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Non-linearity and Asymmetry of Economic Effects on PD

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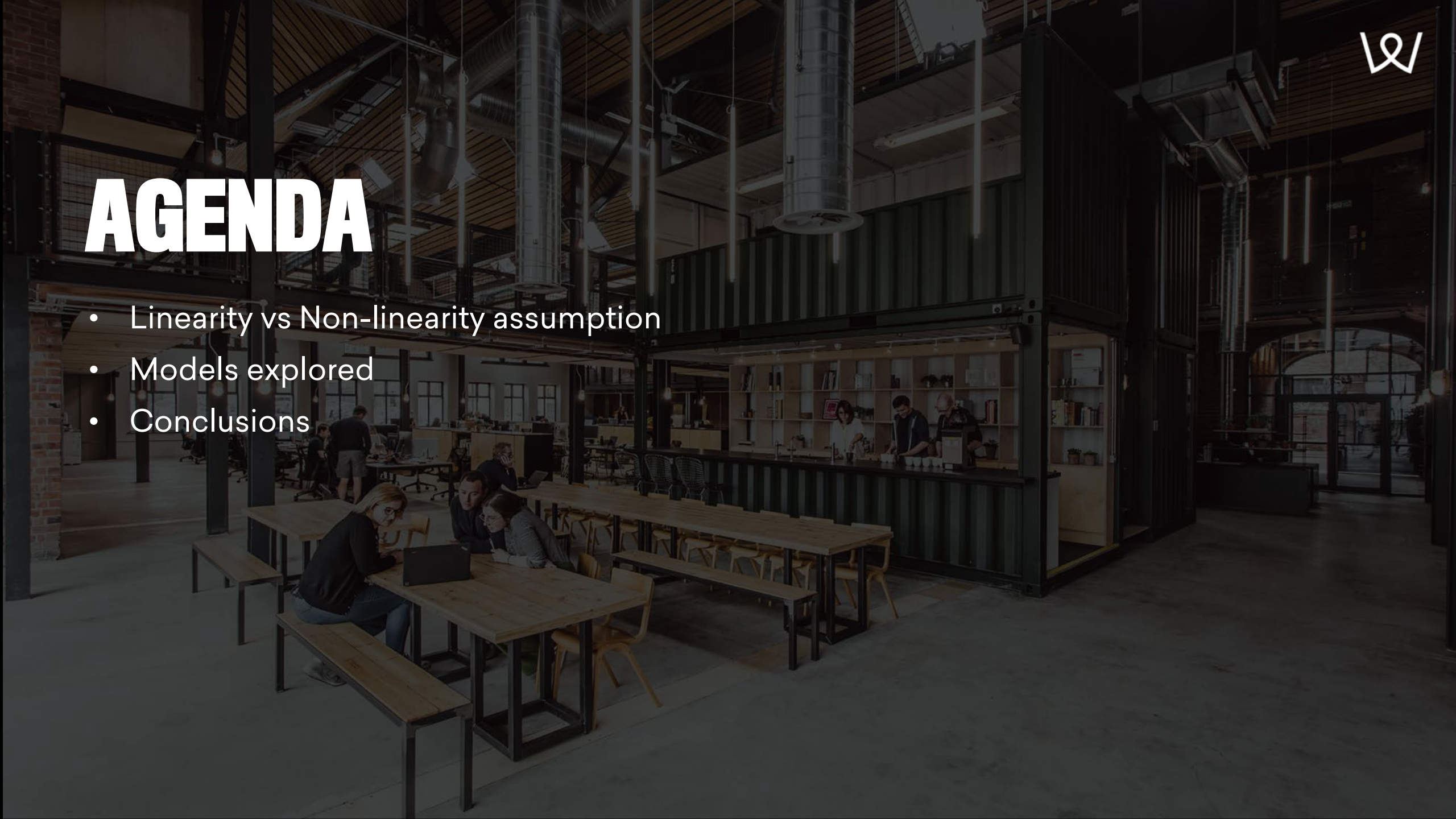


