Moody's Analytics

Better Faster Decisions

Forward-looking Risk Measurement

A Moody's Analytics Presentation

Armen Mirzoyan, Associate Director, *MA Predictive Analytics Unit*

Gega Todua, Assistant Director, *MA Predictive Analytics Unit*

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1 Overview

Regulatory Origins of Forward-Looking Risk

IFRS 9 Requirements

> "An entity shall measure ECL of a financial instrument in a way that reflects an unbiased and probability-weighted amount that is determined by evaluating a range of possible outcomes."
>
> *(5.5.17)*

> "When measuring ECL, an entity need not necessarily identify every possible scenario. However, it shall consider the risk of probability that a credit loss occurs by reflecting the possibility that a credit loss occurs and the possibility that no credit loss occurs, even if the possibility of a credit loss occurring is very low."
>
> *(5.5.18)*

> "This may not need to be complex analysis. In some cases, relatively simple modelling may be sufficient, without the need for a large number of detailed simulations of scenarios."
>
> *(B5.5.42)*

> "…an entity need not necessarily identify every possible scenario." *(5.5.18)*

Key Take-Aways

Forward Looking & Probability-Weighted Outcomes

- Requires expected credit losses (ECL) to account for forward-looking information
- Requires probability-weighted outcomes when measuring expected credit losses
  - Estimates should reflect the possibility that a credit loss occurs and the possibility that no credit loss occurs

Macroeconomic modelling satisfies both requirements above

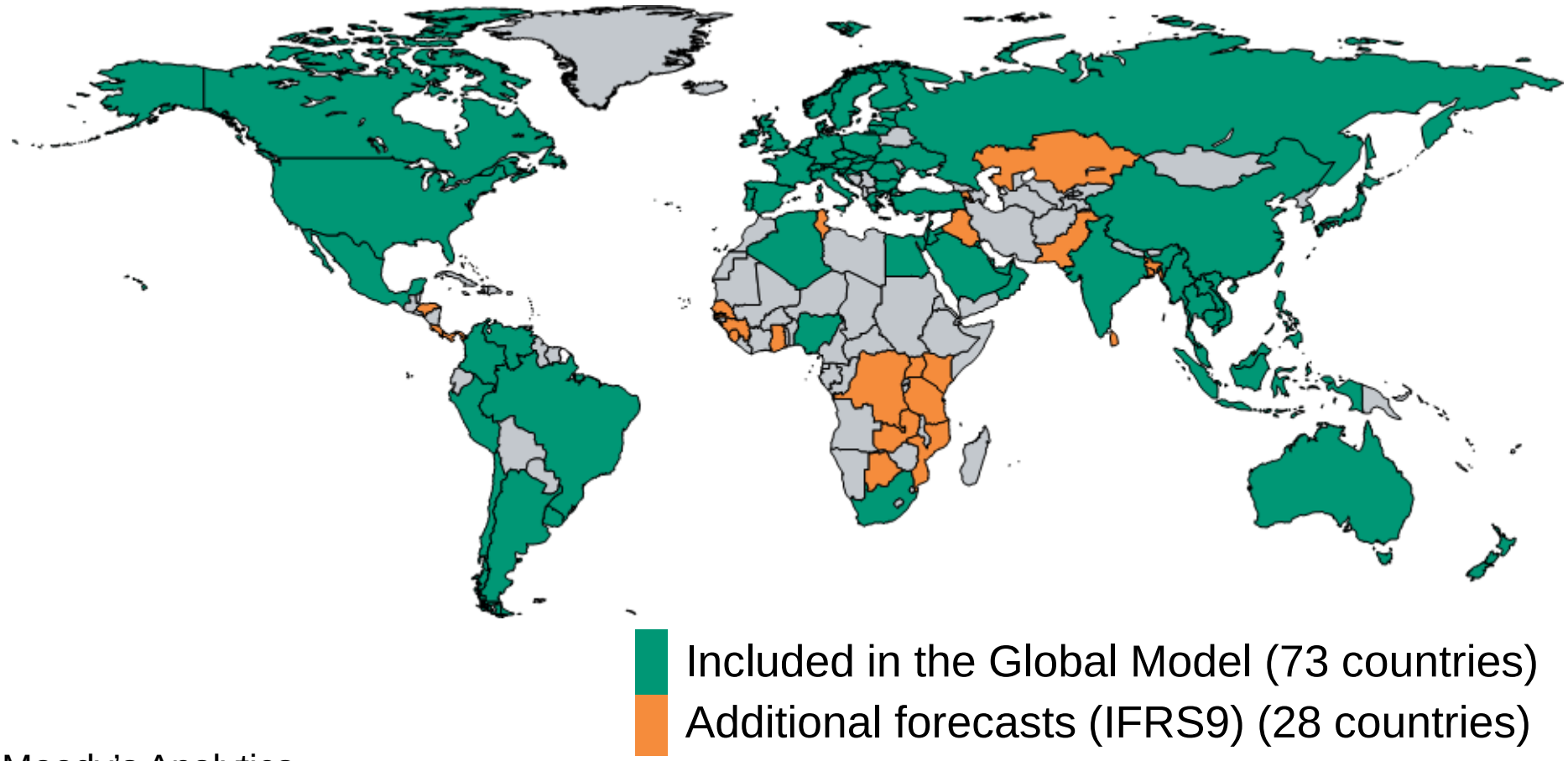
2 Macroeconomic Forecasting

2.1

Coverage and Key Features

Moody’s Analytics Global Forecast Coverage

April 2021



Sources: Moody’s Analytics

Key Features

Collaborative Access and Integration

Develop scenarios individually or collaboratively in a real-time, multi-user environment.

Integrate forecasts into your workflow seamlessly through our API and Excel Add-In.

Comprehensive Coverage

Create scenarios for 101 countries and 10 regional aggregates, out to 30-years.

Evaluate monthly updated forecasts for 10,000+ economic and financial time series.

Robust Editing & Visualization Tools

Adjust detailed variables to simulate shocks or more discrete factors.

Visualize your changes through interactive dashboards, charting and data tables.

2.2

Moody’s Global Macroeconomic Model

Global Macroeconomic Model

Provides Globally Linked Forecasts

Linkages in the model allow for global shock propagation and contagion effects, and help ensure scenario consistency

- ***Trade flows*** (exports reflect partner imports)
- ***Financial markets*** (stock prices and bond yields)
- ***Prices*** (exchange rates, terms of trade and global commodity prices)
- ***Investment*** (foreign direct investment and capital flows)

Diagnostic processes ensure that our forecasts are stable from month to month and consistent with the business cycle outlook of each nation.

Modelling Approach

Each Country-model is a Mix of Theory and Data

Theory

- Quality of forecast and scenarios
- Complex
- Limited quantity of forecasts

Data

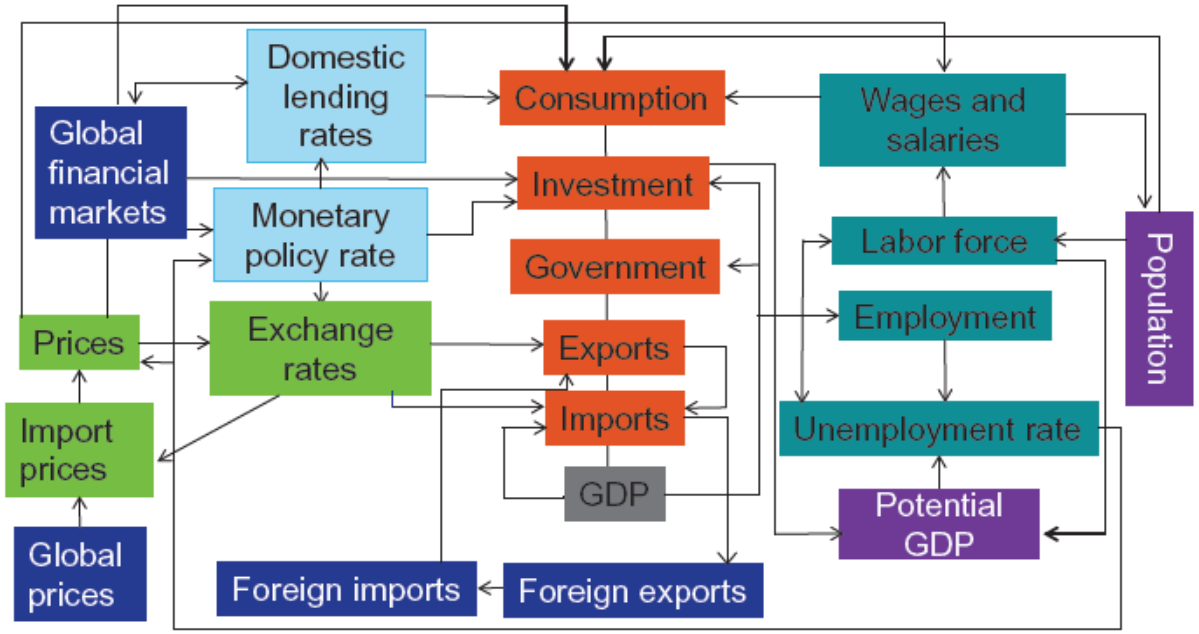
- Quality and quantity of forecasts
- Easy to produce
- Not ideal for scenario analysis

Our Models

Intersection of purely data- and purely theory-based models

Country-model Methodology Overview

Detailed Quantitative & Qualitative Testing



Specification choice

- Theoretical reasoning versus statistical properties

In-sample equation fit

- R-squared, RMSE, information criteria
- Fitted values and residuals

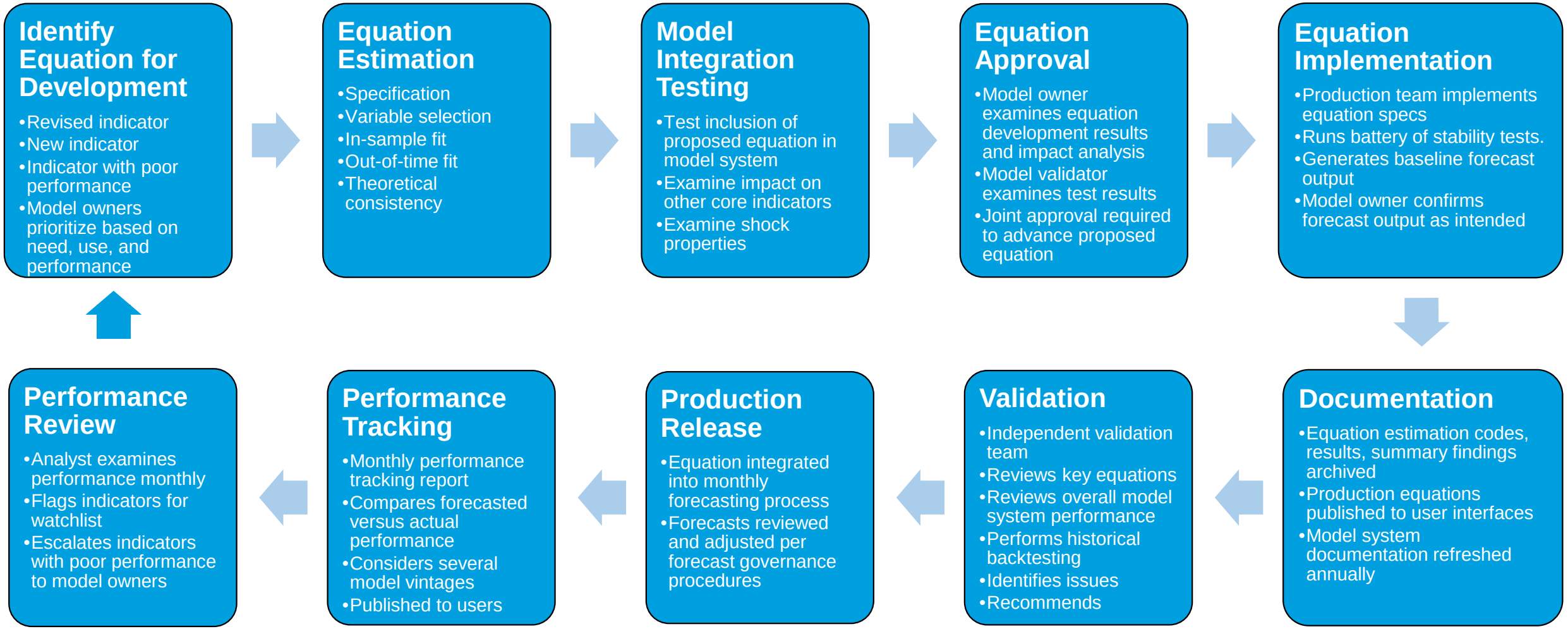
Forecasting performance

- Back-testing: conditional and unconditional evaluation
- Benchmarking during important past episodes

