Forward-looking Risk Measurement
A Moody’s Analytics Presentation

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Overview
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."
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
Macroeconomic Forecasting
2.1 Coverage and Key Features
Moody’s Analytics Global Forecast Coverage

April 2021

Sources: Moody’s Analytics

- Included in the Global Model (73 countries)
- Additional forecasts (IFRS9) (28 countries)
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

Identify Equation for Development
- Revised indicator
- New indicator
- Indicator with poor performance
- Model owners prioritize based on need, use, and performance

Equation Estimation
- Specification
- Variable selection
- In-sample fit
- Out-of-time fit
- Theoretical consistency

Model Integration Testing
- Test inclusion of proposed equation in model system
- Examine impact on other core indicators
- Examine shock properties

Equation Approval
- Model owner examines equation development results and impact analysis
- Model validator examines test results
- Joint approval required to advance proposed equation

Equation Implementation
- Production team implements equation specs
- Runs battery of stability tests
- Generates baseline forecast output
- Model owner confirms forecast output as intended

Performance Review
- Analyst examines performance monthly
- Flags indicators for watchlist
- Escalates indicators with poor performance to model owners

Performance Tracking
- Monthly performance tracking report
- Compares forecasted versus actual performance
- Considers several model vintages
- Published to users

Production Release
- Equation integrated into monthly forecasting process
- Forecasts reviewed and adjusted per forecast governance procedures

Validation
- Independent validation team
- Reviews key equations
- Reviews overall model system performance
- Performs historical backtesting
- Identifies issues
- Recommends

Documentation
- Equation estimation codes, results, summary findings archived
- Production equations published to user interfaces
- Model system documentation refreshed annually
### Equations Designed to Balance Theory & Empirics

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

GDP Identity

Real Demand
- Output Gap
- Growth Expectations
- (Lending Rate - Monetary Policy rate)

Real Net Exports
- Output Gap
- Real Potential GDP
- Aggregate Demand
- External Shock (e.g., U.S. GDP)
Baseline Forecasting

Real GDP, % chg year ago

US

Real GDP, % chg year ago

China

Real GDP, % chg year ago

Eurozone

Real GDP, % chg year ago

Kenya

Sources: ECB, Moody's Analytics
2.3 Scenario Generation
Phases of Scenario Workflow

- **Key Assumptions** $x$
- **Global Macroeconomic Model** $y$
- **Market and Credit Risk Models** $z(x,y)$
- **Combined Forecast** $(x,y,z)$

Credit risk (PD, LGD, EAD, ECL) and market risk instruments forecast

Macroeconomic series forecast
Scenario Generation Using Moody’s Analytics Global Model

Forecasts for 70+ countries used by 780 Clients worldwide
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
Forward-looking Risk
Linking Scenarios to Risk Measures

IFRS9, ICAAP, IRRBB, Stress Testing, Business Planning

Key Risk Models
- Credit risk
- Market risk
- Interest rate risk
- Liquidity risk

Global Macroeconomic Model
- Macroeconomic data
- Baseline scenario forecasts
- Alternative scenarios forecasts

Key Risk Measures
- Expected Credit Loss
- Capital Assessment
- Change in Net Interest Income
- Change in Economic Value of Equity

Forward-Looking Risk

MOODY’S ANALYTICS
Expected/Stressed Loss Calculation Framework

1. Macroeconomic Scenario Forecast
   - Minimum 3 scenarios (baseline, upside & downside)
2. Scenario Probability Weights
4. Credit Stage
   - 1, 2 or 3 based on credit risk
5. Point-in-Time Conversion
   - If through-the-cycle
6. Default Risk Measure
   - PD model; external or internal rating
7. Loss Given Default
8. Exposure at Default
9. Discount Factor
10. Expected Credit Loss

\[
\text{Expected Credit Loss} = (\text{Loss Given Default} \times \text{Exposure at Default} \times \text{Discount Factor})
\]
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)

- **Lifecycle**: Dynamic evolution of vintages as they mature
- **Quality of Vintage**: Variable capturing the heterogeneity across cohorts: vintage dummies, portfolio characteristics (LTV, asset class/collateral type, geography, etc.) and/or economic conditions at origination
- **Forward-looking Indicator**: Sensitivity of performance to the evolution of macroeconomic and credit series
PD Vintage-level Approach

Mortgages Example

1. Lifecycle
   - Predicted Lifecycle vs. Lifecycle
   - Economic conditions at origination
   - Portfolio data at origination

2. Quality of Vintage
   - Vintage dummies

3. Forward-looking Indicator
   - HPI YoY Growth

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
3. Forward-looking Indicator

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.

<table>
<thead>
<tr>
<th>DPD Range</th>
<th>0-29 DPD</th>
<th>30-59 DPD</th>
<th>60-89 DPD</th>
<th>90-119 DPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-29 DPD</td>
<td>95.37%</td>
<td>2.13%</td>
<td>0.69%</td>
<td>1.81%</td>
</tr>
<tr>
<td>30-59 DPD</td>
<td>77.57%</td>
<td>1.82%</td>
<td>0.64%</td>
<td>19.97%</td>
</tr>
<tr>
<td>60-89 DPD</td>
<td>43.57%</td>
<td>1.05%</td>
<td>0.38%</td>
<td>55.00%</td>
</tr>
<tr>
<td>90-119 DPD</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
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

- **Selection Criteria (optional)**
  - Expected estimated signs on drivers
  - Statistically significant drivers

- **Ranking Criteria**
  - Adjusted R²/RMSE
  - Likelihood-based criteria
  - Stationarity and cointegration
  - Validation

- **Pairwise Correlations (optional)**
  - Exclude models with collinear drivers

- **Optimal Model**

**Formulas and Notations**
- $C^k_m$
  - $k$: right-hand-side variables
  - $m$: potential economic & internal drivers
  - All combinations of size $k$ from vector $m$
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)
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 PD₀(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:

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

Default Vintages & Macro Drivers

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%.

Roll Rate Modelling

\[ RR_{it} = 1 - LGD_{it} \]
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

- **Baseline**
- **Moderate Recession**
- **Protracted Slump**
- **Strong Growth**

Graph showing prepayment rates from 2018-Jan to 2030-Jan with different economic scenarios:
- 25% for Baseline
- 20% for Moderate Recession
- 15% for Protracted Slump
- 10% for Strong Growth

**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)