AGENDA

- Linearity vs Non-linearity assumption
- Models explored
- Conclusions

Introduction

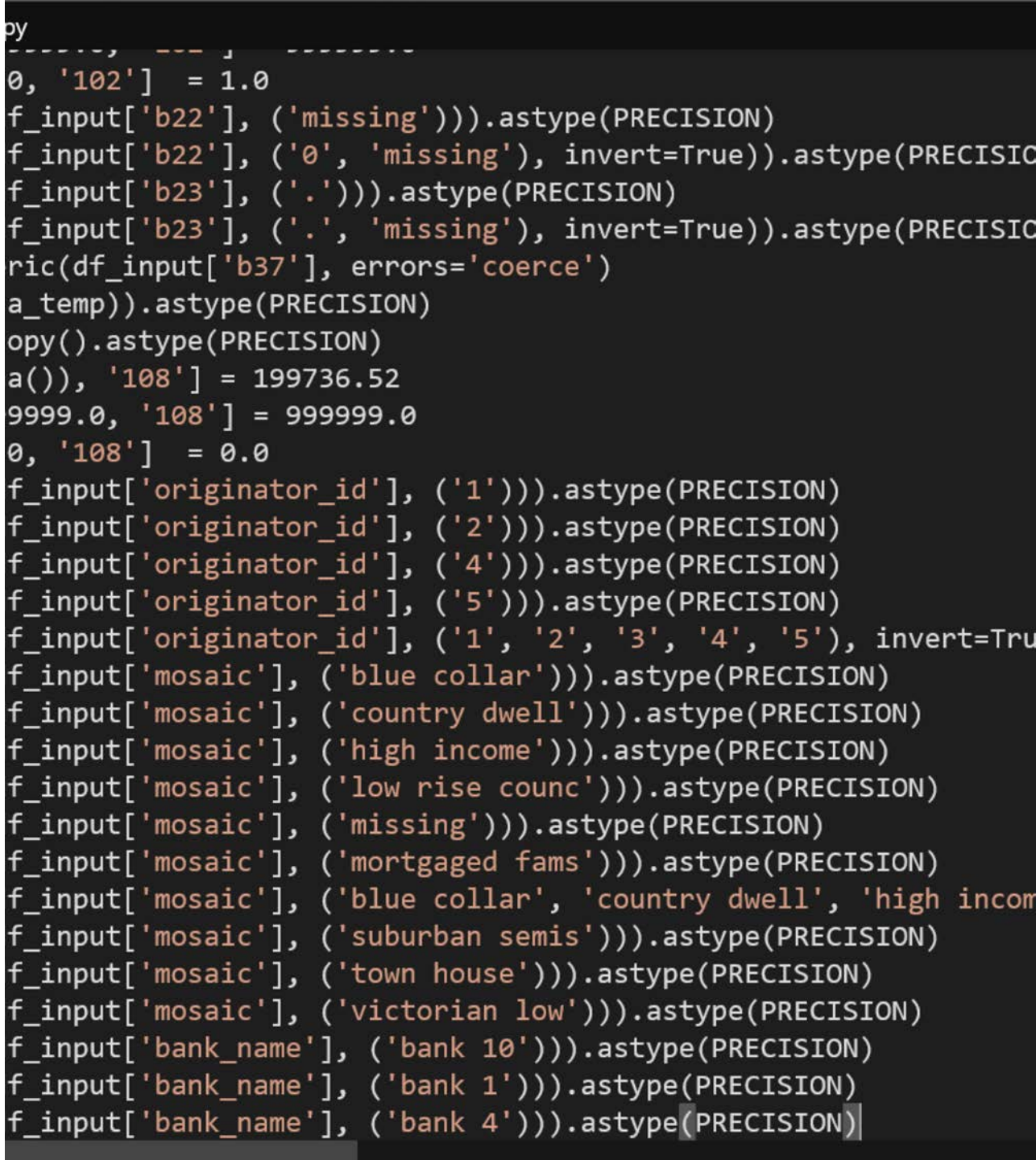
The importance of capturing non-linearity of economic effects on losses

- Following the 2008 recession, economic modelling has increased in prominence in credit risk management. Regulators expect financial institutions to be able to predict the impact of an economic downturn on portfolio losses, both in impairment calculation and stress testing.
- The industry standard approach is to include macro-economic drivers through linear (or log-linear) ERM (Economic Response Models), which assume that the impact of a change in economic driver will be of the same magnitude, regardless of the direction of movement.