Sensitivity to shocks

- Forecasts across scenarios
- Response to individual shocks

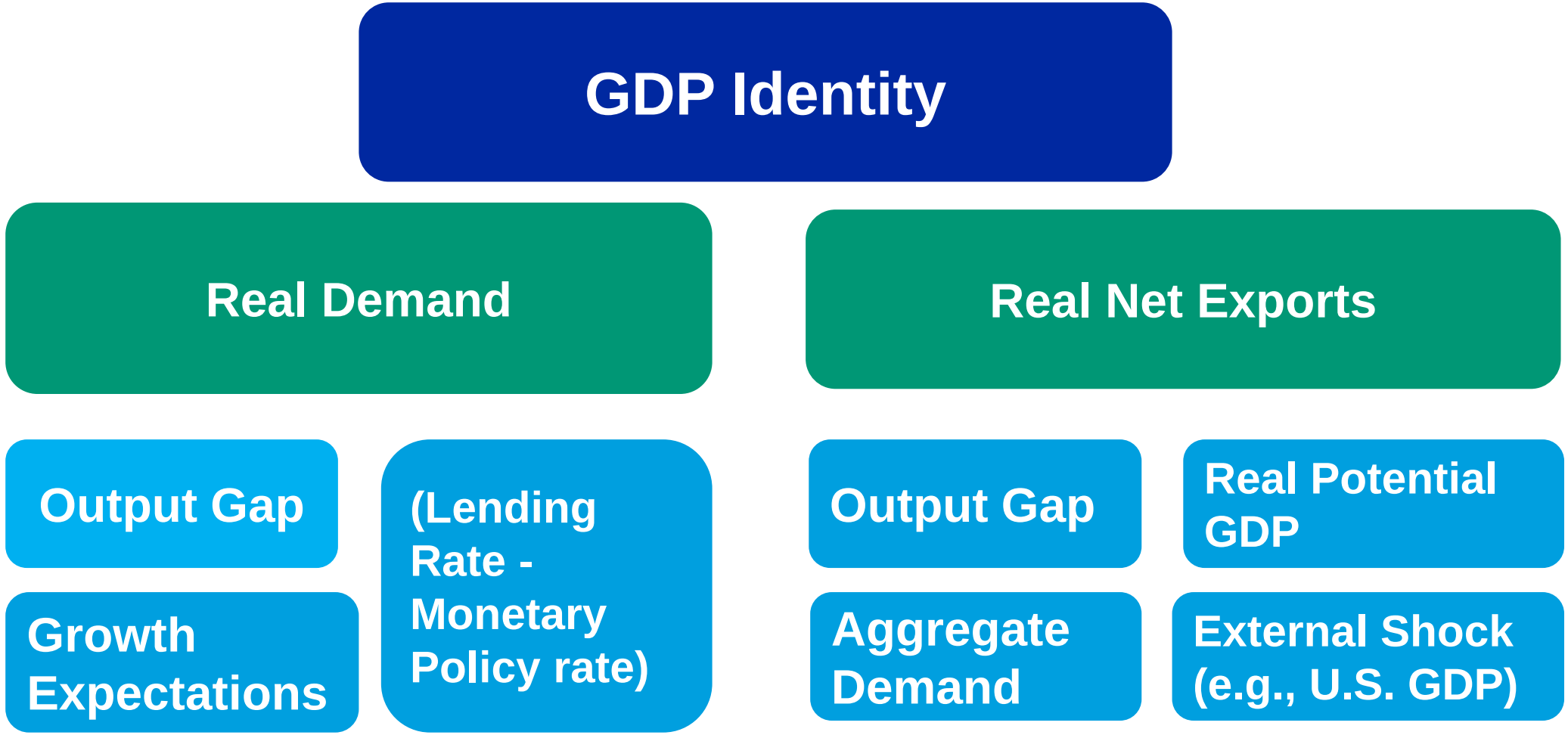
Rigorous Equation Development Process



Equations Designed to Balance Theory & Empirics

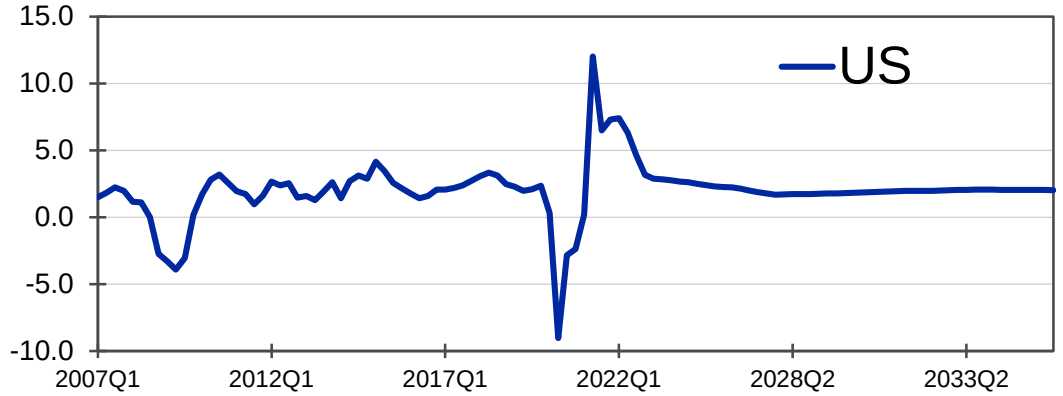
Variable	Specification suggested by economic theory draws on…
Unemployment rate	Okun's Law
Labor Force	Participation rate & demographics
Private consumption expenditure	Keynesian consumption function / Euler equation
Public consumption expenditure	Baumol's disease w/ endogenous responses to fiscal space
Fixed investment	Accelerator model / Tobin's Q
Inventory investment	Adjustment process in deviations of final spending to firm output
Exports	Trading partner import demand and real effective exchange rate
Imports	Imports reflect domestic demand + re-exporting demand
Labor income (wages & salaries)	Wage bargaining over revenue product of labor
Central bank target rate	Policy assumption, based on an augmented Taylor Rule
10yr Gov bond yield	Fisher Rule w/ sovereign risk premium, global interest rate parity
Yield curve & market lending rates	Term-structure of interest rates
Exchange rate (floating)	Interest rate parity (short-run) & purchasing power parity (long-run)
Import price deflator	Exchange rate pass-through of foreign prices, global commodity prices
Consumer price index	Expectations augmented Phillip's curve based on firm price setting function
House prices, stock prices	Asset pricing theory
Government total expenditure	Sum of government consumption + debt service + net transfers
Government total revenues	Revenues equal the effective tax rate multiplied by income
Industrial production	IP tracks the aggregate value added of goods-producing industries
Domestic credit (money supply)	Liquidity demand depends on transactions value (GDP) and interest rates
CA balance	(Identity) CA = net exports + net income + net transfers

