MATLAB for Use in Finance

Portfolio Optimization (Mean Variance, CVaR & MAD)
Market, Credit, Counterparty Risk Analysis and beyond

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MathWorks

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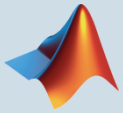
Agenda

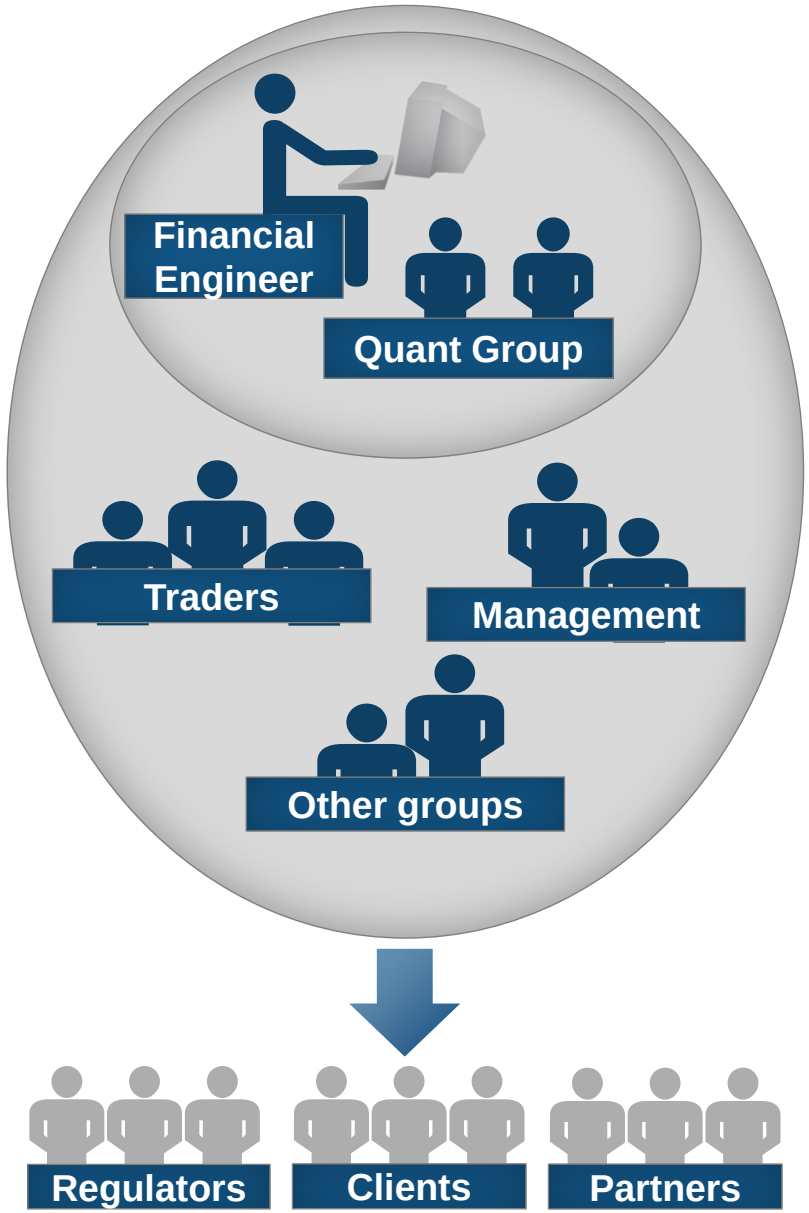


Introduction: Knowing your risk

- Overview of the MATLAB Solution
  - Connect to financial data sources
  - Perform financial modeling & analysis
  - Share results & deploy applications
- Finance Application Examples
  - Portfolio Construction using Frameworks
  - Evaluating Risks
  - Constructing your own Portfolio Management Framework

Challenges in Financial Analysis

- Volatile markets
  - Ever-changing needs
- Lack of computing power
  - Large data, large models
- Increased transparency
  - More auditing and regulation
  - More sharing with colleagues



Challenges Faced During Model Development

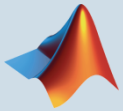
Traditional Approach	Challenge
Off-the-shelf software	***Inability to customize***
Third-party consulting	***Lack of transparency***
Spreadsheets, Excel	***Subpar computational speed, limited data size***
In-house development with traditional languages	***Long development time***
Combination of the above	***Inefficiencies in Integration & Automation***

Who uses MATLAB in Financial Services?

- The top 15 asset-management companies
- 9 of the top 10 U.S. commercial banks
- 12 of the top 15 hedge funds
- The reserve banks of all OECD member countries
- The top 3 credit rating agencies

