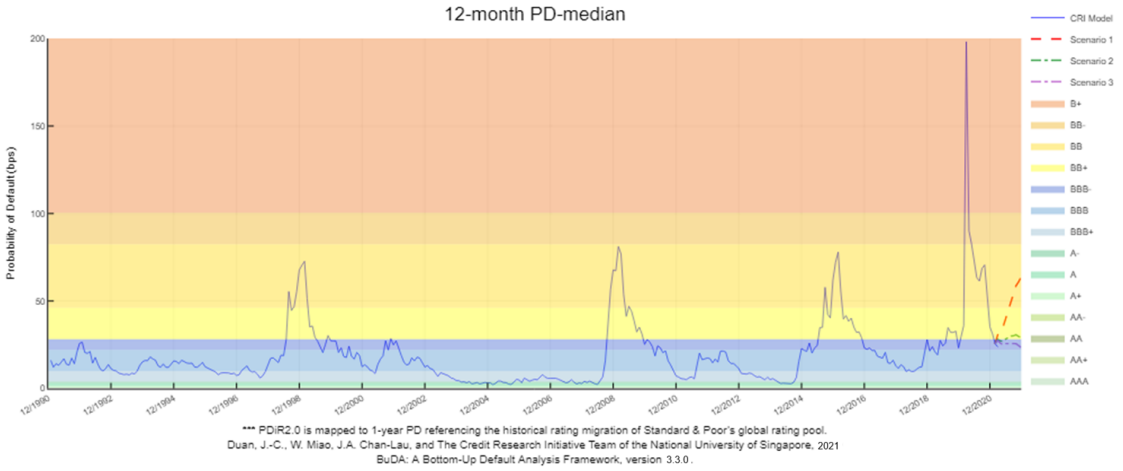
(v) *12mthPDmedian_PDiR2.0(Mean).png*

"*12mthPDmedian_PDiR2.0(Mean).png*" reports the bottom-up aggregated portfolio PDs (medians) for both the historical data (training data) and the user-specified scenarios.

For computing the stressed portfolio PD, the median PD for all individual firm in the target portfolio is computed under each simulation run. Since 1000 simulation is chosen in this example, the stressed portfolio PD, BuDA generates 1000 stressed median PDs and average them to obtain the final stressed portfolio PD. Their values for different time points are displayed in Figure 34.

The blue solid line in this figure is the actual CRI-PD of the portfolio, whereas the three dotted lines are the stressed portfolio PDs corresponding to the three given scenarios (adverse, current and improved scenarios, denoted as Scenario 1, 2 and 3). As expected, the results show the highest stressed portfolio PD under the adverse scenario.

Since v3.3.3, we add a new function that caters for user-specified aggregation method. Therefore, some additional results figures, named as "12mthPD(aggregated_method) _PDiR2.0(Mean).png", may be generated.



*PD is reported in basis point

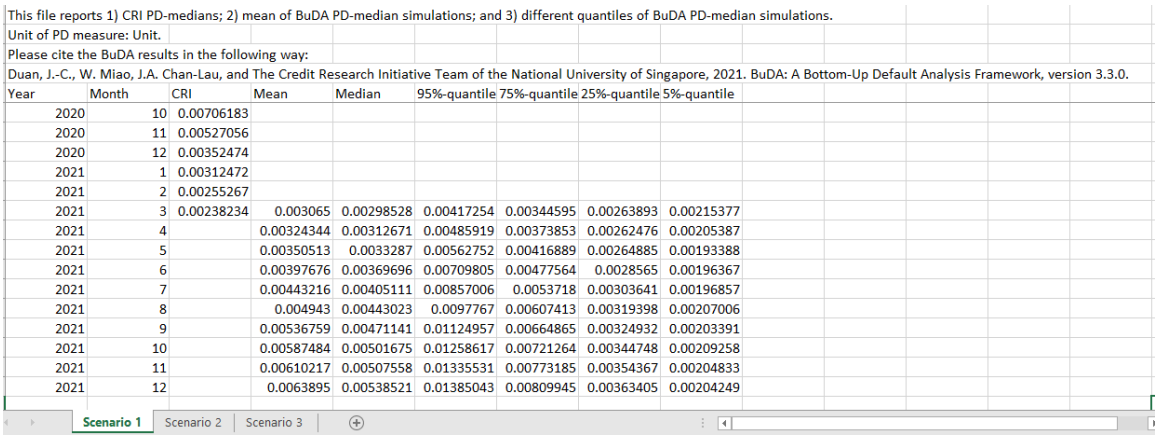
Figure 34: 12-Month PD of the bottom-up portfolio