Kenya GDP Components – Model Drivers



Baseline Forecasting

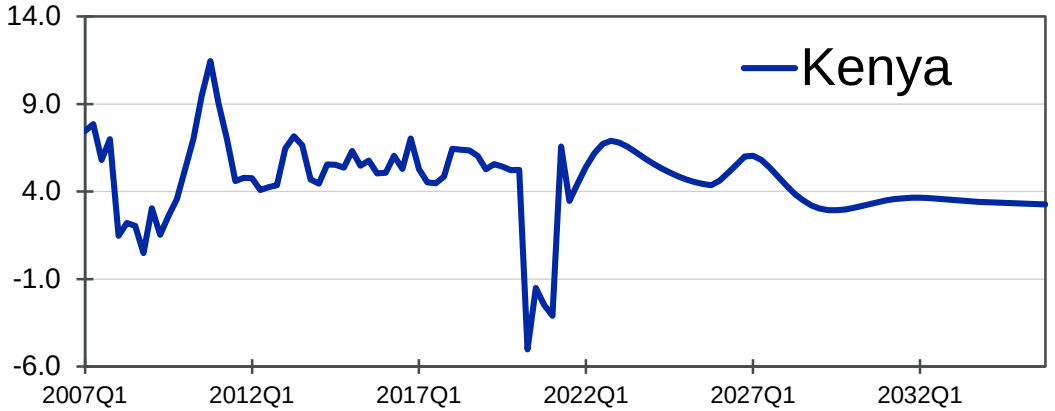
Real GDP, % chg year ago



Real GDP, % chg year ago

Real GDP, % chg year ago

Real GDP, % chg year ago

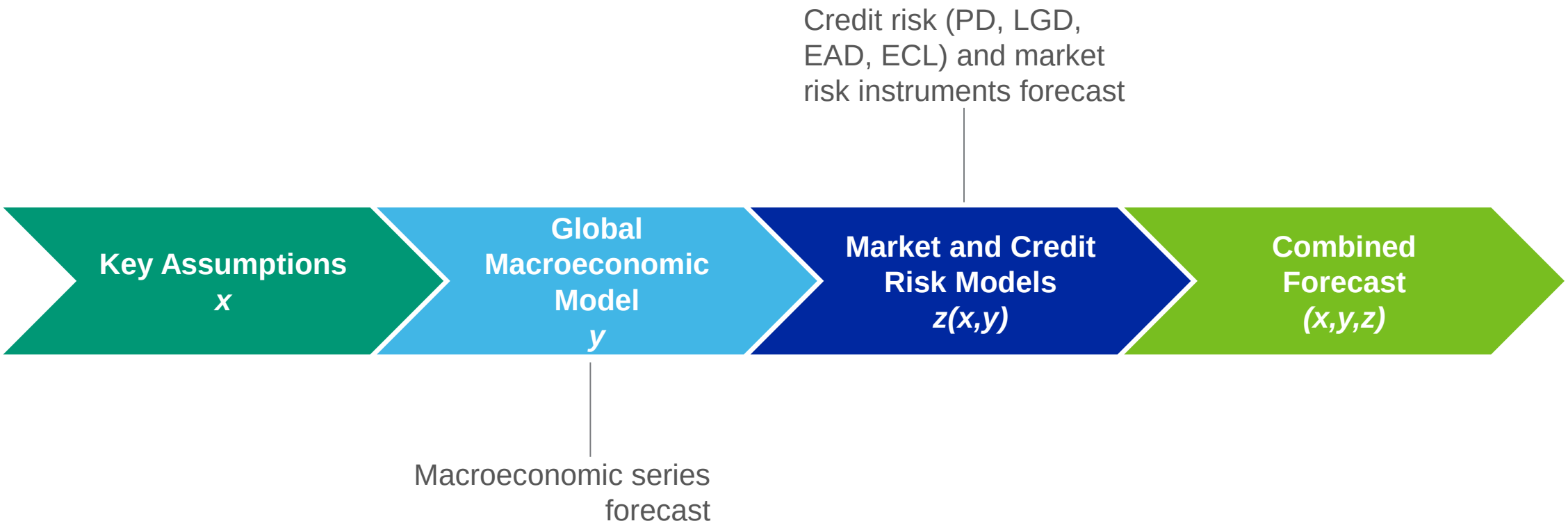


Sources: ECB, Moody's Analytics

2.3

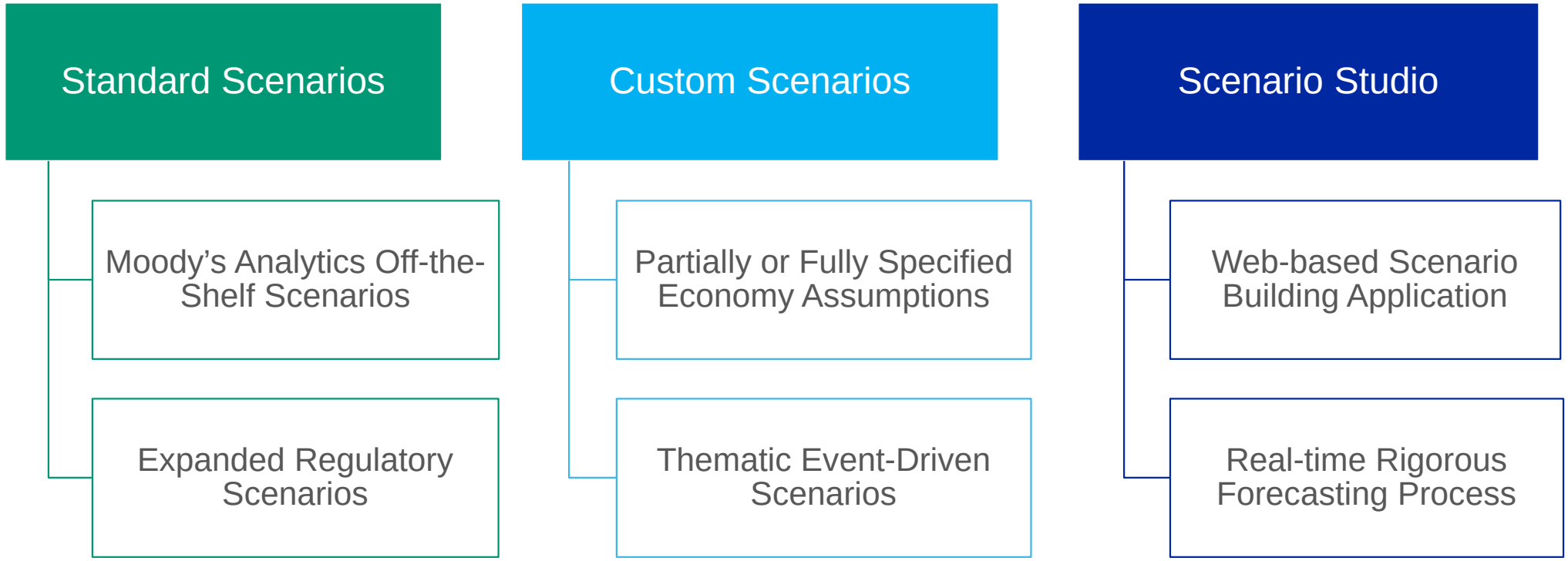
Scenario Generation

Phases of Scenario Workflow



Scenario Generation Using Moody's Analytics Global Model

Forecasts for 70+ countries used by 780 Clients worldwide



MOODYS' ANALYTICS BASELINE + S1-S8 , S0

BL S0 S1 S2 S3 S4 S5 S6 S8

EXPANDED REGULATORY

FED PRA EBA

CUSTOM

CU

CONSENSUS

CO

Pillars of Scenario Generation

I Severity

Quantitative representation of “How favorable/adverse is given scenario”

Ensures that scenarios are representative and symmetric around baseline

Guides assignment of probability weights

II Narrative

Determines overall nature of the scenario and guides the exact path of forecasts

Helps with understanding and interpretation of scenarios

Ensures that scenarios are globally consistent

III Transmission

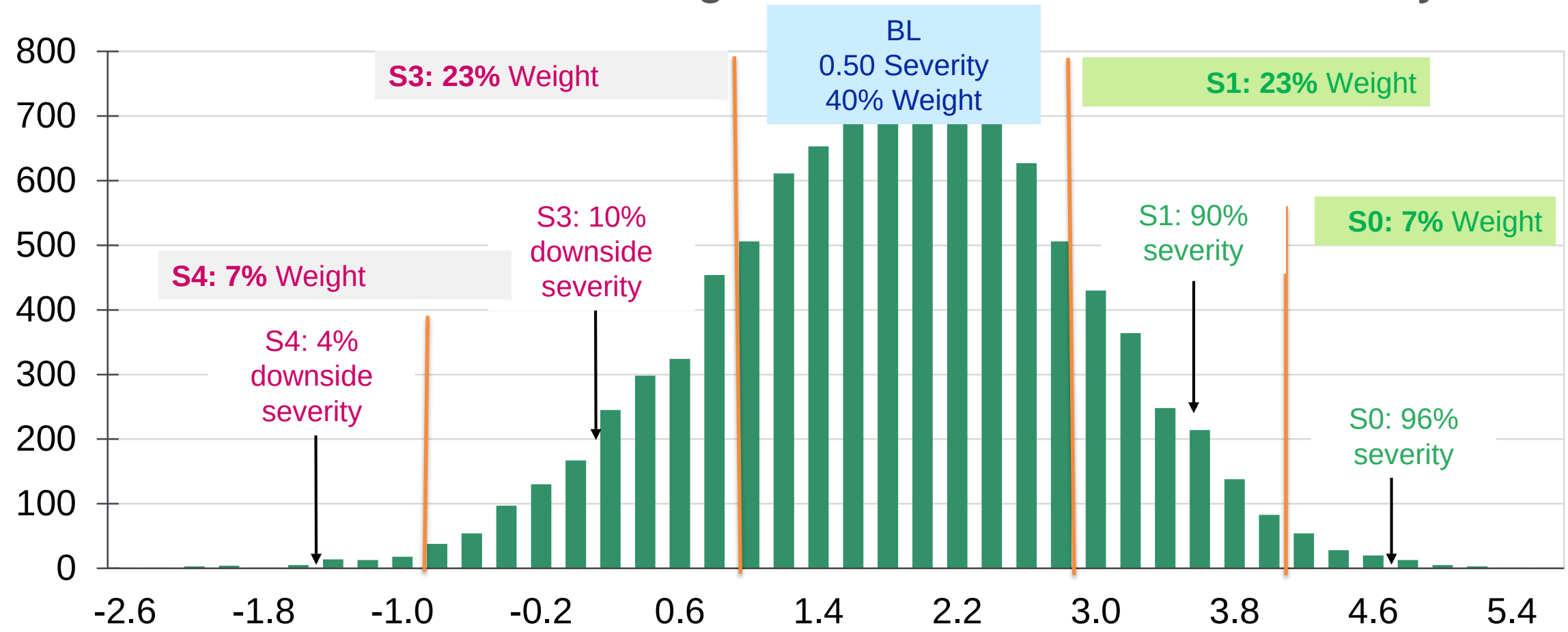
Global linkages in models transmit shocks across countries

Ensures consistency of forecasts across countries

Delivers sizable initial shocks to models

Scenario Calibration: Discrete Scenario Prob.

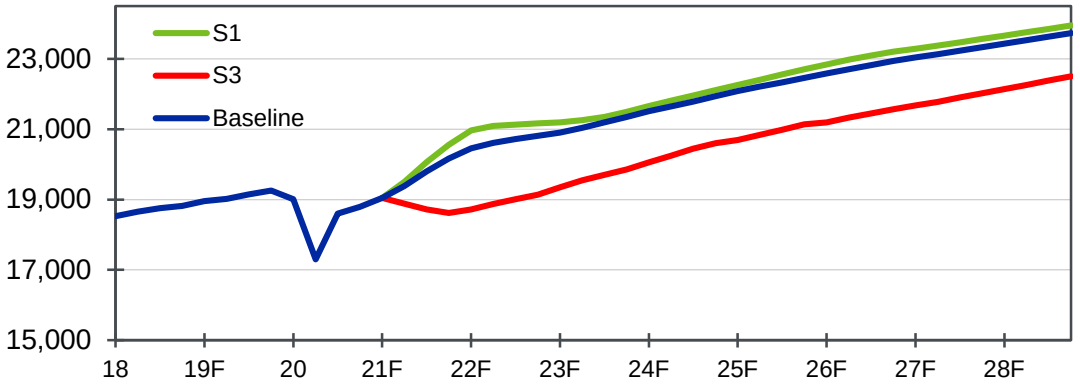
GDP Growth %, Annualized avg., 10,000 Simulations over a 5-yr Period