Agenda

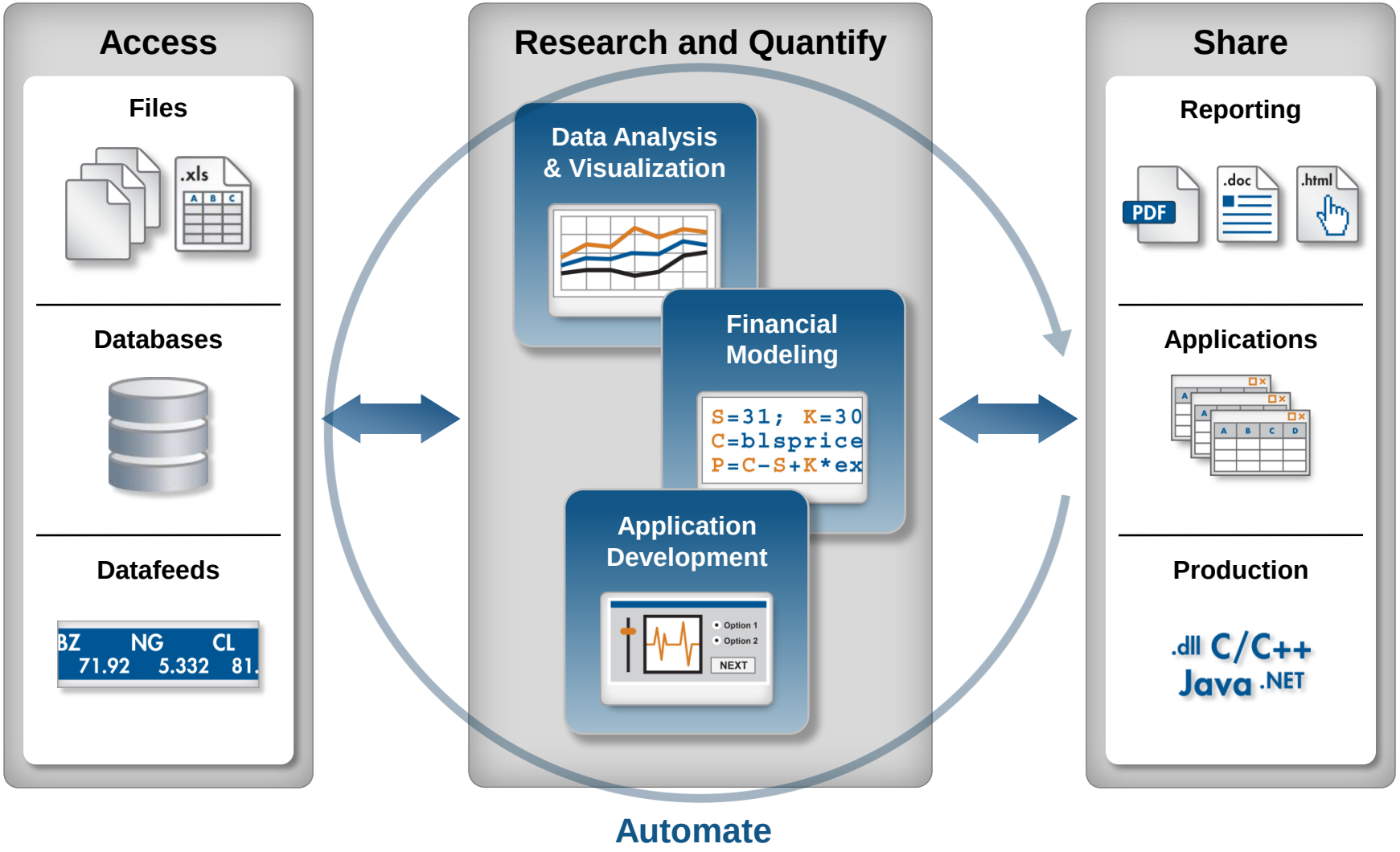
- Introduction: Knowing your risk



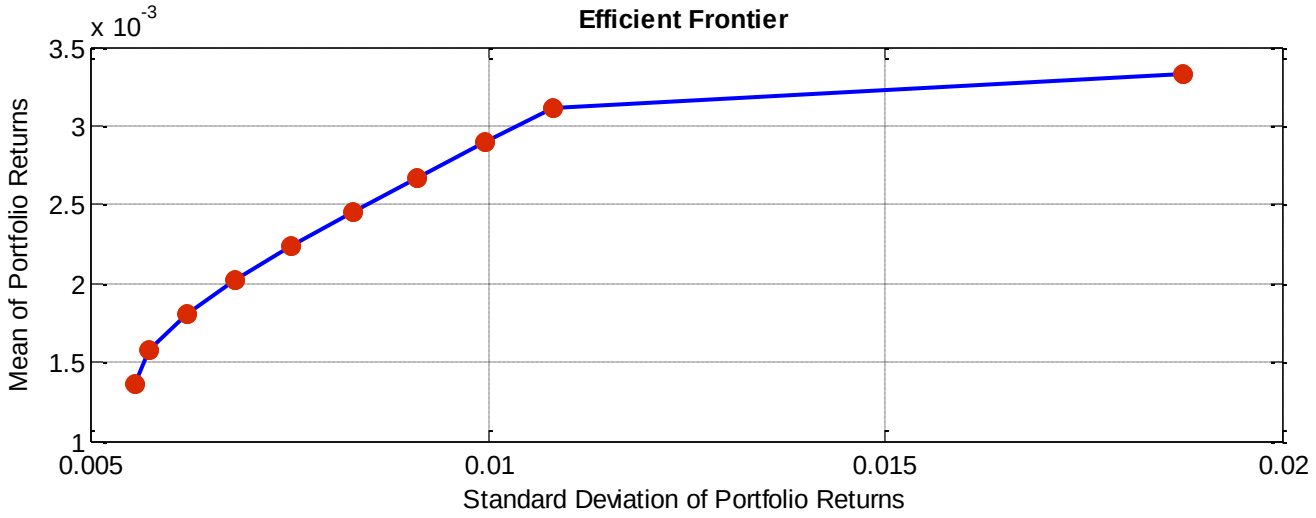
- Overview of the MATLAB Solution
  - Connect to financial data sources
  - Perform financial modeling & analysis
  - Share results & deploy applications

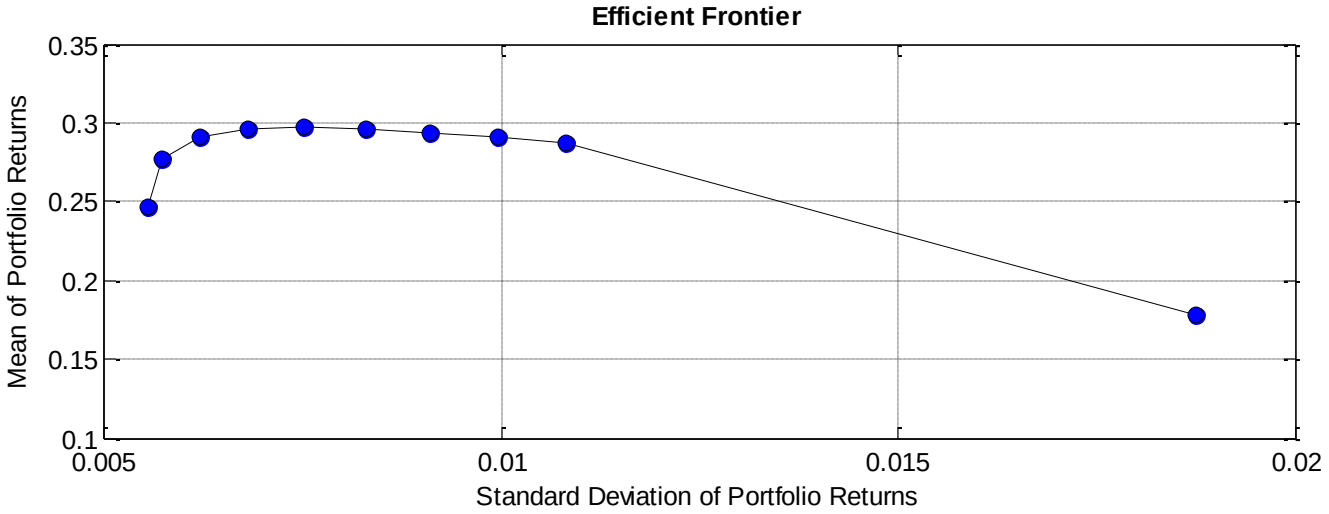
- Finance Application Examples
  - Macroeconomic modeling & forecasting
  - Cash flow hedging & scenario analysis
  - Credit risk assessment

Computational Finance Workflow



Portfolio Optimization





Modeling Market Risk Factor Time Series

Need model that captures:

- Correlation & overall volatilities
- Time-varying volatility
- Fat-tailed distributions

Candidate model: Geometric Brownian Motion

- Correlation & overall volatilities
- Time-varying volatility
- Fat-tailed distributions

Market Risk Using Copulas, GARCH & EVT
"Forecasting risk factors"

Need model that captures:

- Time-varying volatility ⟺ GARCH
- Fat-tailed distributions ⟺ Generalized Pareto
- Factor Correlations ⟺ Copulas

Market Risk Using Copulas & Extreme Value Theory
"Asymmetric GARCH using a GJR Model"

- Model returns using a asymmetric GARCH Model

Similar to QGARCH, The Glosten-Chris Hughton-Runkle GARCH (GJR-GARCH) model by Glosten, Jagannathan and Runkle (1993) also models asymmetry in the ARCH process. The suggestion is to model $\epsilon_t = \sigma_t z_t$ where z_t is i.i.d., and

$$\sigma_t^2 = K + \delta\,\sigma_{t-1}^2 + \alpha\,\epsilon_{t-1}^2 + \phi\,\epsilon_{t-1}^2 I_{t-1}$$

where $I_{t-1} = 0$ if $\epsilon_{t-1} \geq 0$, and $I_{t-1} = 1$ if $\epsilon_{t-1} < 0$.