Introduction

The importance of capturing non-linearity of economic effects on losses

- The limitations of this approach leads to firms having to introduce significant expert-judgment based overlays on models results, and to maintain separate ERM models for IFRS9/stress testing.
- In this presentation, we discuss the opportunity to introduce asymmetric economic effects on PD modelling, comparing a traditional linear model vs non-linear alternatives.
- The analysis should be useful for financial institutions looking to improve their forecast techniques, in light of ever-increasing regulatory expectations on firms' modelling capabilities.



LINEARITY VS NON-LINEARITY

Linearity - Concept

Linearity is the approach traditionally adopted in ERM models in the industry...

Linear models assume the impact of a change in an economic driver is of the same magnitude, regardless of the starting point or direction of movement.

For example, a 1% increase in interest rates will predict default rates to increase by the same amount as a 1% decrease would reduce them.

Non-linearity - Concept

...in reality non-linearity seems the most likely outcome

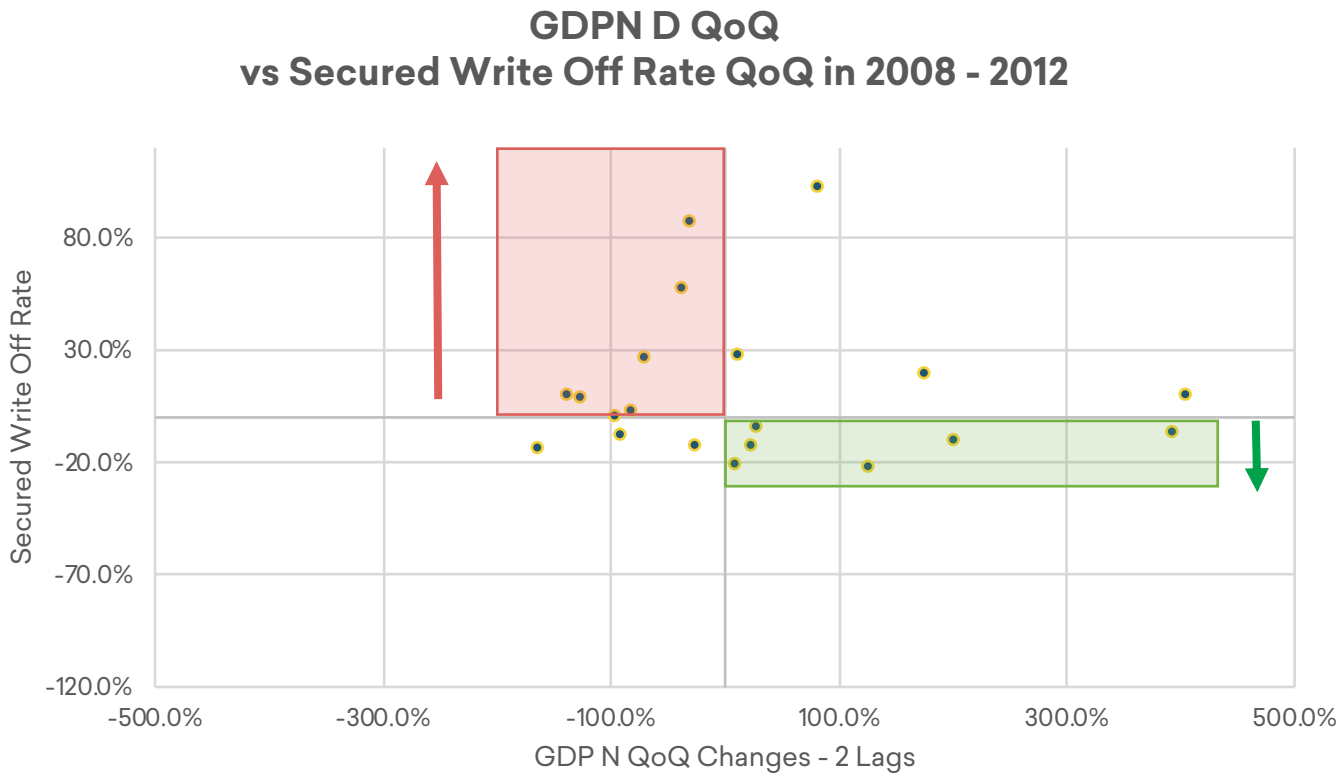
In this presentation we want to test the hypothesis that there is an asymmetric response to economic changes dependent on the underlying conditions, with a more severe impact on losses expected under worsening conditions.