(vi) *PDmedian_Mean&Quantiles_12mth.xlsx*

PDmedian_Mean&Quantiles_12mth.xlsx displayed in Figure 35 below shows the results produced under Scenario 1 (Adverse case). While the plot discussed in (iii) uses the stressed portfolio PD computed as the mean of the 1000 simulated median firm PDs,

users can apply other statistics. For example, users may consider using mean or other quantiles, instead of median, of the individual PDs in the target portfolio.

Since v3.3.3, we add a new function that caters for user-specified aggregation method. Therefore, some additional results figures, named as "PD(aggregation_method) _Mean&Quantiles_12mth.xlsx", may be generated.



This file reports 1) CRI PD-medians; 2) mean of BuDA PD-median simulations; and 3) different quantiles of BuDA PD-median simulations.
Unit of PD measure: Unit.
Please cite the BuDA results in the following way:
Duan, J.-C., W. Miao, J.A. Chan-Lau, and The Credit Research Initiative Team of the National University of Singapore, 2021. BuDA: A Bottom-Up Default Analysis Framework, version 3.3.0.

Year	Month	CRI	Mean	Median	95%-quantile	75%-quantile	25%-quantile	5%-quantile
2020	10	0.00706183						
2020	11	0.00527056						
2020	12	0.00352474						
2021	1	0.00312472						
2021	2	0.00255267						
2021	3	0.00238234	0.003065	0.00298528	0.00417254	0.00344595	0.00263893	0.00215377
2021	4		0.00324344	0.00312671	0.00485919	0.00373853	0.00262476	0.00205387
2021	5		0.00350513	0.0033287	0.00562752	0.00416889	0.00264885	0.00193388
2021	6		0.00397676	0.00369696	0.00709805	0.00477564	0.0028565	0.00196367
2021	7		0.00443216	0.00405111	0.00857006	0.0053718	0.00303641	0.00196857
2021	8		0.004943	0.00443023	0.0097767	0.00607413	0.00319398	0.00207006
2021	9		0.00536759	0.00471141	0.01124957	0.00664865	0.00324932	0.00203391
2021	10		0.00587484	0.00501675	0.01258617	0.00721264	0.00344748	0.00209258
2021	11		0.00610217	0.00507558	0.01335531	0.00773185	0.00354367	0.00204833
2021	12		0.0063895	0.00538521	0.01385043	0.00809945	0.00363405	0.00204249

Scenario 1 | Scenario 2 | Scenario 3

Figure 35: Median, Mean, and Quantiles of simulated PD-median

(vii) PDmedian_Mean&Multiplies_12mth.xlsx

Additional results pertaining to portfolio median PD simulations are also available to users. Columns E to I of "*PDmedian_Mean&Multiplies_12mth.xlsx*" as seen in Figure 36 provide the probabilities for the portfolio's stressed PD at time t+1, t+2, etc. to exceed the portfolio PD at the testing time point, t. The fact that 90%, 52.9%, and 27.7%, etc. of the simulated stressed portfolio PDs in December 2021 (last row) under the adverse scenario are higher than the portfolio median PD in February 2021 (testing time point) is in line with expectations.

Since v3.3.3, we add a new function that caters for user-specified aggregation method. Therefore, some additional results figures, named as PD(aggregation_method) _Mean&Multiplies_12mth.xlsx", may be generated.

This file reports: 1) CRI PD-medians; 2) mean of BuDA PD-median simulations; and 3) probabilities of BuDA PD-median simulations exceeding different multiple times of the CRI PD-medians at the time of BuDA analysis.
Unit of PD measure: Unit.
Please cite the BuDA results in the following way:
Duan, J.-C., W. Miao, J.A. Chan-Lau, and The Credit Research Initiative Team of the National University of Singapore, 2021. BuDA: A Bottom-Up Default Analysis Framework, version 3.3.0.