- Estimate a Marginal CDF – Kernel + Pareto Tails

- Fit a Student-T Copula and induce correlation amongst the simulated residuals

- Estimate a VaR & CVaR

The GARCH Model

"Non-symmetric, Non-Gaussian residuals"

$$y_t = C + \sum_{i=1}^{R} \phi_i y_{t-i} + \sum_{j=1}^{M} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

AR **ARMA**

$$\sigma_t^2 = \kappa + \sum_{i=1}^{P} G_i \sigma_{t-i}^2 + \sum_{j=1}^{Q} A_j \varepsilon_{t-j}^2$$

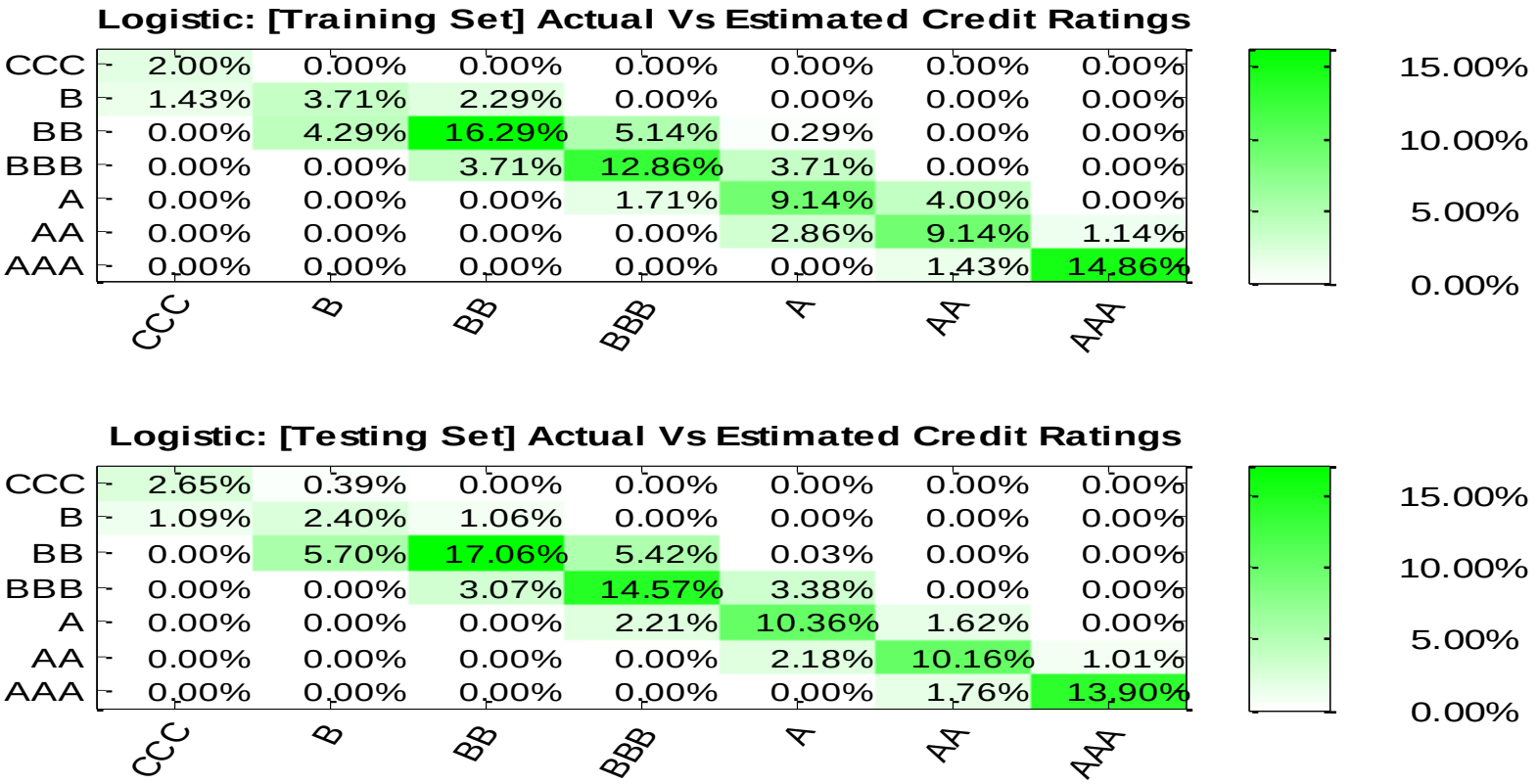
$$\varepsilon_t = \sigma_t z_t$$

$$z_t \sim N(0,1)$$

GARCH **ARCH**

Credit Classification

"Logistic Regression Vs. TreeBagger"



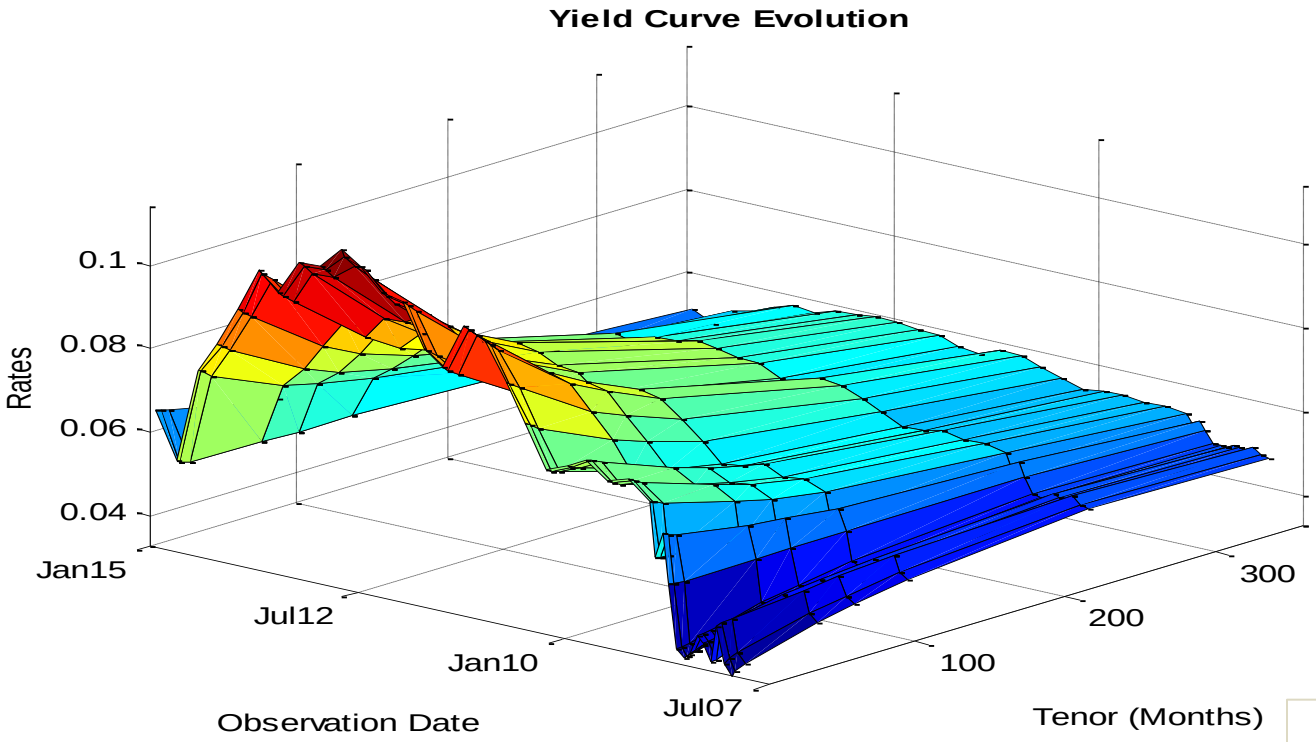
>> doc mnrfit
>> doc mnrval
>> doc treebagger
>> doc confusionmat

Popular in classifying the credit quality of instruments is the use of logistic regression. This example illustrates this classification but takes a step further by using a Tree Bagger classifier.