The aim is to increase accuracy and intuitiveness of the size and timing of losses forecast in all economic scenarios.

Based on this, we would expect an increase of 1% in interest rate to have a more significant negative impact on losses compared to the benefits of a 1% reduction.

Non-linearity - intuition

2008 Recession data – Secured Write Offs vs GDP Quarterly changes

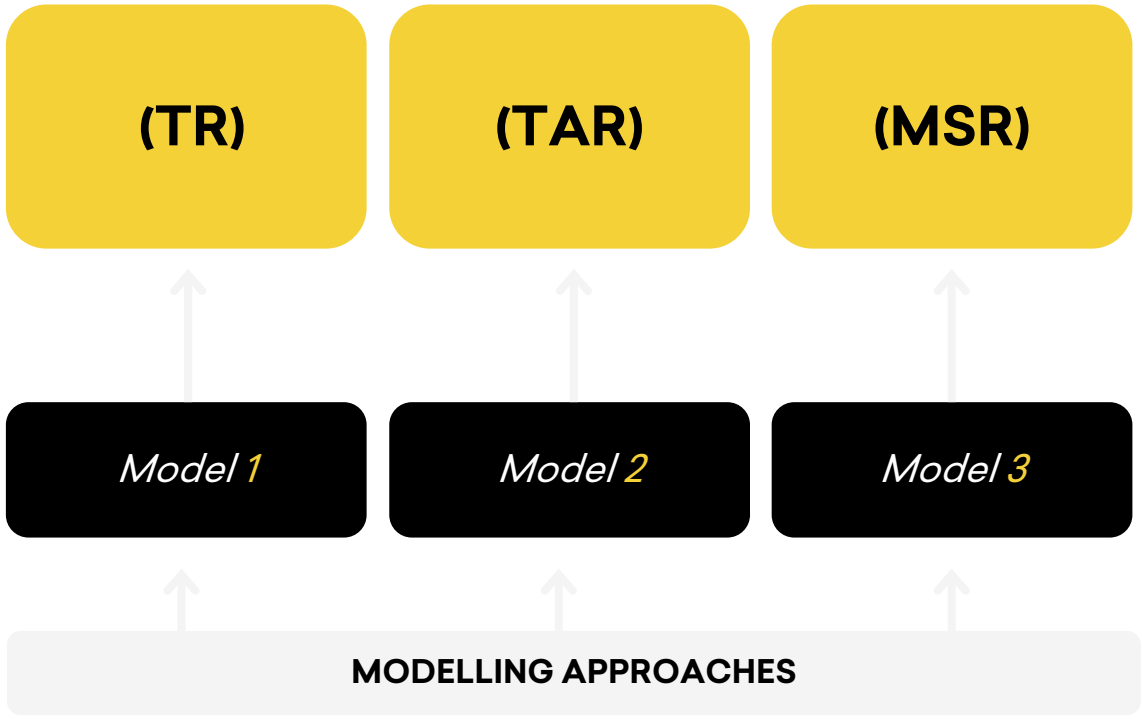


MODELS EXPLORED

Approach

Three modelling approaches have been used to test the assumption

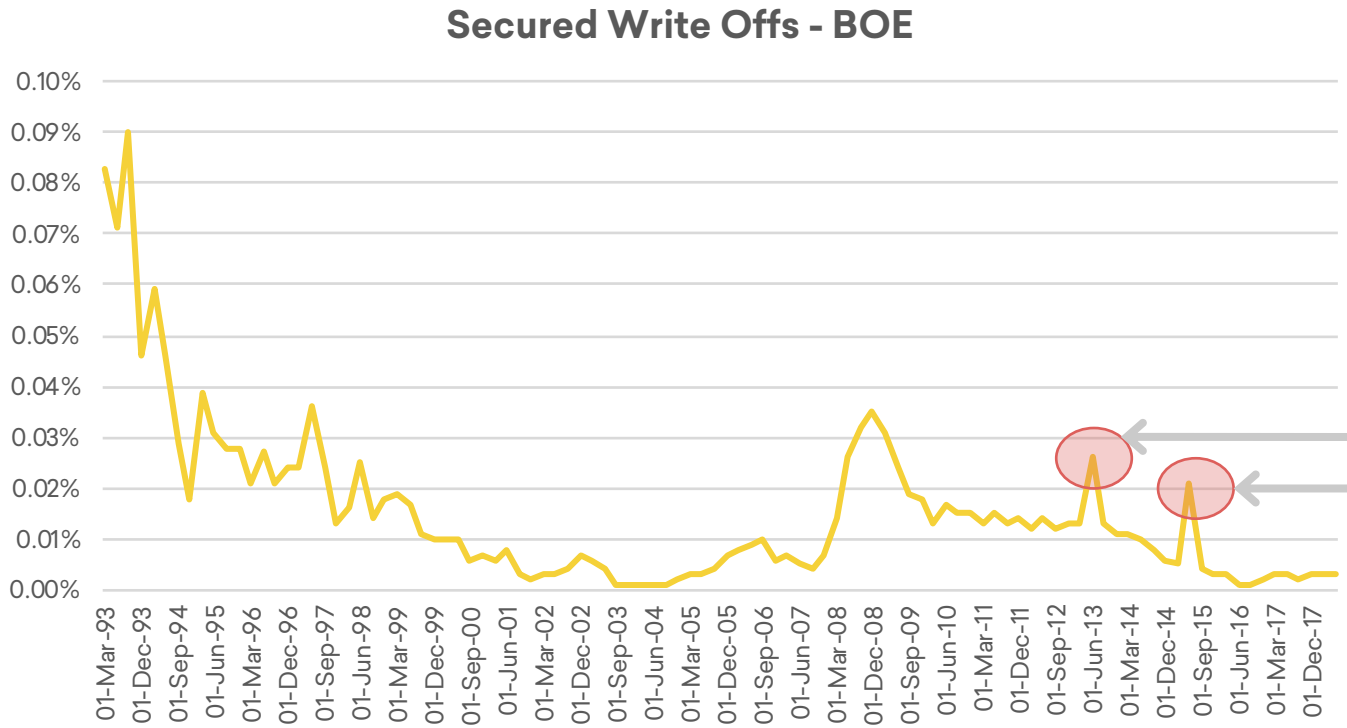
- Using industry level data, we compared a traditional linear model vs non-linear alternatives. The non-linear models include:
    1. A Threshold (TR) model
    2. A Threshold Autoregressive (TAR) model
    3. A Markov switching regime (MSR) model
- All three models produce alternative predictions of default rates depending on the state of the economy in the scenario.
- The analysis is conducted using the Secured write off series available from the BOE Interactive database, on Quarterly data.
- The stress scenario used for the macroeconomic variables is the ACS from the BOE 2019 Concurrent Stress Test (CST).



Dependent Variable

The dependent variable is the Secured write off series (BOE)

There re some limitations in using industry-level data (not capturing change in quality, maturation effects etc.)



These spikes have been removed as they are unlikely to be economy-driven.

Macroeconomic variables

Macroeconomic variables have been sourced from ONS/BOE

- A limited set of variables has been tested (GDP, Unemployment, BOE Interest Rate, House Price Index, Consumer Price Index, Total Secured Exposure to Income).
- The standard variables transformations have been applied:
  - ✓ Quarterly Differences
  - ✓ Yearly Differences
  - ✓ Quarterly Growth rates (and differences)
  - ✓ Yearly Growth rates (and differences)
- Four lags have been tested for each variable.
- A preliminary stationarity analysis has been conducted on all variables and transformations to allow only stationary variables in the models.

Results assessment

Models have been assessed on goodness of fit and sensitivity to stress

This is a proof of concept and models underwent limited validation and back testing.
Models results were assessed based on:

01.
Accuracy

Accuracy (*specifically over the 2008 recession*) – Accuracy measures used: **R-Squared** and **AIC information criterion**.

02.
Sensitivity

Sensitivity – magnitude of response under future stress scenario.