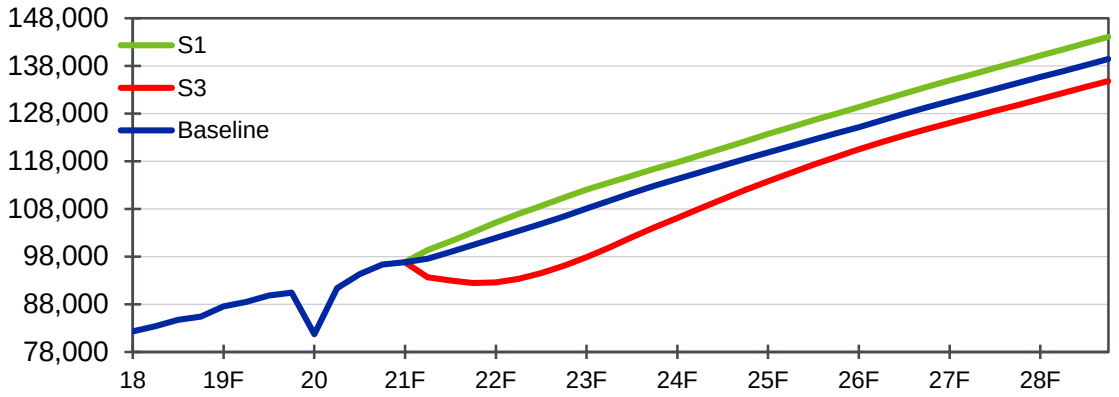
Source: Moody's Analytics

Scenario Forecasting

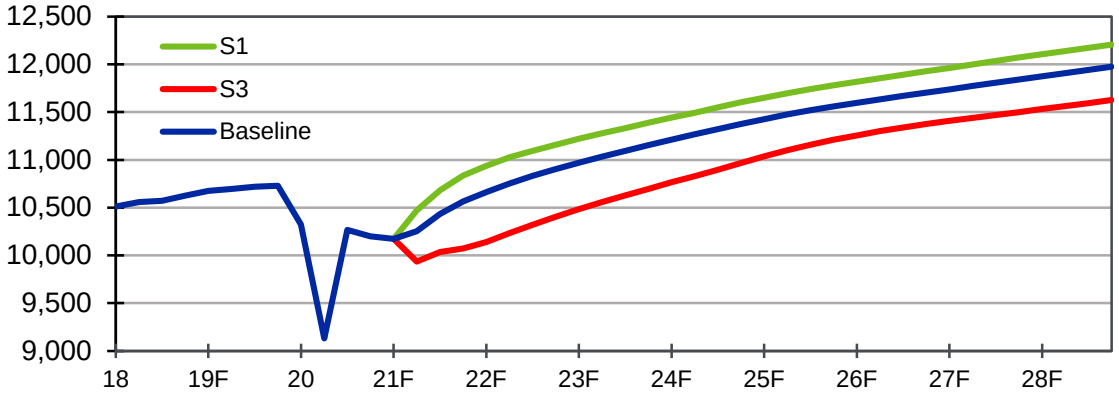
U.S. GDP, 2012 bil. USD



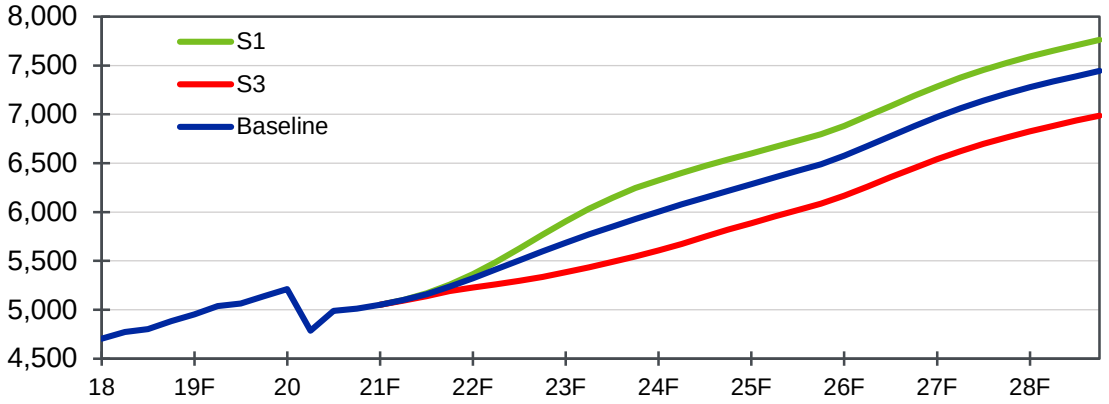
China GDP, 2015 Bil. CNY



Euro Zone Inflation, % change yr ago



Kenya GDP, 2009 Bil. KES



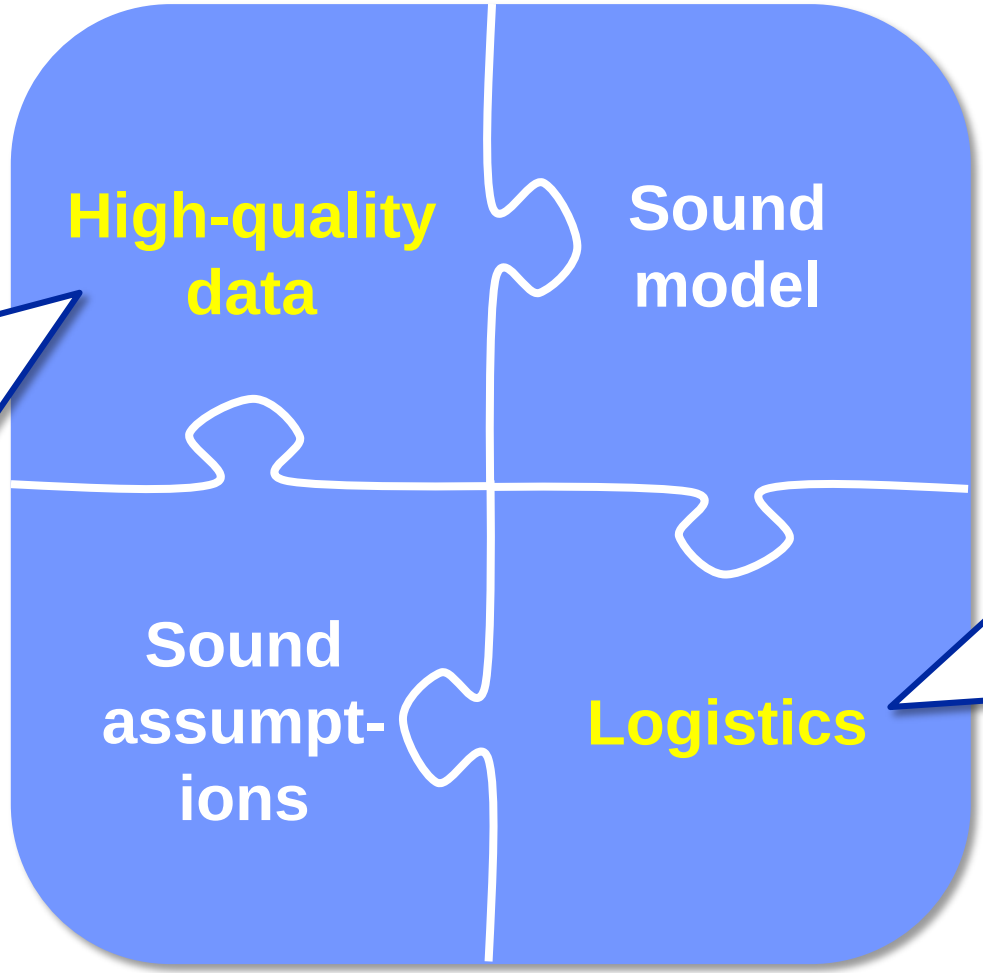
Sources: Eurostat, ECB, Moody's Analytics

2.4 Scenario Studio

Elements of Forecast Integrity

Specifically:

- Up-to-date
- No errors
- Long time series
- Temporally consistent
- Accurately calculated



Comprising:

- Process – The steps taken in the production of a forecast
- Platform – the tools used to implement the forecasting process

Technology-enabled forecasting

A cloud platform enables a distributed process with a globally linked model

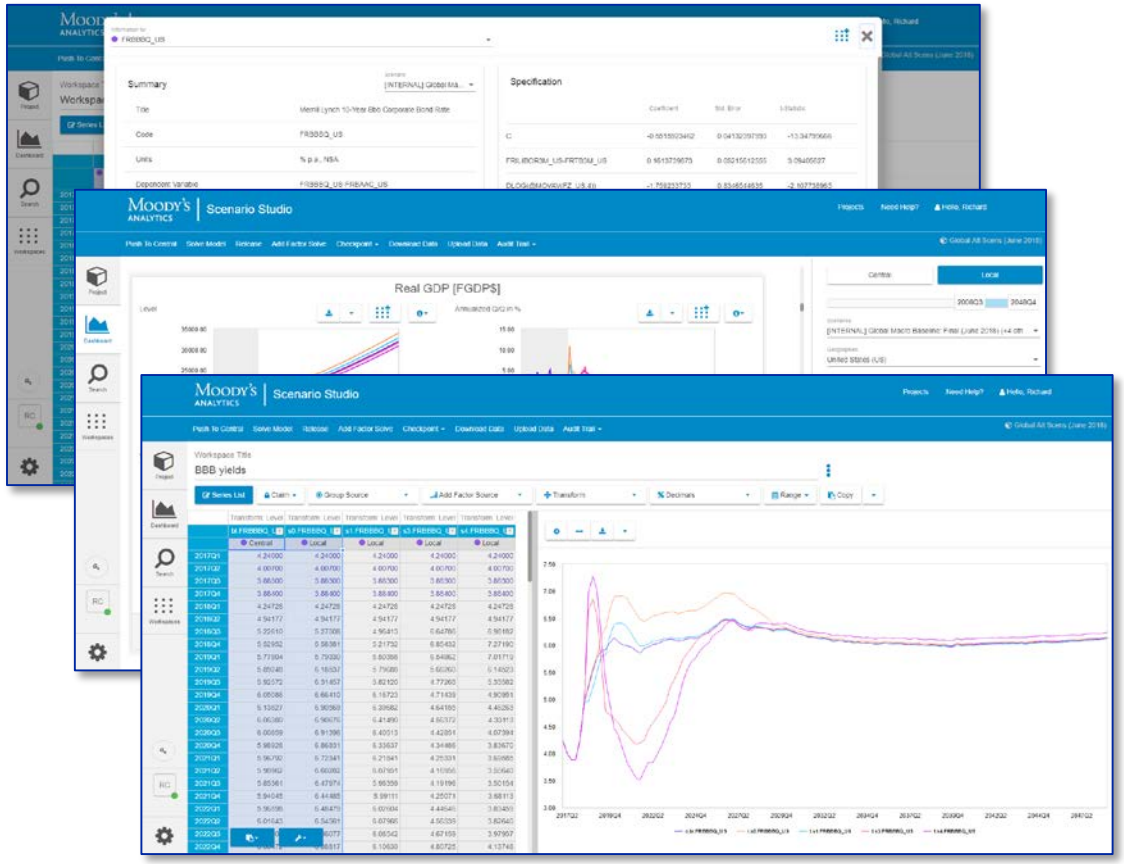
Installed-software world

- Sequential economic linkages
- Simplified international interactions
- Laborious cross-country comparison
- Geographic aggregates post-processed
- Serial computing
- File juggling
- High analyst coordination costs

Cloud platform world

- Simultaneous economic linkages
- Sophisticated international interactions
- Rapid cross-country comparisons
- Geographic aggregates endogenous
- Parallel computing
- Single database
- Reduced analyst coordination costs