Year	Month	CRI	Mean	1-time proba	2-time proba	3-time proba	4-time proba	5-time probability
2020	7	0.00633383						
2020	8	0.00613829						
2020	9	0.00686662						
2020	10	0.00706183						
2020	11	0.00527056						
2020	12	0.00352474						
2021	1	0.00312472						
2021	2	0.00255267						
2021	3	0.00238234	0.003065	0.802	0.004	0	0	0
2021	4		0.00324344	0.782	0.036	0.002	0	0
2021	5		0.00350513	0.78	0.094	0.008	0.001	0
2021	6		0.00397676	0.829	0.191	0.033	0.004	0.001
2021	7		0.00443216	0.849	0.281	0.07	0.019	0.004
2021	8		0.004943	0.891	0.379	0.135	0.04	0.009
2021	9		0.00536759	0.872	0.432	0.167	0.07	0.029
2021	10		0.00587484	0.892	0.491	0.219	0.096	0.046
2021	11		0.00610217	0.89	0.494	0.259	0.123	0.06
2021	12		0.0063895	0.9	0.529	0.277	0.142	0.07

Scenario 1 | Scenario 2 | Scenario 3

Figure 36:PDmedian_Mean&Multiplies_12mth.xlsx

(viii) *RiskFactor_analysis folder*

This folder provides details of the shock to the PD predictors based on the specified stress scenario. The image file in the folder illustrates the simulated paths of the stressed PD predictors. Those Excel files provide the historical data of the PD predictors along with their stressed values.

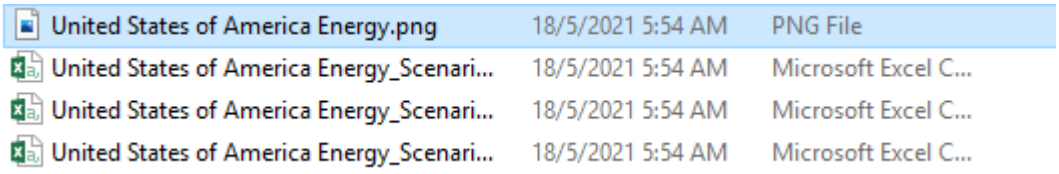


Figure 37: Risk Factor Analysis Folder

Figure 38 below shows how DTD responds under the specified scenarios. The blue line represents the stressed PD under the adverse scenario, suggesting that DTD is expected to decline which will in turn cause an increase in the stressed PD value. In contrast, DTD increases significantly under the improving scenario (green line) and increases, though relatively less, if the current operating climate continues (red line). The raw data to generate this plot can be found in United States of America Energy_ Scenario 1, _ Scenario 2, and _ Scenario 3.csv.

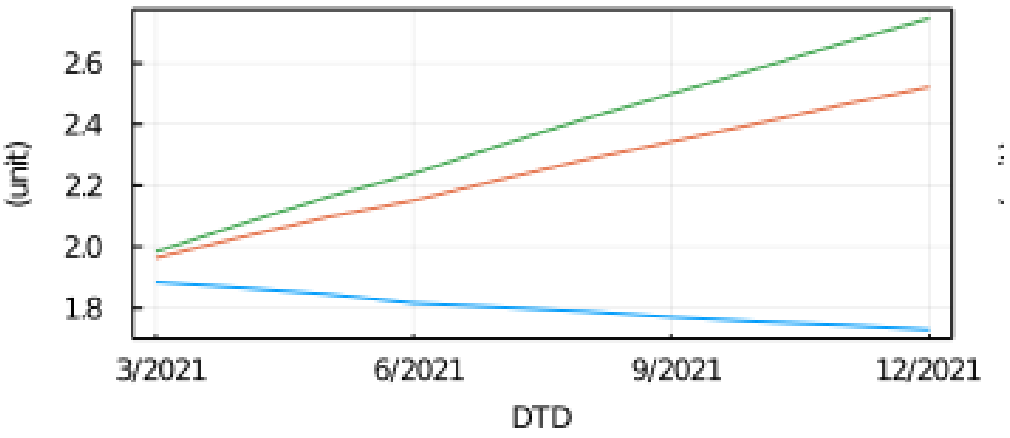


Figure 38: Simulated Paths of the Stressed Predictor using DTD as an example

(ix) *Sensitivity_analysis folder*

BuDA also has an optional function, "Output Cross-effect and Individual Variable Contribution", which can be selected in the advance settings in Step 3. If this option is selected, an additional "*Sensitivity_Analysis*" folder will be provided. This folder contains the files representing the contribution of the stressed variables to the stressed portfolio PD.