Credit Value Adjustment – Expected loss on portfolio

$$CVA = (1 - R) \int_0^T discEE(t) * ProbOfDefault(t)$$

1. Given an interest rate exposed portfolio – Swap Portfolio
2. Generate Yield Curve Scenarios - Hull White Short Rate model
3. Calibrate Probability of Default Curve for each Counter Party



[Section 3|EX 1]

Evaluate Counterparty Exposures

Stochastic Differential Equation Model

$$dXt = S(t) * [L(t) - Xt]dt + V(t)dWt$$

$$L(t) = LevelFun(t, FwdRates, Alpha, Sigma)$$

$$S(t) = 0.2$$

$$Sigma = 0.015$$

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>> doc IRDataCurve
>> doc hwv
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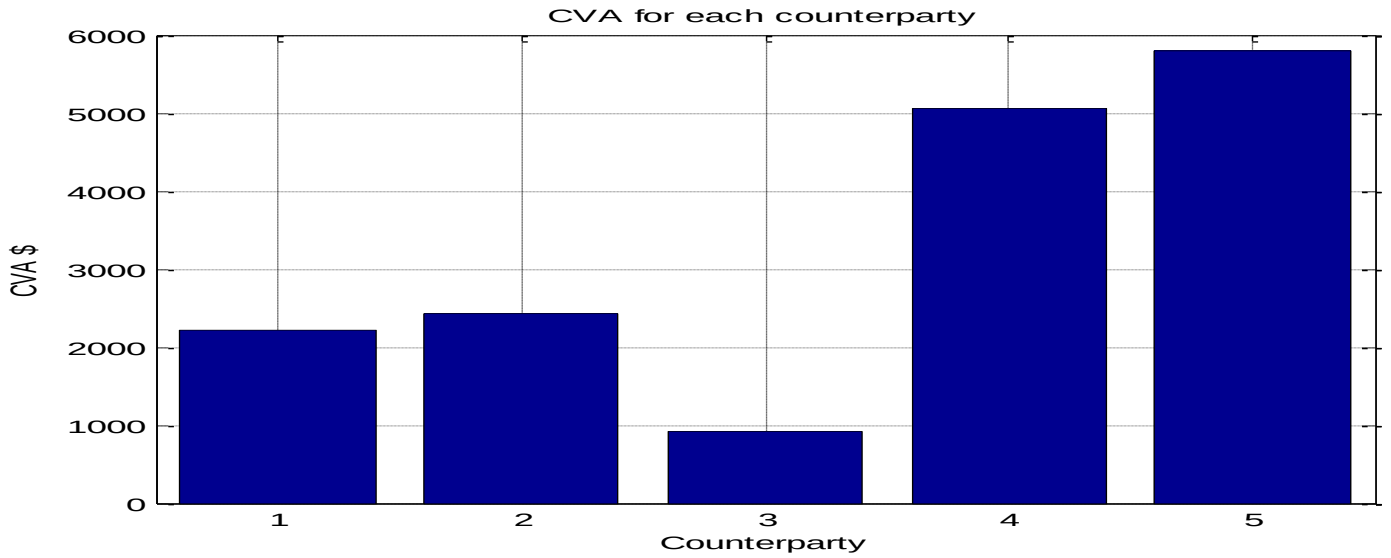
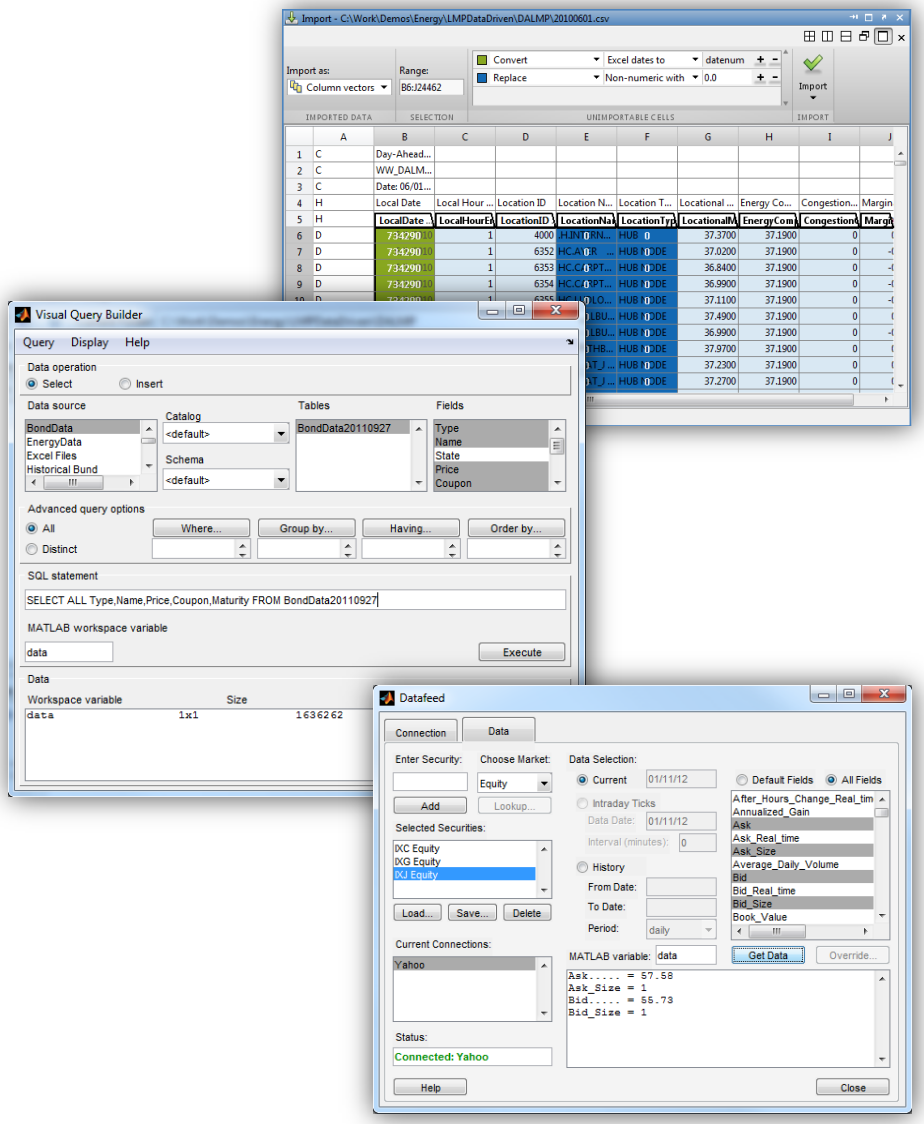


[Section 3 | EX 1]

Connect to Data from Various Sources

- Excel spreadsheets and flat files
- ODBC or JDBC compliant databases
- Data feeds including Bloomberg, Reuters, Factset®, eSignal® and others
- Web services (SOAP)