Scenario Studio is …



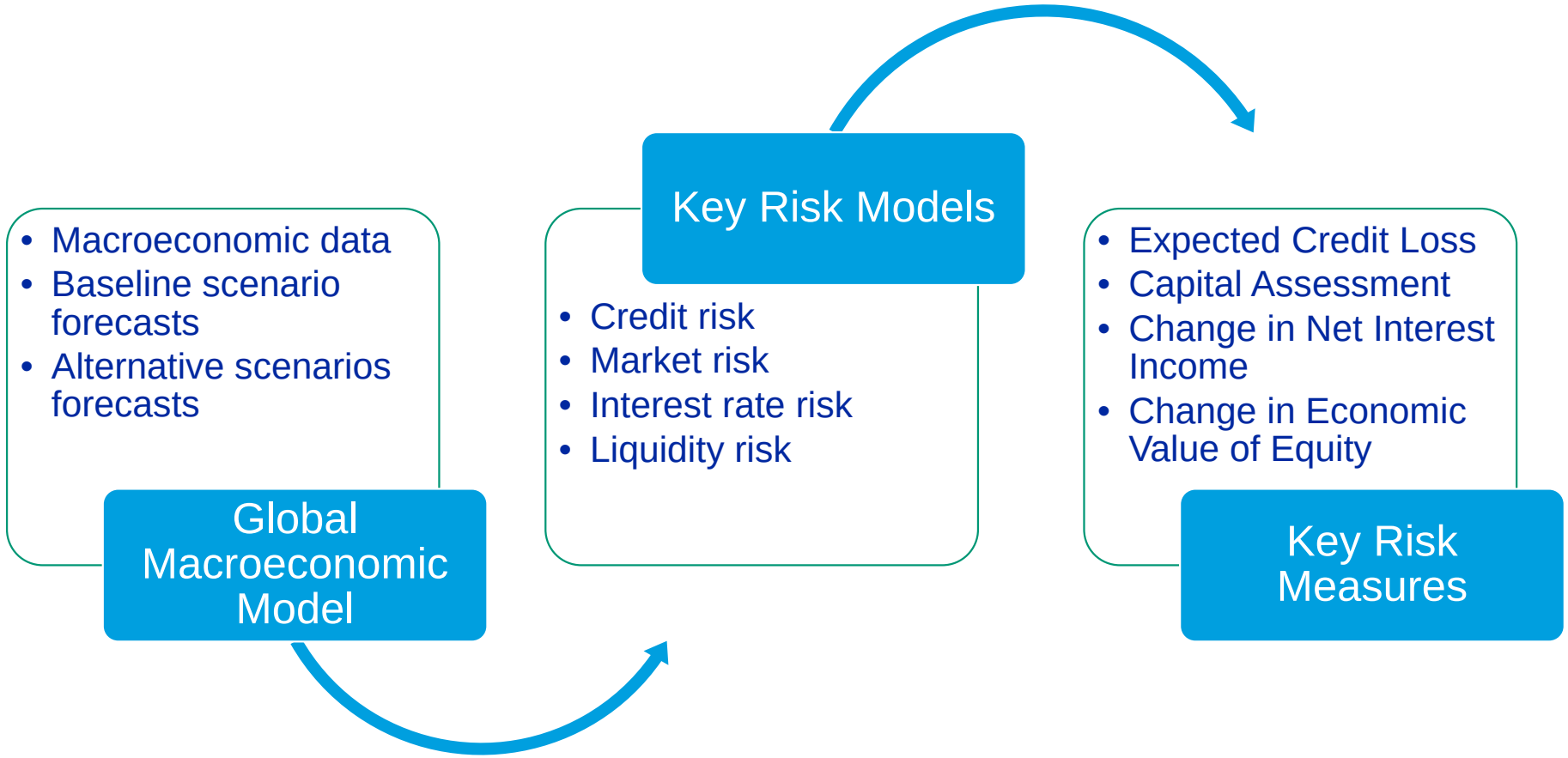
- A secure web application for scenario forecasting
- Facilitates collaborative forecasting
- Hosts several Moody's Analytics models – Global, U.S., sub-national
- Supports rigorous forecast governance processes
- Enables model customization

3

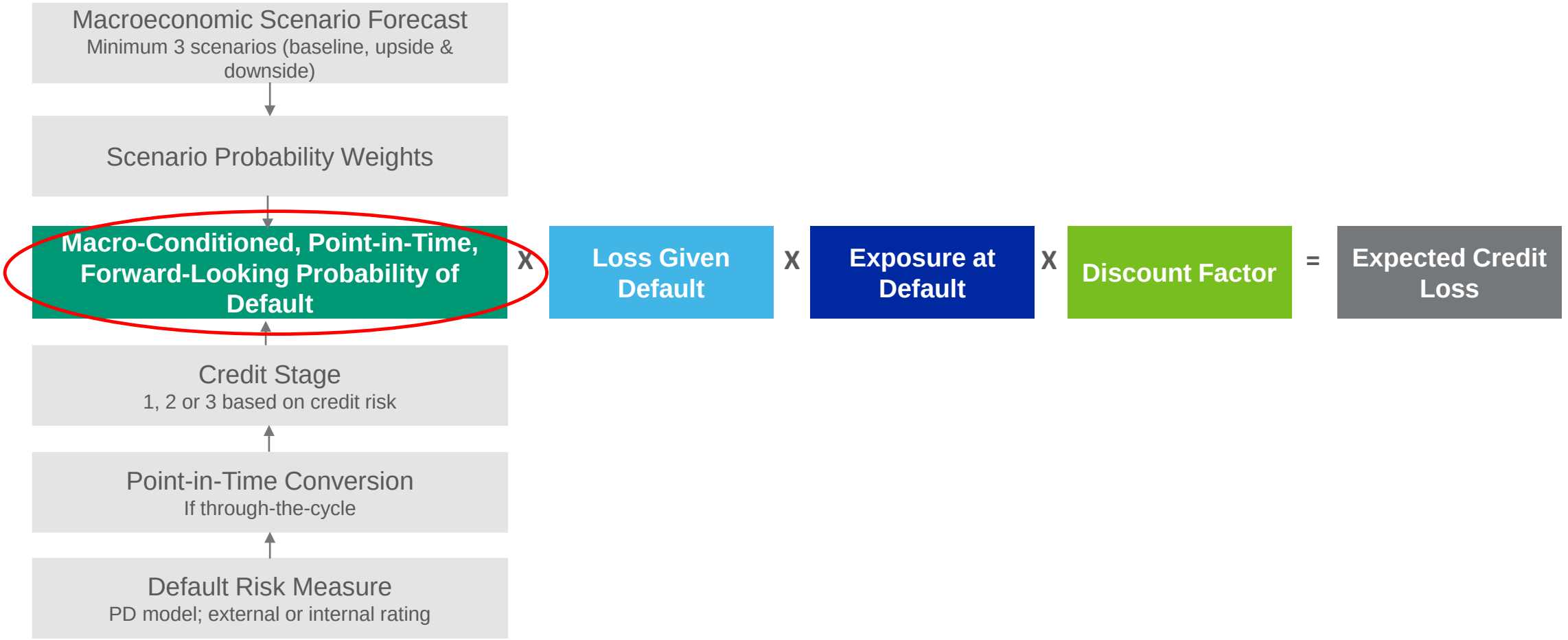
Forward-looking Risk

Linking Scenarios to Risk Measures

IFRS9, ICAAP, IRRBB, Stress Testing, Business Planning

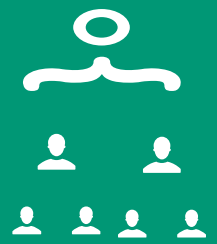


Expected/Stressed Loss Calculation Framework



PD Modelling Techniques and Approaches

Model Types Vary by Need



Portfolio-level

PD directly linked to macroeconomic drivers using time series techniques

Portfolio has restricted aggregate information available such as number of accounts in DPD buckets, outstanding balance in DPD buckets, etc

More suitable for banks with lack of customer level data

Vintage-level

Panel-data modelling approach where the data is split by vintages

Historical data covers at least five years and there is a large number of accounts in the portfolio

More suitable for big banks with long historical data and A-IRB models

Account-level

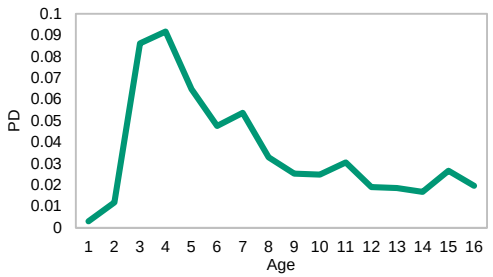
PD is forecasted using customer and loan characteristics, and macroeconomic indicators

Historical data is short (e.g. 1-2 years) and/or the frequency of the data is low.

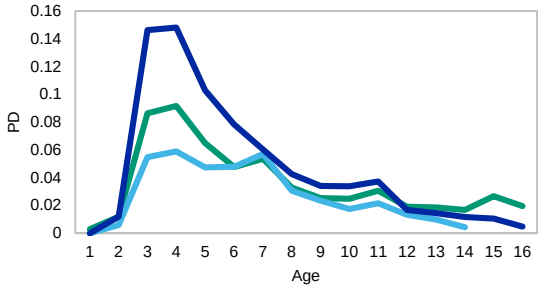
More suitable for medium/small size banks

PD Vintage-level Approach

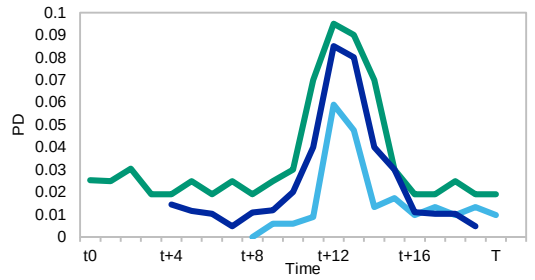
PD= f(**Lifecycle** , **Quality of Vintage** , **Forward-looking Indicator**)



Dynamic evolution of vintages as they mature



Variable capturing the heterogeneity across cohorts: vintage dummies, portfolio characteristics (LTV, asset class/collateral type, geography, etc.) and/or economic conditions at origination