The main result is illustrated as an image file for each scenario. Figure 39 shows the contribution of WTI Crude spot price, US GDP growth rate, and cross-effect of these two variables to the stressed portfolio PD under the adverse scenario. Table 2 below provides additional notations for understanding this plot.

Table 2: Notations and description for sensitivity analysis

Notation	Description
PD_{GDP}	The stressed portfolio PD that is estimated when only US GDP has moved as specified, while WTI Crude spot price stays flat
PD_{WTI}	The stressed portfolio PD that is estimated when only WTI Crude spot price has changed as specified, and US GDP remains constant
PD_{flat}	The portfolio PD when both variables remain constant in the years to come
PD_{all}	The original stressed portfolio PD when both variables have moved as specified in the testing scenario

As we have two stress variables, we assume that there are three partial contributions to the change in the stress PD for each scenario. These contributions are derived from WTI Crude spot price, US GDP growth rate, and interaction between these two variables. Define the total contribution of these three terms as $PD_{all} - PD_{flat}$. The partial contribution of WTI Crude to the stressed portfolio PD can be seen as $PD_{WTI} - PD_{flat}$, while that of US GDP will then be $PD_{GDP} - PD_{flat}$. The

contribution of the cross-effect is the difference between the sum of partial contributions of WTI Crude and US GDP and the total contribution, i.e. $\left(PD_{GDP} + PD_{WTI} - 2PD_{flat}\right) - \left(PD_{all} - PD_{flat}\right)$.

The partial contribution of WTI Crude is the blue line in Figure 38. As the blue line is much greater than zero, it means that the change in WTI Crude in the adverse scenario significantly raises the stressed portfolio PD. The sum of partial contributions of WTI Crude and US GDP is displayed by the red dotted line. As the red dotted line is above the blue line but not substantially, it implies that the increase in PD for the adverse scenario is mainly contributed by WTI Crude followed by US GDP. The cross-effect, the black line, appears to be mildly negative.

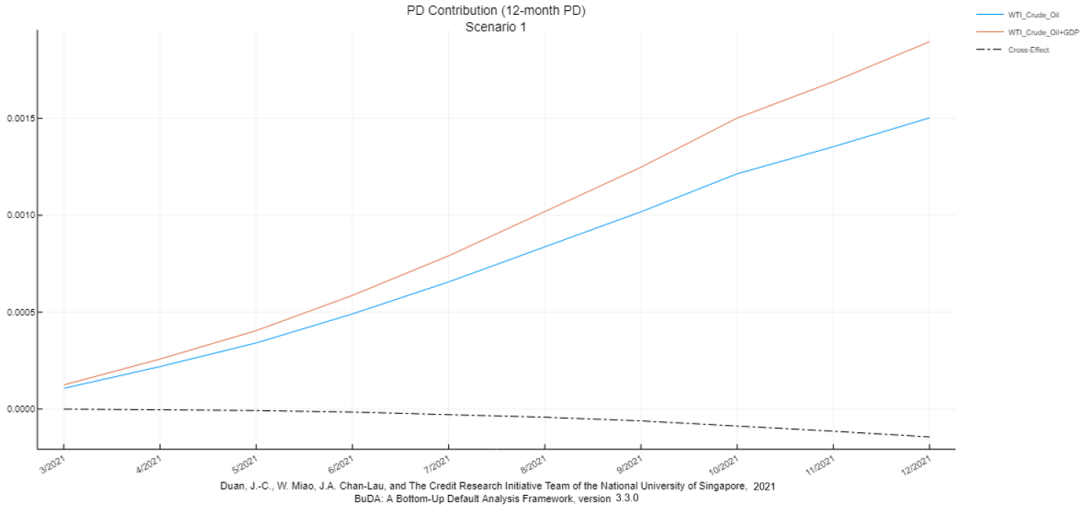


Figure 39: Cross-effect and Individual Variable Contribution

The remaining files in the "*Sensitivity_Analysis"* folder have similar descriptions as those of the main results. However, these files show the effect of movement in only one variable *ceteris paribus*. As there are three scenarios and two stressed variables in this example, the sensitivity analysis will provide six different scenario plots in total.

NUS Credit Research Initiative
Address: 21 Heng Mui Keng Terrace, I^3 Building, Level 4, Singapore 119613
Tel: (65) 6516 3380 Fax: (65) 6874 5430
Website: http://nuscri.org/

Credit Research Initiative
National University of Singapore