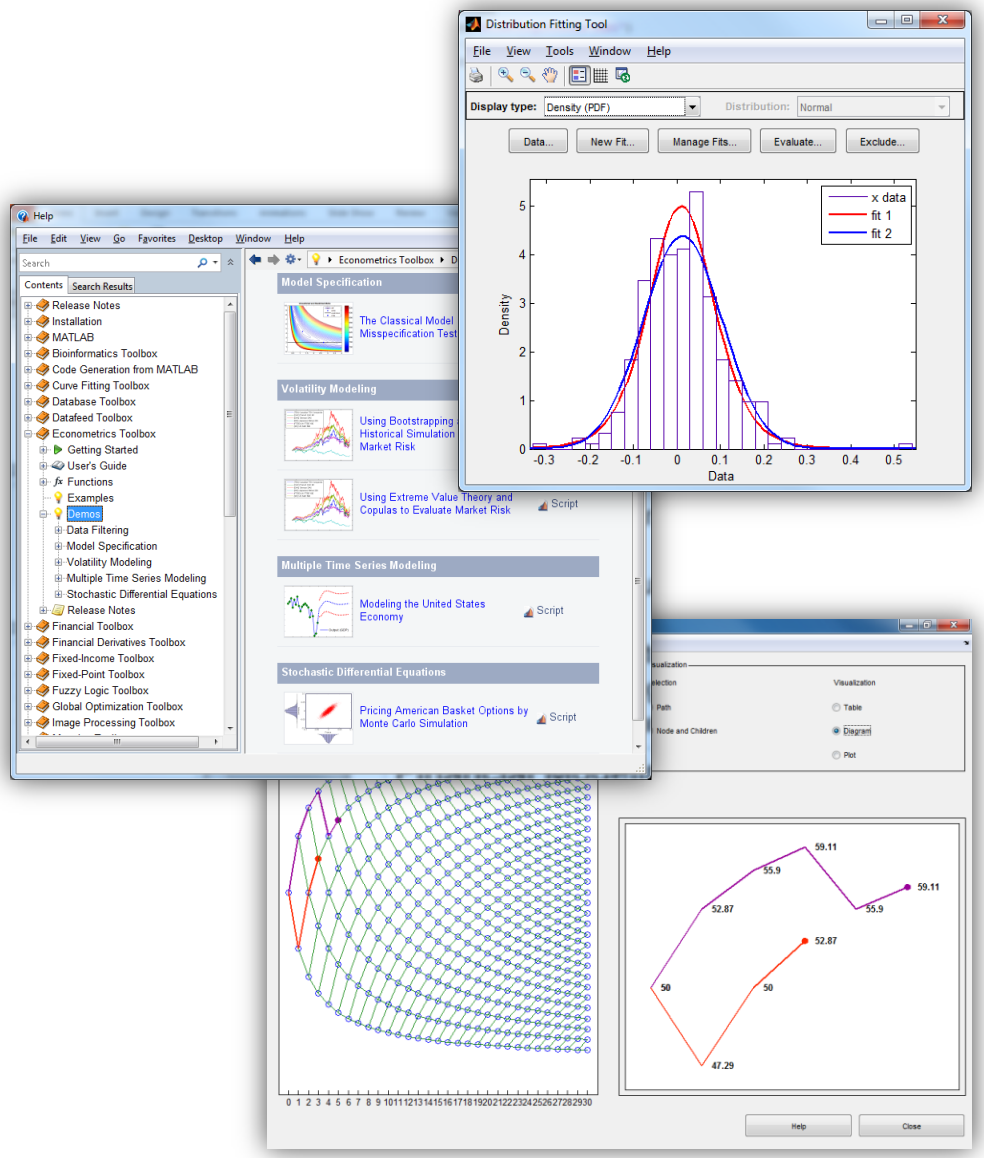
Leverage Built-in Functions to Save Time

Mathematics

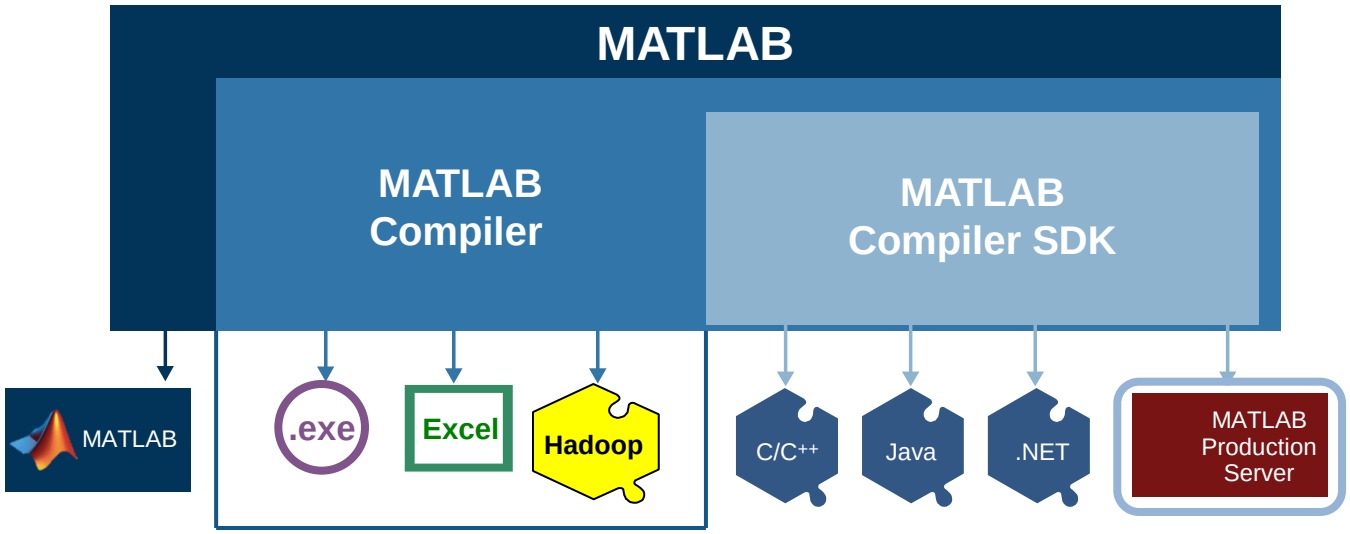
- Regression (Linear, Non-Linear)
- Curve Fitting
- Probability Distributions, RNG
- Clustering
- Multivariate & Factor Analysis
- Predictive Modeling, AI
- Optimization, Parameter Estimation

Financial Modeling

- Portfolio Optimization & Analysis
- Derivative Pricing & Hedging
- Yield Curve Modeling
- Monte Carlo Simulation
- Risk Quantification
- ARMA/GARCH Analysis