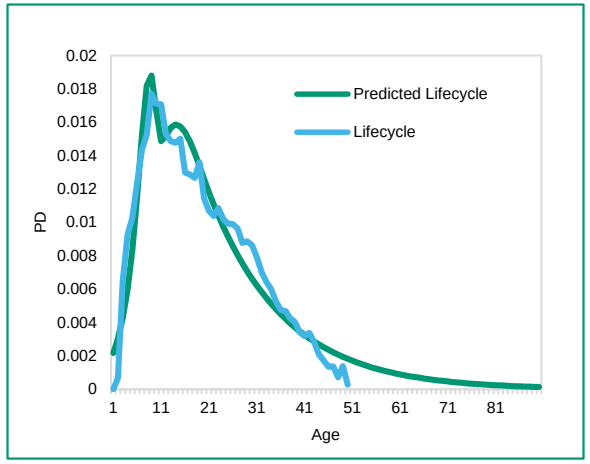


Sensitivity of performance to the evolution of macroeconomic and credit series

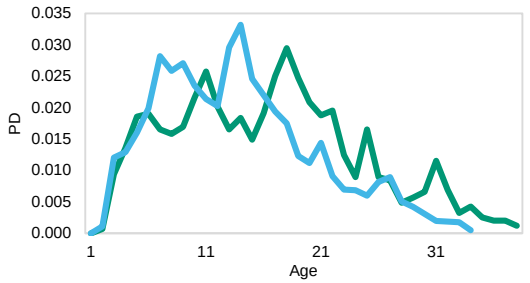
PD Vintage-level Approach

Mortgages Example

1. Lifecycle



2. Quality of Vintage

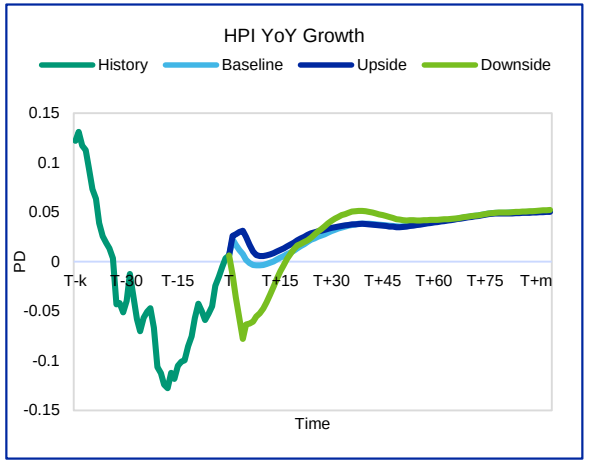


Vintage dummies

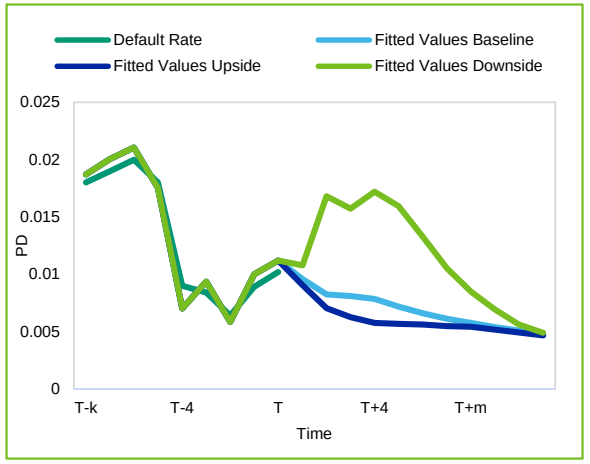
Economic conditions at origination

Portfolio data at origination

3. Forward-looking Indicator



Final PD Model



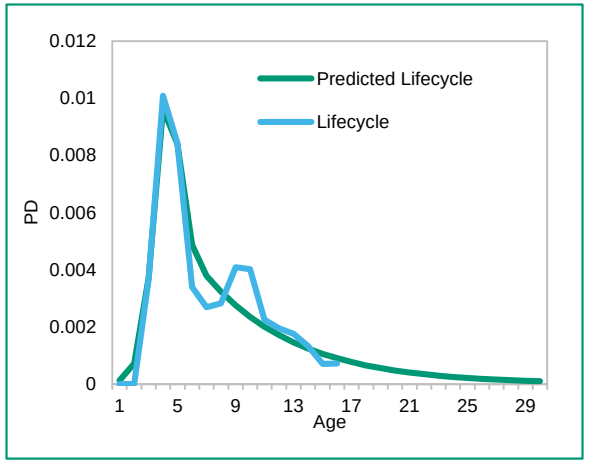
Large number of accounts leads to implementation problems.

Solution:
Build curves based on the different combinations of score bins, segments and vintages.

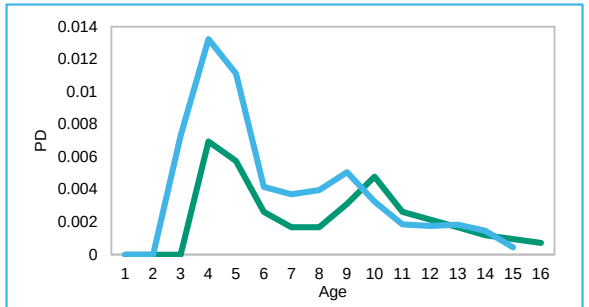
PD Vintage-level Approach

Credit Cards Example

1. Lifecycle



2. Quality of Vintage



Vintage dummies

Economic conditions at origination

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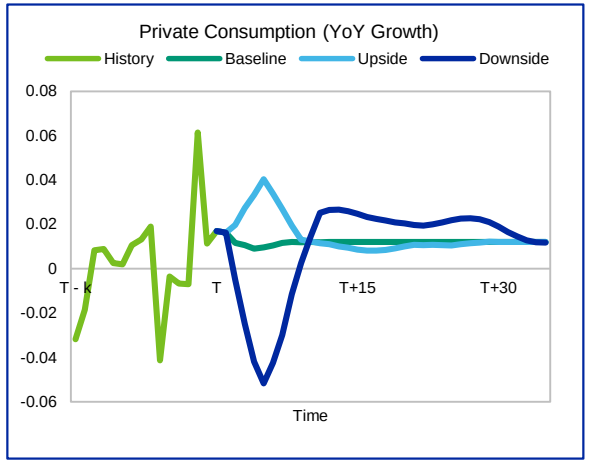

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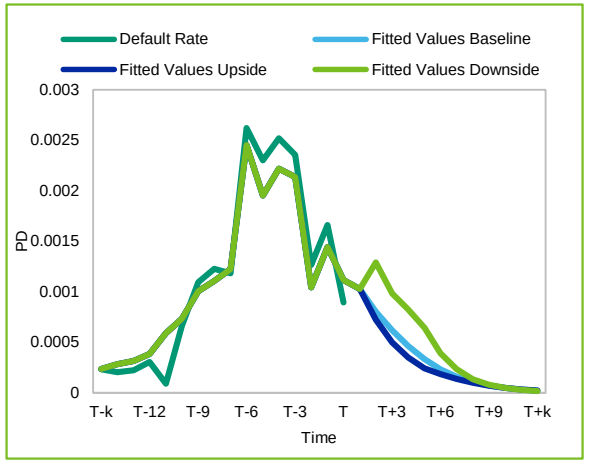


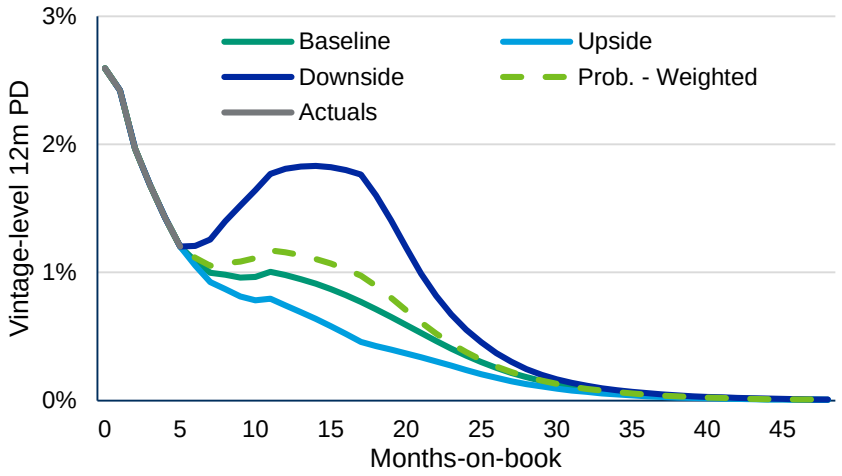
Large number of accounts leads to implementation problems.

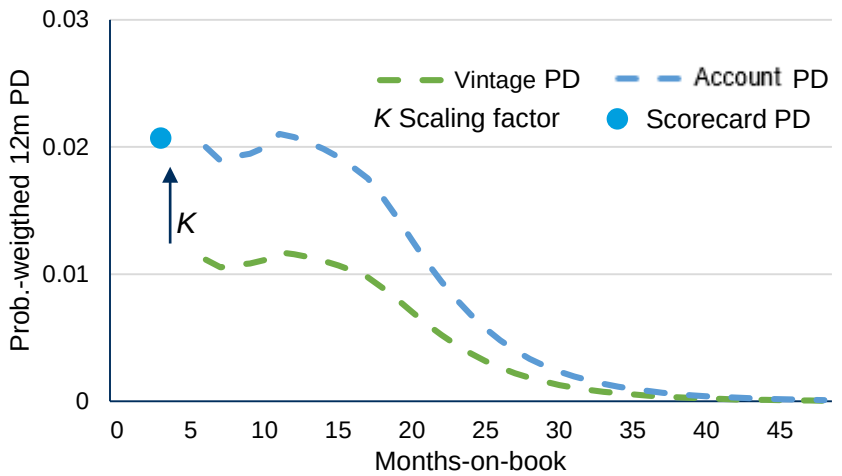
Solution:
Build curves based on the different combinations of score bins, segments and vintages.

Account-level PiT PD

Mapping IFRS9 PDs to IRB PD

The vintage PD model is used to map the shape of the PD curves to an account-specific risk metric in order to obtain consistent PD levels based on the latest available credit risk information.

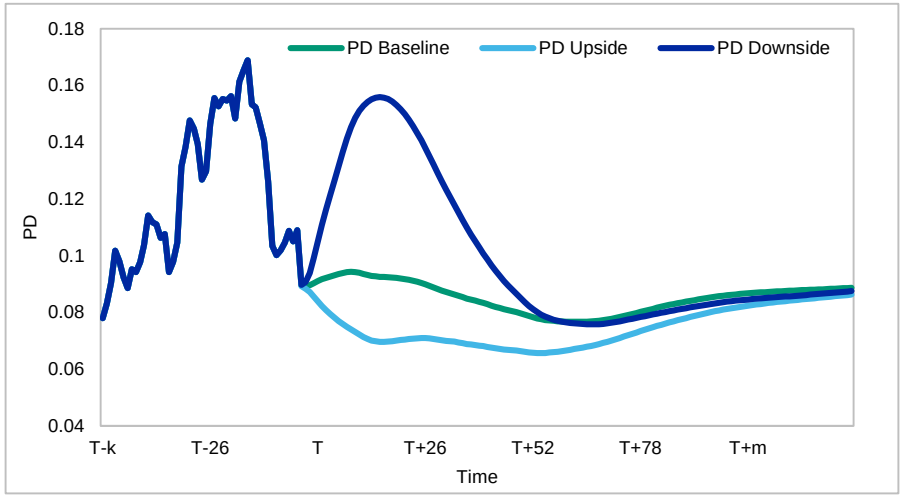




Portfolio-level Modelling

- If a portfolio has restricted aggregate information available such as number of accounts in DPD buckets, outstanding balance in DPD buckets, etc.:
  - Model default rate calculated as number of defaulted accounts at time t on total number of accounts at time t. Link to macro drivers.
  - Alternatively, use another portfolio-related metric as the dependent variable: portfolio delinquency, total balance, portfolio age, etc.

	0 – 29 DPD	30-59 DPD	60-89 DPD	90-119 DPD
0-29 DPD	95.37%	2.13%	0.69%	1.81%
30-59 DPD	77.57%	1.82%	0.64%	19.97%
60-89 DPD	43.57%	1.05%	0.38%	55.00%
90-119 DPD	0.00%	0.00%	0.00%	100.00%



Optimal Variable Searching Tool

User friendly

Performs the Variable Selection Algorithm for as much as 25 potential drivers in one step.

Flexible and customizable

Allows the user to specify the model as desired.

Functional

Exports pre-selected models and estimation statistics to an Excel file.

Makes historical two-way graphs with drivers.

Computes cross-validation.