03.
Bias

Bias – peer review expert- judgment.

MODELS EXPLORED

Threshold (TR) Model

TR Model - Theory

The threshold is driven by the exogenous variables

The theory behind threshold models is that the default rate may behave differently, and therefore a different model would apply, depending on the value of a variable(s) exceeding a pre-determined threshold.

Model representation (example):

$$Write - Off\ Rate_t$$

Depending

$$= \alpha_1 + \beta_1 GDP_t + \epsilon_t$$

if $GDP_t < T$

$$= \alpha_2 + \beta_2 GDP_t + \epsilon_t$$

or $GDP_t \geq T$

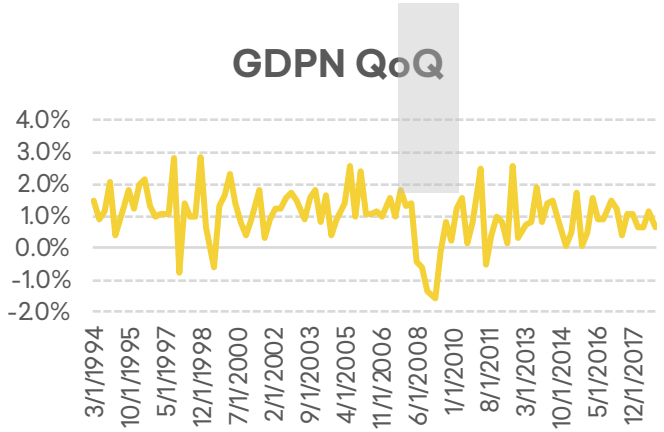
The model can assume two forms, depending on the exogenous variable(s) crossing a certain threshold T.

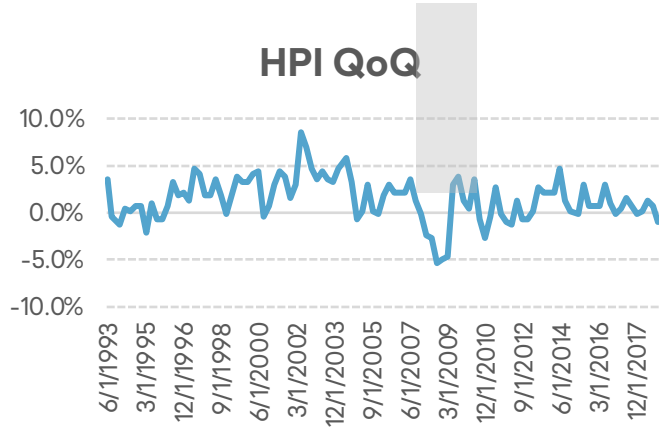
TR Model – Choice of the Threshold T

The threshold T can be defined in different ways

- **T** was defined on a recessionary time period, and same time-split was applied to all **macro variables.**
- Rules adopted: **GDP_QoQ < 0** for at least two consecutive quarters, or **Urate_YoY >= 10%** or **HPI_QoQ <= -2%.** The period identified is **31mar2008** to **31mar2010.**