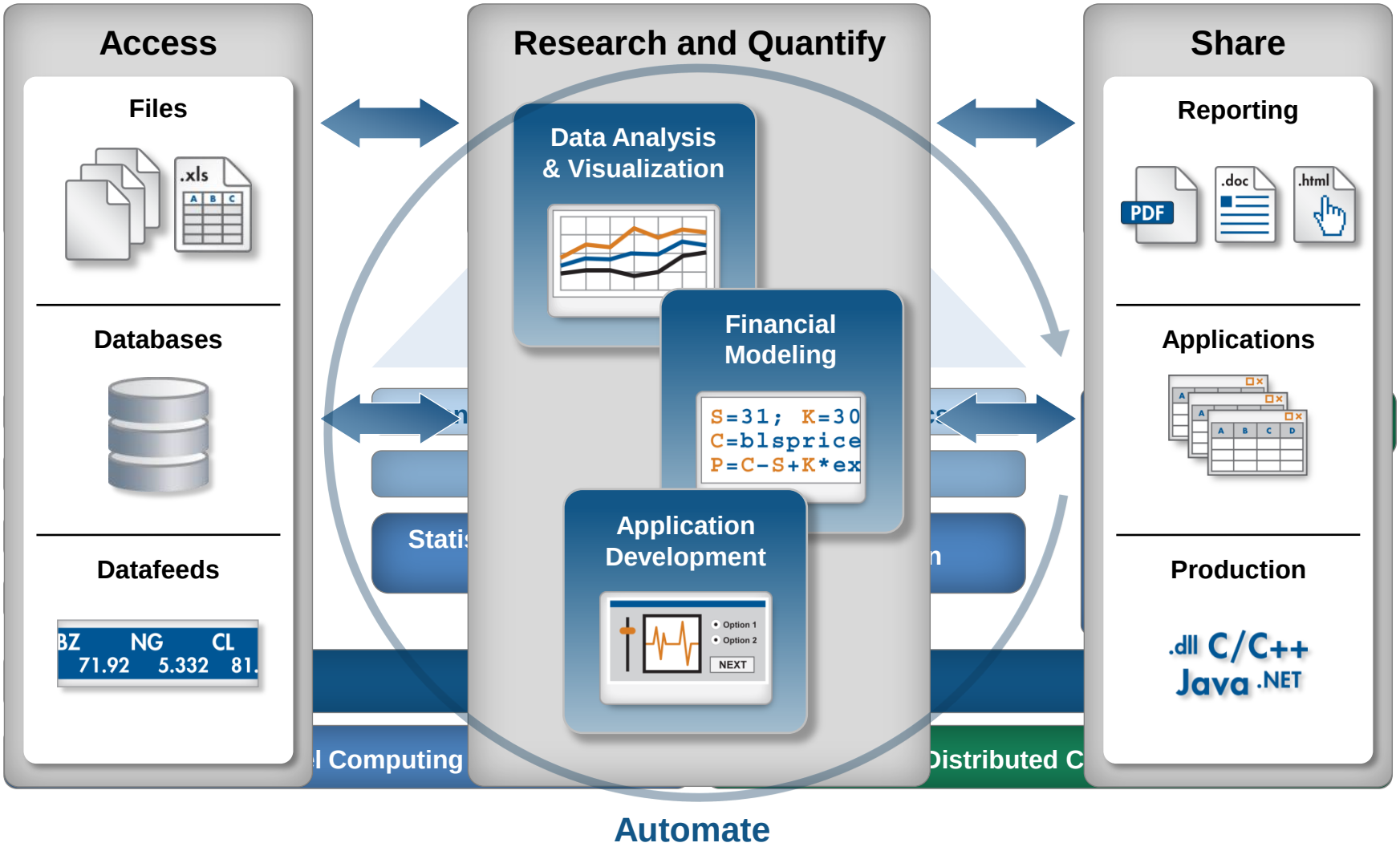


Sharing MATLAB Applications

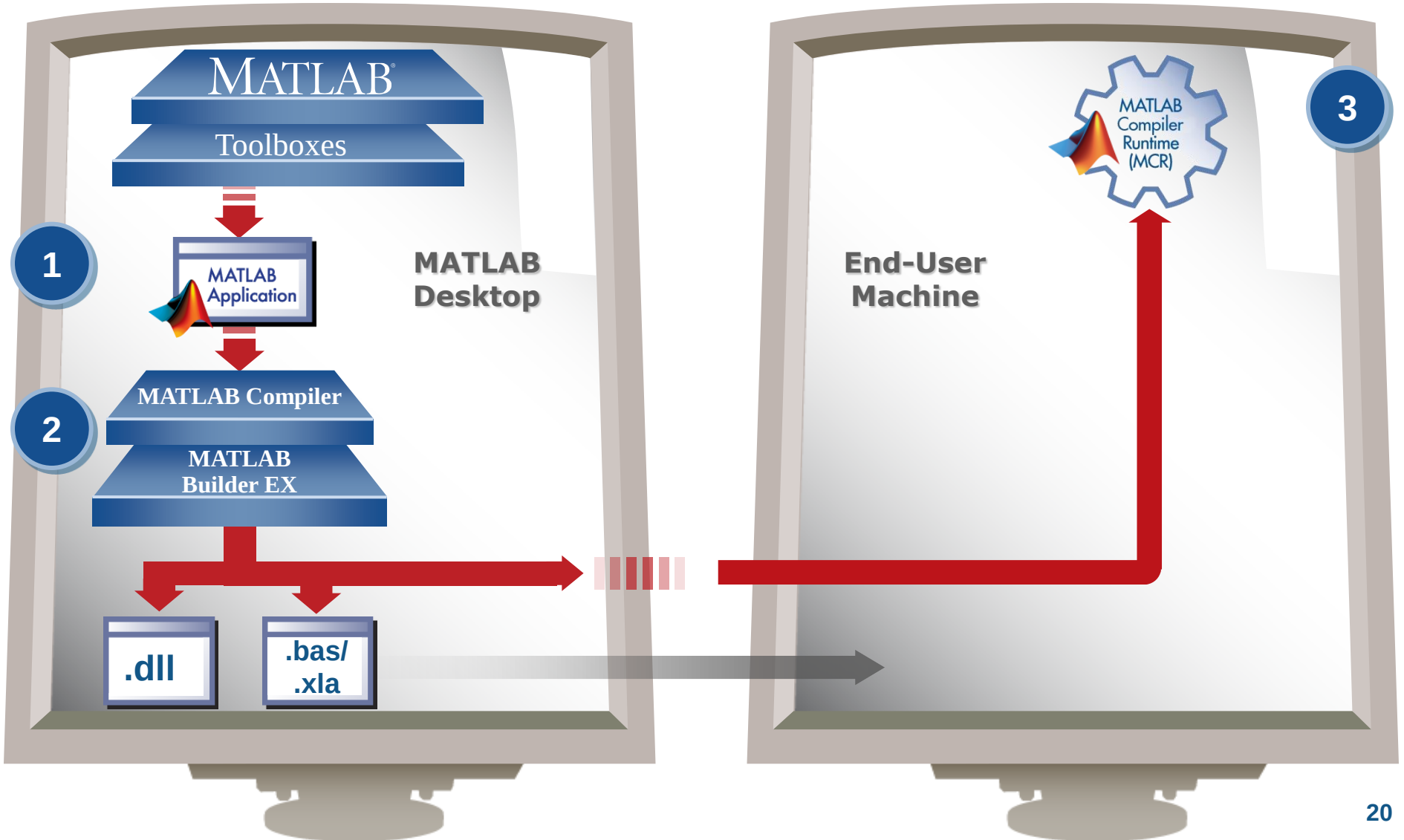


- Share applications with those who do not need MATLAB
- Royalty free
- ***MATLAB Production Server*** provides most efficient path for secure and scalable enterprise applications