OVS Customizable Features

- Target variable
- Scenarios
- Potential drivers and expected signs
- Maximum number of drivers in the final model
- Maximum number of lags for drivers
- Estimator and estimation options: any built-in estimator in the software
- Correlation coefficient threshold. Default value is 0.75.
- Maximum p-value on estimated coefficients. Default is 0.05
- Additional variables that enter in the model by default

Dynamic Credit Risk Model-Building

Best Subset Variable Selection Algorithm

C_m^k

k: right-hand-side variables
m: potential economic & internal drivers

All combinations of size ***k*** from vector ***m***

Pairwise Correlations
(optional)

Exclude models with collinear drivers

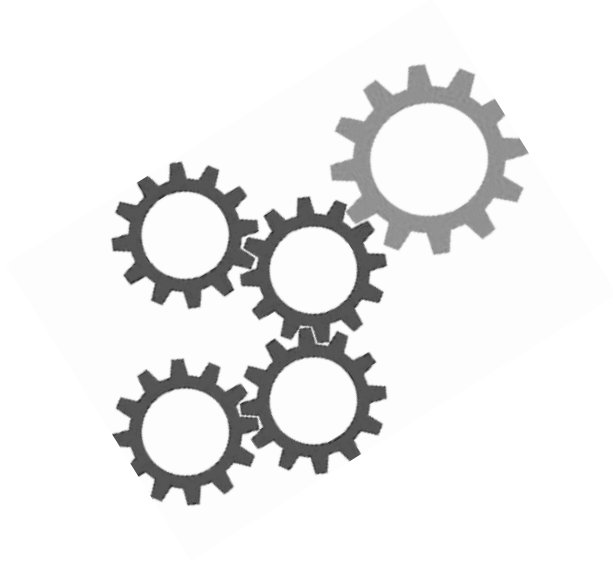
Selection Criteria
(optional)

- Expected estimated signs on drivers
- Statistically significant drivers

Ranking Criteria

- Adjusted R^2/RMSE
- Likelihood-based criteria
- Stationarity and cointegration
- Validation

Optimal Model

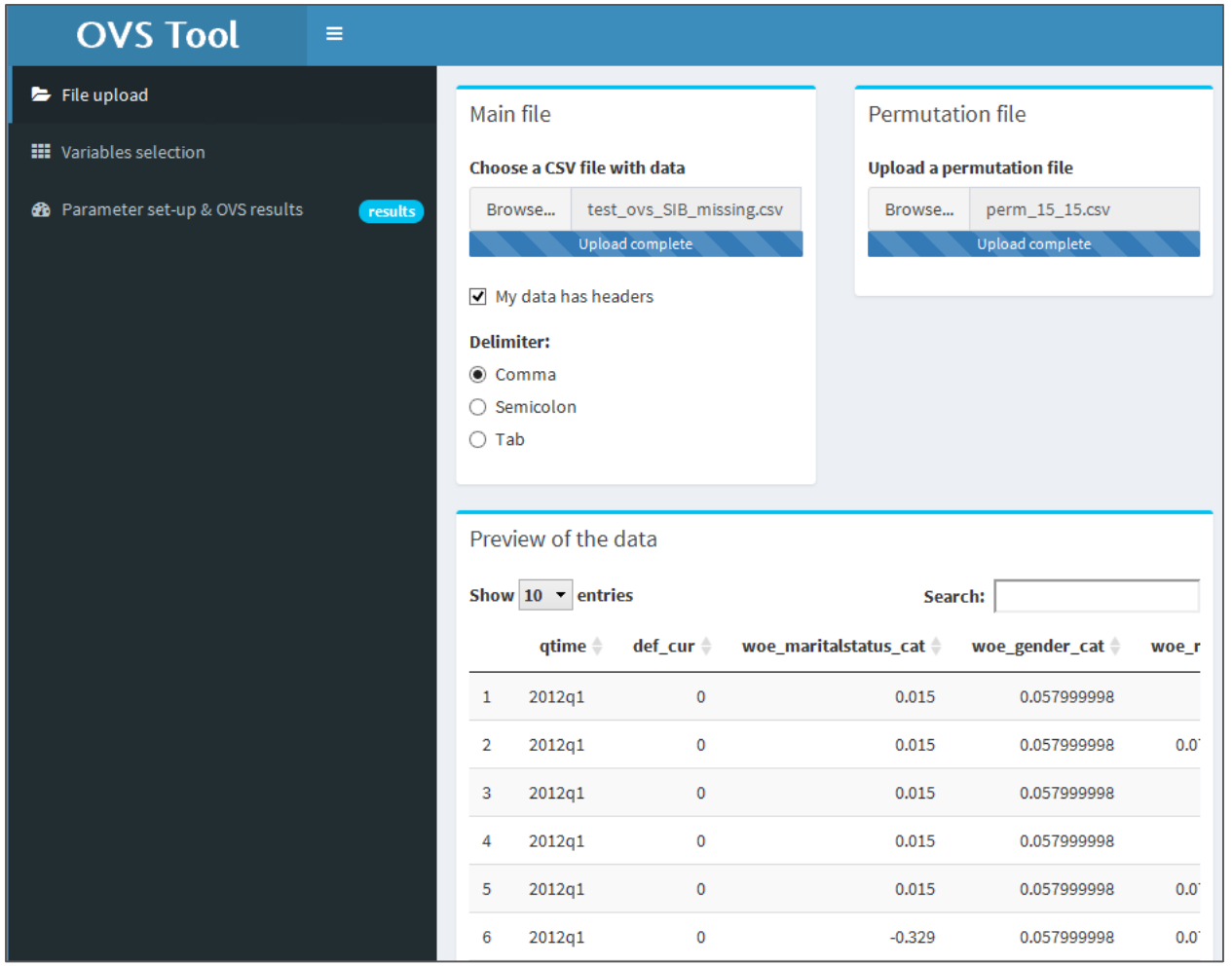


Optimal Variable Searching Tool

Web Application

- Allows to run OVS on your own data
- No R installation needed
- Runs in browser
- Easy-to-use, no code involved
- 3 menu items on the sidebar with the last one showing OVS results

1. File upload
   - upload a file with data in CSV format
   - upload the appropriate permutation file – supplied by Moody's

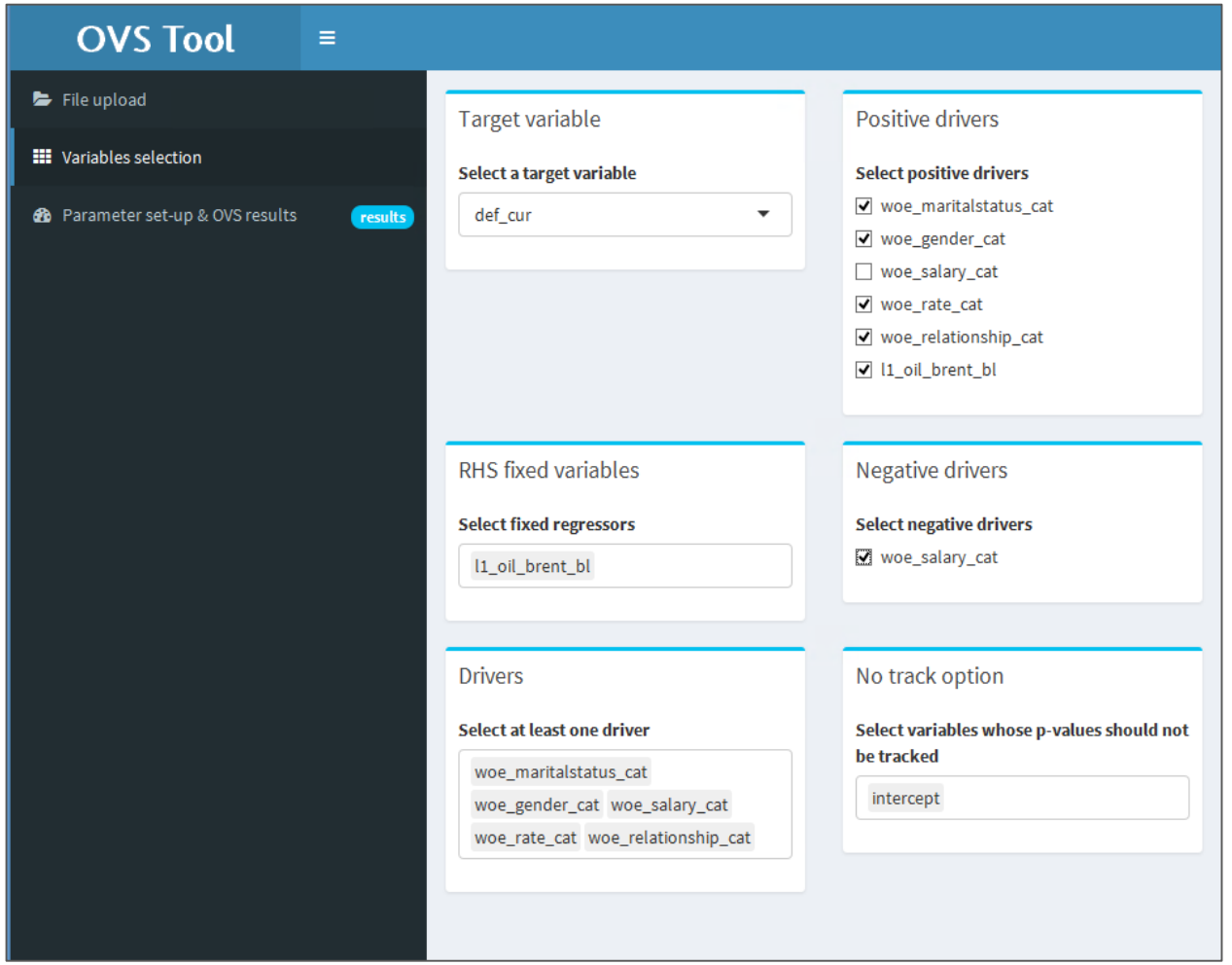


OVS Tool Web Application

Variables Selection

2. Variable selection

- Choose one target variable
- Select fixed explanatory variables (optional)
- Select potential drivers from the remaining variables
- Specify the explanatory variables for which positive coefficient is required (optional)
- Specify the explanatory variables for which negative coefficient is required
- Select variables for which p-value should not be tracked (optional)