Risk of Overfitting

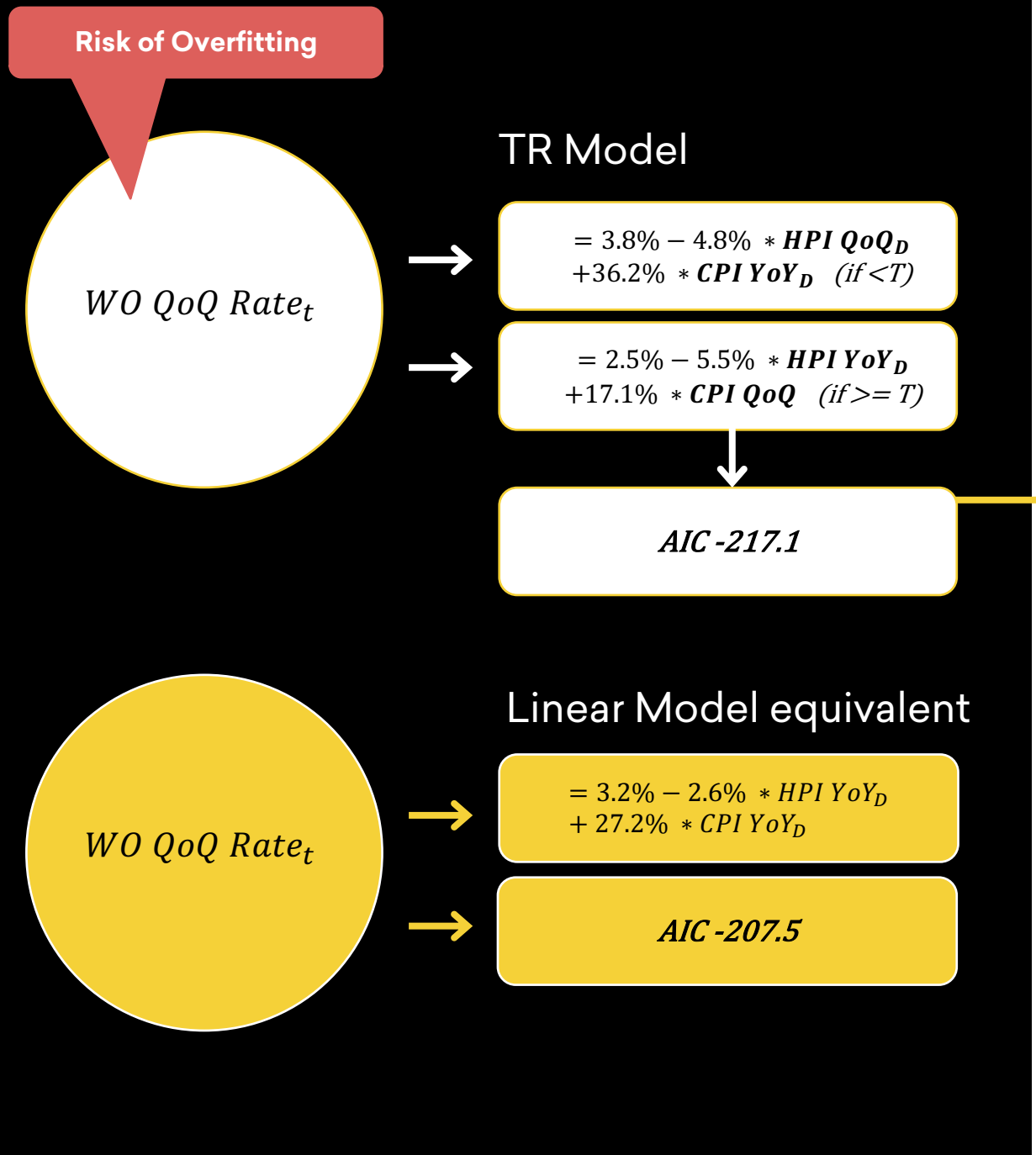




TR Model - Approach

Three modelling approaches have been tested on the same data

MODEL TYPE	ADVANTAGES	LIMITATIONS
OLS Regression on level of write off rate	Simple	• Dep var non-stationary • When producing forecasts, insensitive to default rate starting point
OLS Regression on quarterly changes of write off rate	Simple	• Difficult to obtain a strong fit as the trend is removed
ECM (Error Correction) Model	Allows to model the long-term trend as well as the short term movements.	• Two (four) equations • More challenging to interpret and explain results