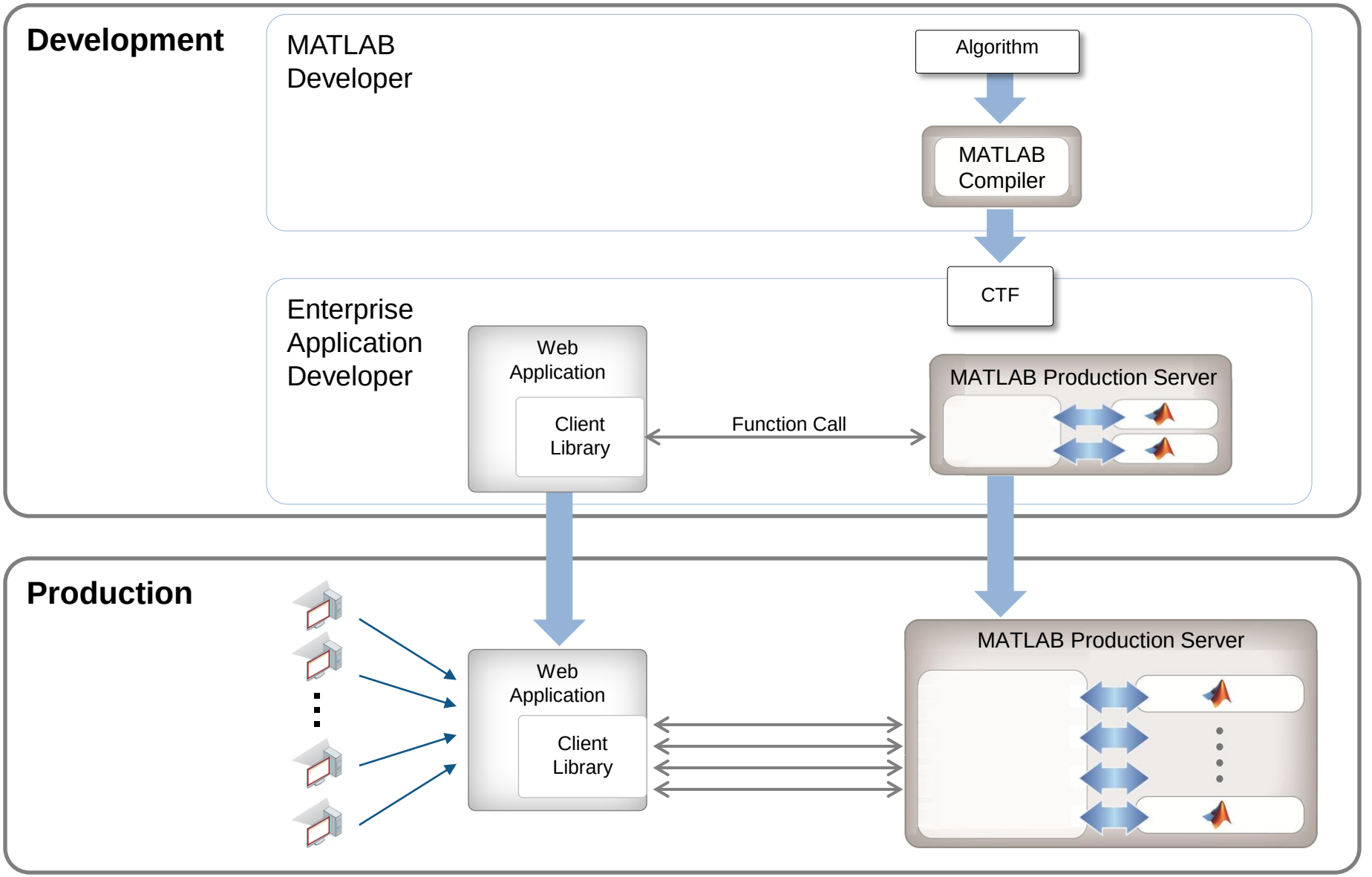
Financial Modeling Workflow



Deploying MATLAB Applications to Excel

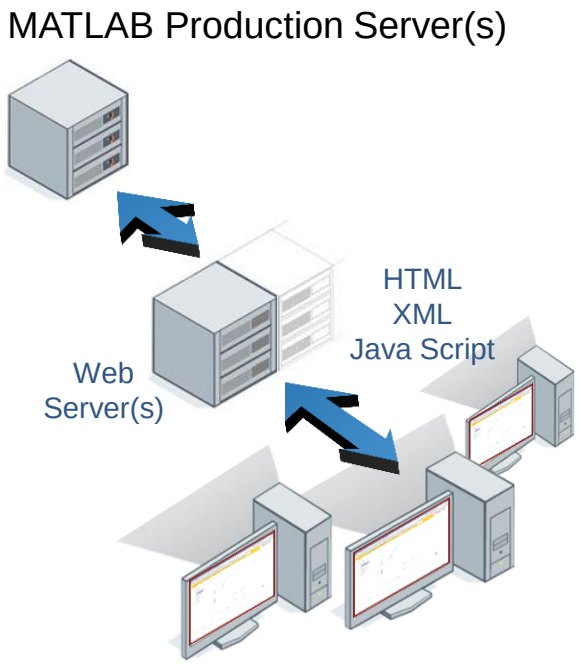


Production Deployment Workflow

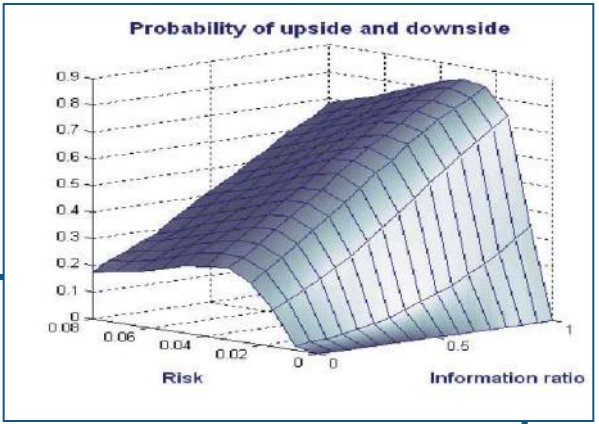


Value of MATLAB Production Server

- Directly deploy MATLAB programs into production
  - Supports multiple MATLAB programs and MCR versions
- Scalable & reliable
  - Service large numbers of concurrent requests
  - Add capacity or redundancy with additional servers
- Use with web, database & application servers
  - Lightweight client library isolates MATLAB processing



CAMRADATA Models Dependencies for Quantitative Risk Assessment with MathWorks Tools



Risk-assessment model developed in MATLAB.

Challenge

Rapidly develop quantitative tools for factor analysis, risk analysis, and defensive asset allocation

Solution

Use MATLAB to model complex non-linear dependencies between assets, liabilities, and economic variables using copulas

Results

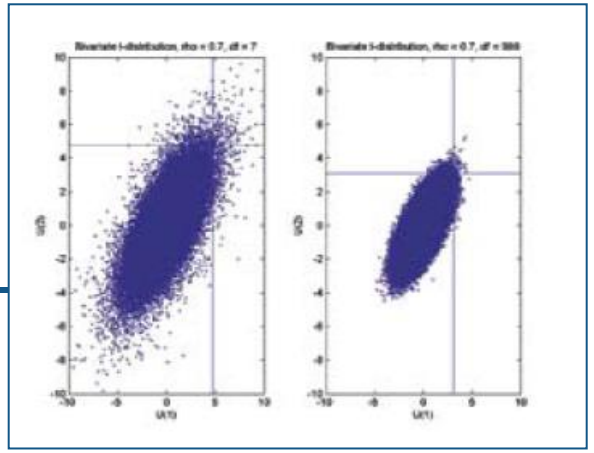
- Development time reduced by 90 percent
- Risk calculated in hours, not weeks
- Diverse skill sets leveraged

"Using MATLAB we can build a model in one morning. It would take two weeks to write the equivalent code in Visual Basic."

Martyn Dorey
CAMRADATA

Link to user story

Capgemini Helps Clients Achieve Basel II Compliance and Deliver Economic Capital, Risk, and Valuation Models with MATLAB



Scatterplots showing 500,000 simulations drawn from bivariate t-copulas with the same correlation coefficient but differing degrees of freedom.

Challenge

Enable banking clients to meet Basel II regulatory guidelines and perform other risk management tasks

Solution

Use MATLAB to develop risk management models and to perform valuations of complex products

Results

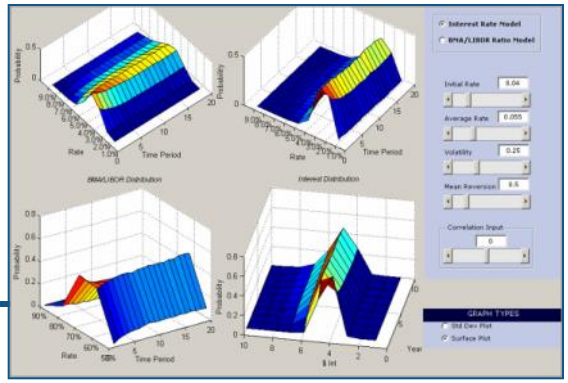
- Strong competitive advantage established
- Scalable solution delivered
- Customer portfolio revalued

"With its computational power, matrix infrastructure, and ability to perform Monte Carlo simulations, MATLAB gives us a competitive advantage in performing complex risk analyses."