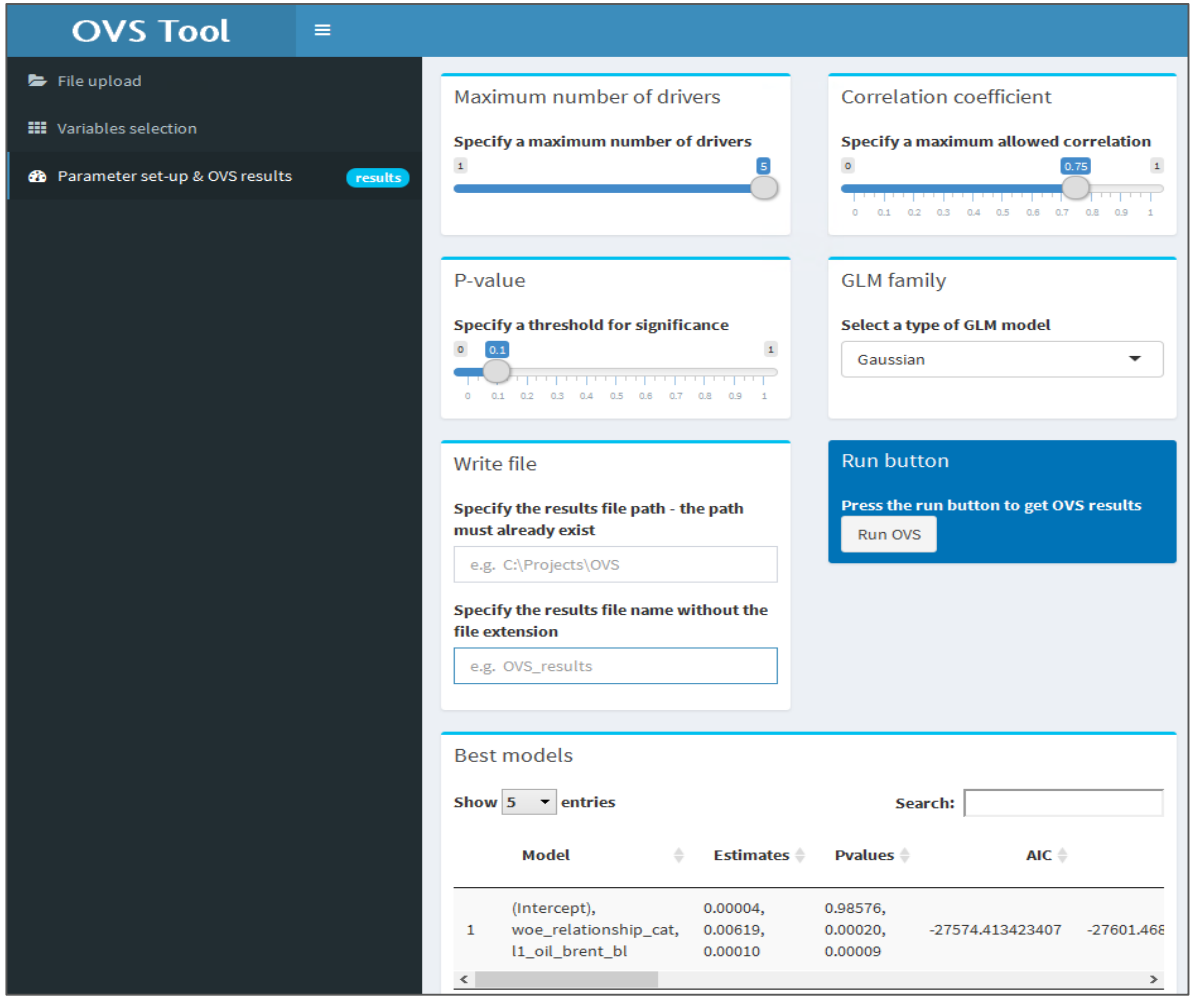


OVS Tool Web Application

Parameter Set-up & Results

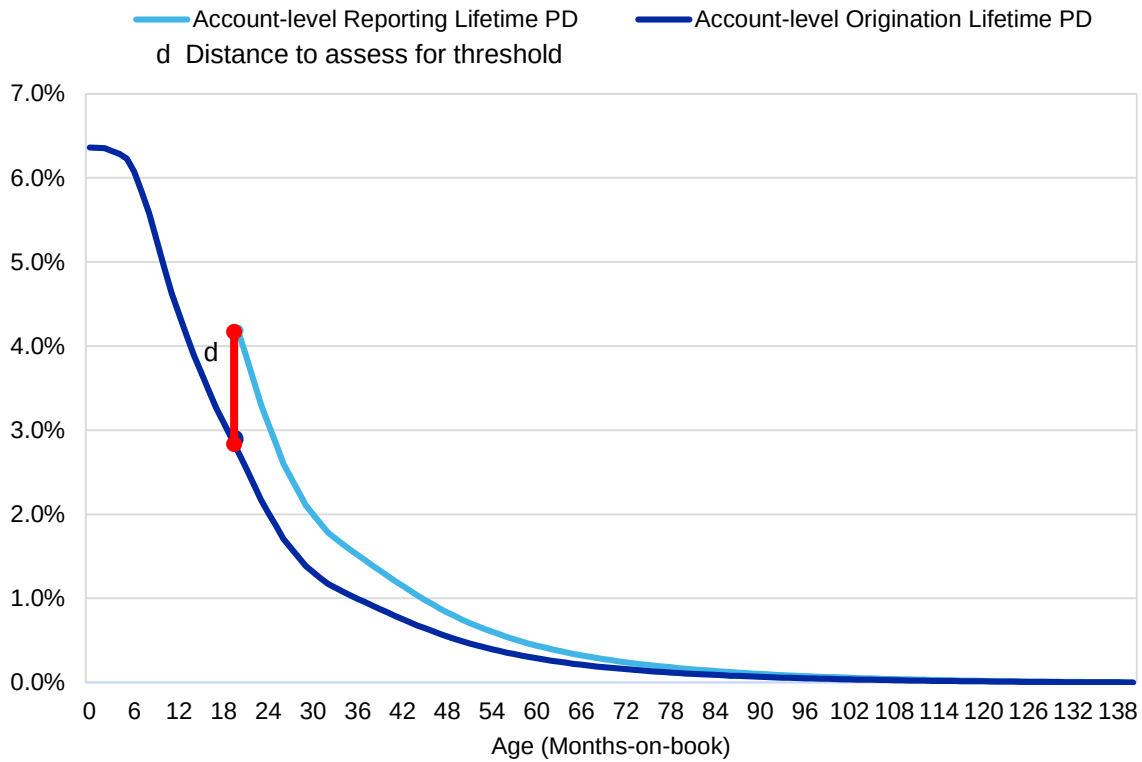
3. Parameter set-up & OVS results

- Choose the maximum number of drivers that can be included in the model
- Specify a p-value threshold for testing significance of explanatory variables
- Input path to a file where you want to export the OVS results and a file name
- Specify the maximum correlation coefficient between each pair of variables
- Choose GLM type that will be used for estimation
- Press the run OVS button to obtain results
- Results appear in the table below and they are exported to the file you specified



Significant Increase in Credit Risk

- To measure the change in risk since initial recognition, we examine the proportional difference between
  - the lifetime PD at the reporting date → Lifetime PD(T) , and
  - the lifetime PD at the same age as the reporting date forecasted at origination → Lifetime $PD_0(T)$
- Distance *b* is utilized as the metric and is the percentage increase to the lifetime PD curve between origination and reporting date. Increases are examined to determine how to identify which are deemed significant.



LGD Design Approaches

Balance and Recoveries

For a facility i, time t and workout period w:

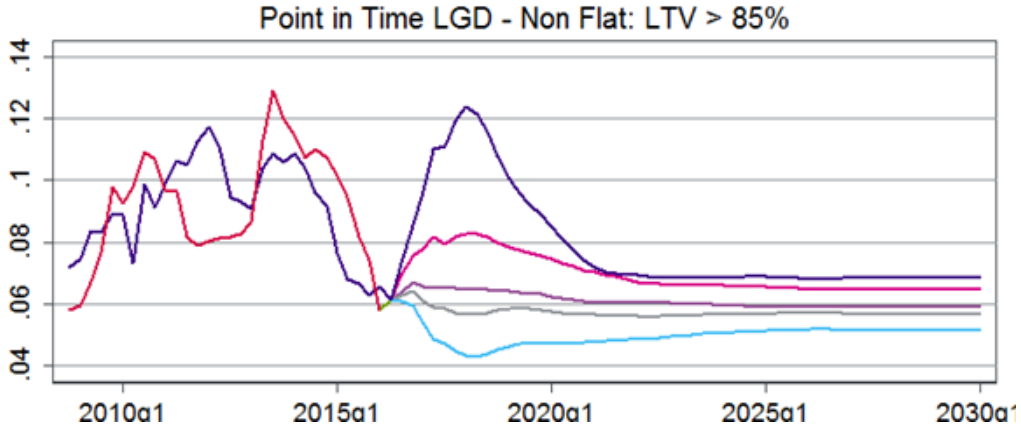
$$LGD_i = 1 - \frac{balance_{i,t} - balance_{i,t+w}}{balance_{i,t}}$$

By Assumption

LGD of 50-60% for PF, 30-40% for RE and 65-75% for CC; fully insured products usually get LGD of 5-10%.

Estimates of recovery costs range from 1-2%.

Default Vintages & Macro Drivers



Roll Rate Modelling

$$RR_{it} = 1 - LGD_{it}$$

		0	1	2	3	4	5	6	7	8	9	10	11	12
Performing	Cycle 0													
	Cycle 1													
	Cycle 2	0.00%	4.73%	5.95%	6.70%	7.23%	7.53%	7.59%	7.61%	7.63%	7.57%	7.63%	7.68%	7.79%
	Cycle 3													
Non - Performing	Cycle 4													
	Cycle 5													
	Cycle 6	100.00%	95.27%	94.05%	93.30%	92.77%	92.47%	92.41%	92.39%	92.37%	92.43%	92.37%	92.32%	92.21%
	Cycle 7													
	Denounced													

Prepayment Model with Macro Overlay

UK Mortgage, Loan-level Model

- Modelling prepayment factor interpreted as the probability for a facility of not being (fully) prepaid by the end of year.
- Logistic/fractional logit depending on the granularity of the model (customer, vintage or portfolio level)

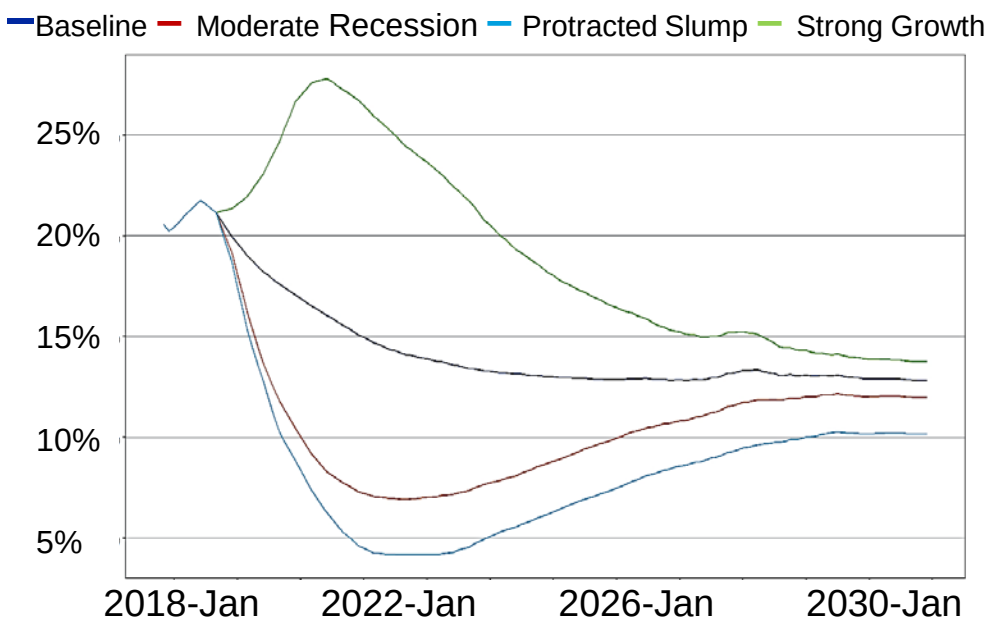
Customer, Loan Characteristics and Macroeconomic Factors

Customer Characteristics: First-time Buyer, Employment Status, Primary Income Verification, Borrower Income, Employment Status

Loan Characteristics: Loan Age Percentage (Lifecycle), Updated LTV with HPI, Equity Release, Debt Consolidation, Loan Restructure, Balance-to-income, Origination Channel, Time to Next Revision Date, Purpose

Macroeconomic Factors: Unemployment Rate

Prepayment Rate Scenario Forecast



Moody's Analytics

Better Faster Decisions

Contact Us: Economics & Business Analytics Offices

West Chester, EBA-HQ
+1.610.235.5299
121 North Walnut Street, Suite 500
West Chester PA 19380
USA

New York, Corporate-HQ
+1.212.553.1653
7 World Trade Center, 14th Floor
250 Greenwich Street
New York, NY 10007
USA

London
+44.20.7772.5454
One Canada Square
Canary Wharf
London E14 5FA
United Kingdom

Toronto
416.681.2133
200 Wellington Street West, 15th Floor
Toronto ON M5V 3C7
Canada

Prague
+420.22.422.2929
Washingtonova 17
110 00 Prague 1
Czech Republic

Sydney
+61.2.9270.8111
Level 10
1 O'Connell Street
Sydney, NSW, 2000
Australia

Singapore
+65.6511.4400
6 Shenton Way
#14-08 OUE Downtown 2
Singapore 068809

Shanghai
+86.21.6101.0172
Unit 2306, Citigroup Tower
33 Huayuanshiqiao Road
Pudong New Area, 200120
China

help@economy.com

moodysanalytics.com