Dr. Marco Folpmers
Capgemini

Link to user story

Intuitive Analytics Uses MATLAB to Build Quantitative Tools to Help Bond Issuers Manage Risk



Using MATLAB technical computing software to provide visual representations of interest rate models.

Challenge

Build and market a quantitative tool for reducing expected cost and risk for municipal bond issuers

Solution

Use MathWorks tools to develop algorithms, visualize results, and simplify deployment of an advanced analytical tool

Results

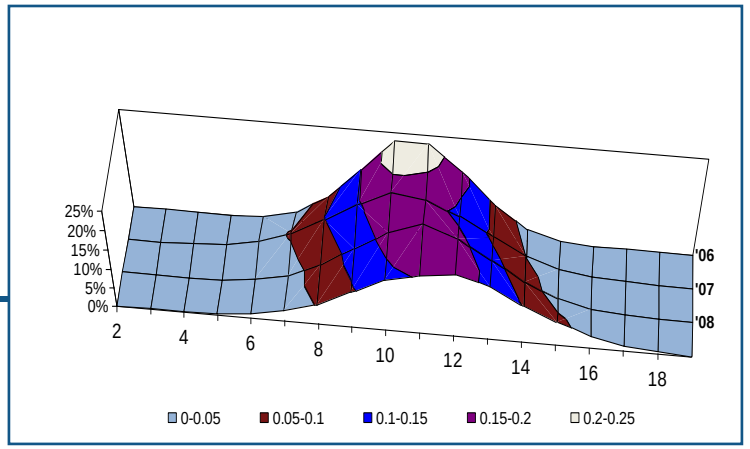
- Development productivity increased by 90%
- Deployment simplified
- Visual environment created

"Because MATLAB enables us to build and distribute applications to analysts that are accessible from Excel, we are quickly bringing to market products that are adopted and deployed by investment banks."

Peter Orr
Intuitive Analytics

Link to user story

IPD Develops and Deploys Real Estate Cash Flow Models with MathWorks Tools



MATLAB graph generated to indicate how total returns from industrial property are likely to behave.

Challenge

Create cash flow models of real estate investment portfolios and project returns using Monte Carlo simulations

Solution

Use MATLAB and MATLAB Builder NE to develop optimization algorithms, build financial models, and deploy solutions

Results

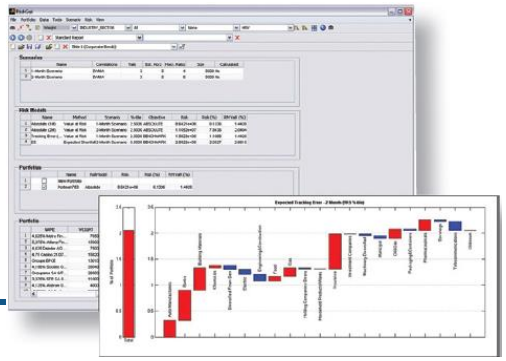
- Development time cut by 16 weeks
- Updates completed in hours
- Deployment simplified

"The only other approach we seriously considered involved developing a class library in .NET and C#. Development, debugging, and testing would have taken us 37 weeks. Using MATLAB, we completed the project in 21 weeks."

Peter McAnena
Investment Property Databank

Link to user story

Nykredit Develops Risk Management and Portfolio Analysis Applications to Minimize Operational Risk



Nykredit's tool for calculating and visualizing risk statistics. The plot shows portfolio expected tracking error broken out by industry.

Challenge

Enable financial analysts to make rapid, fact-based decisions by providing them with direct access to risk management and portfolio analysis information

Solution

Develop and deploy easy-to-use graphical financial analysis applications using MATLAB and MATLAB Compiler

Results

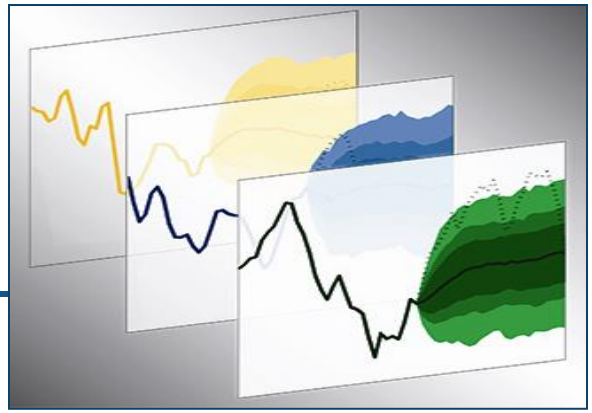
- Productivity increased threefold
- Operational risk mitigated
- Analysis time reduced from days to hours

"Data handling, programming, debugging, and plotting are much easier in MATLAB, where everything is in one environment. For performance calculation GUIs, MATLAB provides a real error-checked application that makes cool customized plots for client reports. This has turned a several-hour task in a spreadsheet into a two-minute no-brainer."

Peter Ahlgren
Nykredit Asset Management

Link to user story

Macroeconomic Modeling and Inflation Rate Forecasting at the Reserve Bank of New Zealand



Sample fancharts produced by RBNZ's macroeconomic model.

Challenge

Support New Zealand monetary policy with a theoretically well-founded model

Solution

Use MATLAB to analyze and forecast macroeconomic variables, and communicate results to stakeholders

Results

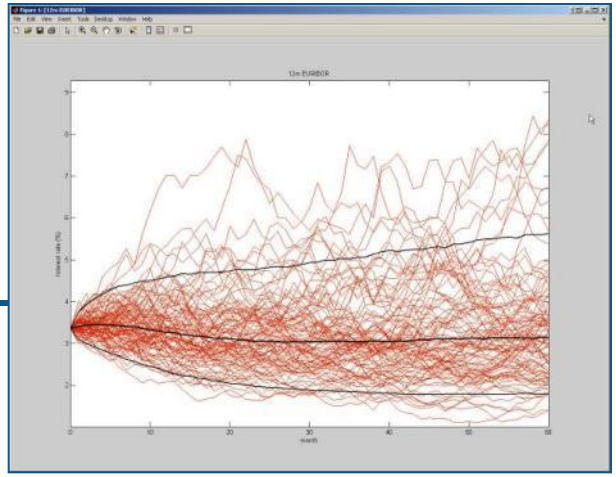
- Entire workflow completed in a single environment
- Code shared with other central banks and financial institutions
- Technical rigor of macroeconomic forecasting increased

"With all RBNZ models now implemented in MATLAB, the RBNZ has a common platform for evaluating the economy and making informed decisions."

Jaromir Benes
International Monetary Fund

Link to article

Robeco Develops Quantitative Stock Selection and Portfolio Optimization Models with MathWorks Tools



Interest rate paths for the risk analysis of a savings product.

Challenge

Develop, distribute, and maintain quantitative tools for portfolio construction and management

Solution

Use MATLAB and MATLAB Builder NE to develop algorithms, build quantitative models, and deploy solutions

Results

- Applications updated faster
- Black-box solutions eliminated
- Scalability and flexibility increased

"Unlike companies that rely on off-the-shelf quantitative analysis solutions, we can see our process improving all the time. We have the flexibility to continuously improve our algorithms and models in MATLAB—and that is a big advantage."

Willem Jellema
Robeco

Link to user story

MATLAB Solutions

Challenge	Solution
Inability to customize	***Flexible modeling*** ▪ Complete development environment
Lack of transparency	***White-box modeling*** ▪ Viewable-source functions
Subpar computational speeds	***Powerful computation engine*** ▪ Run fast Monte-Carlo simulations
Long development time	***Quick prototyping*** ▪ Focus on modeling not programming
Inefficiencies in Integration	***Easy to Integrate & Deploy*** ▪ Point-and-click workflow

Questions