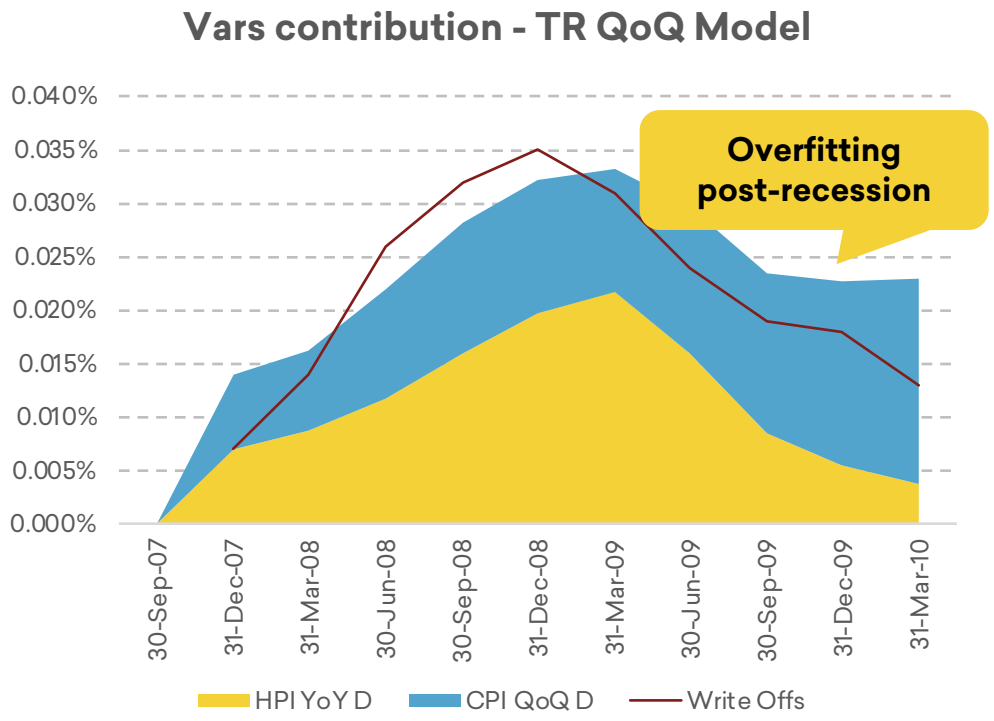
TR Model – Equation (Example)

QoQ Model

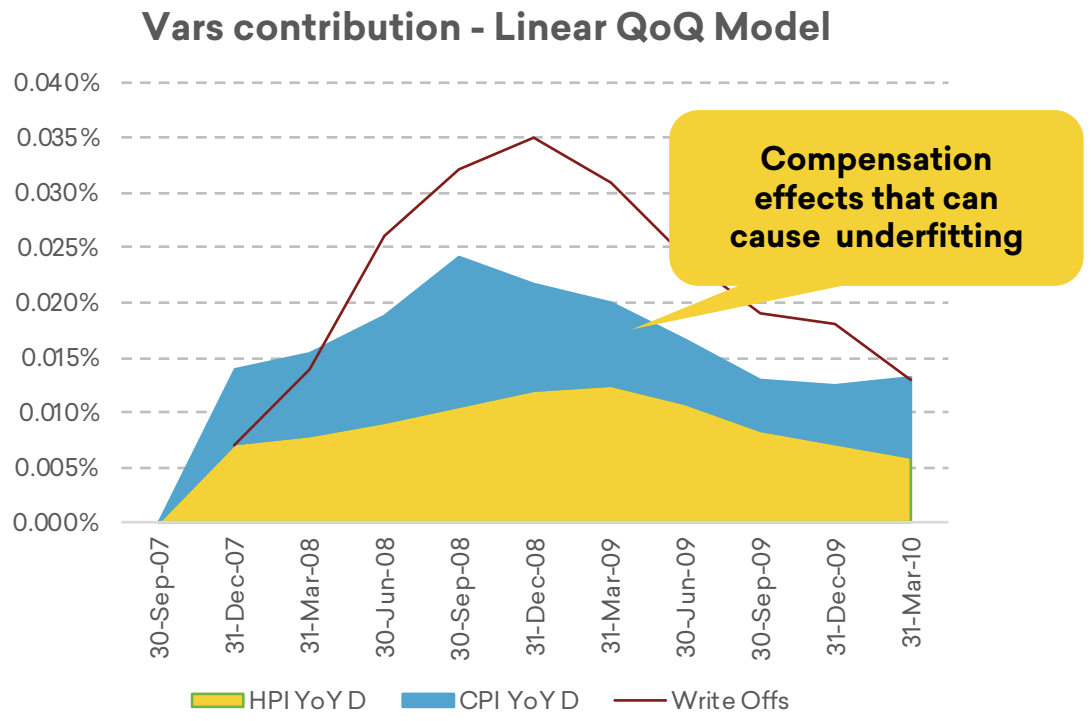
Different transformations of the macroeconomic variables are optimal depending on the side of the threshold.

TR Model – Model Fit

TR QoQ Model vs Linear QoQ Model over 2008 recession



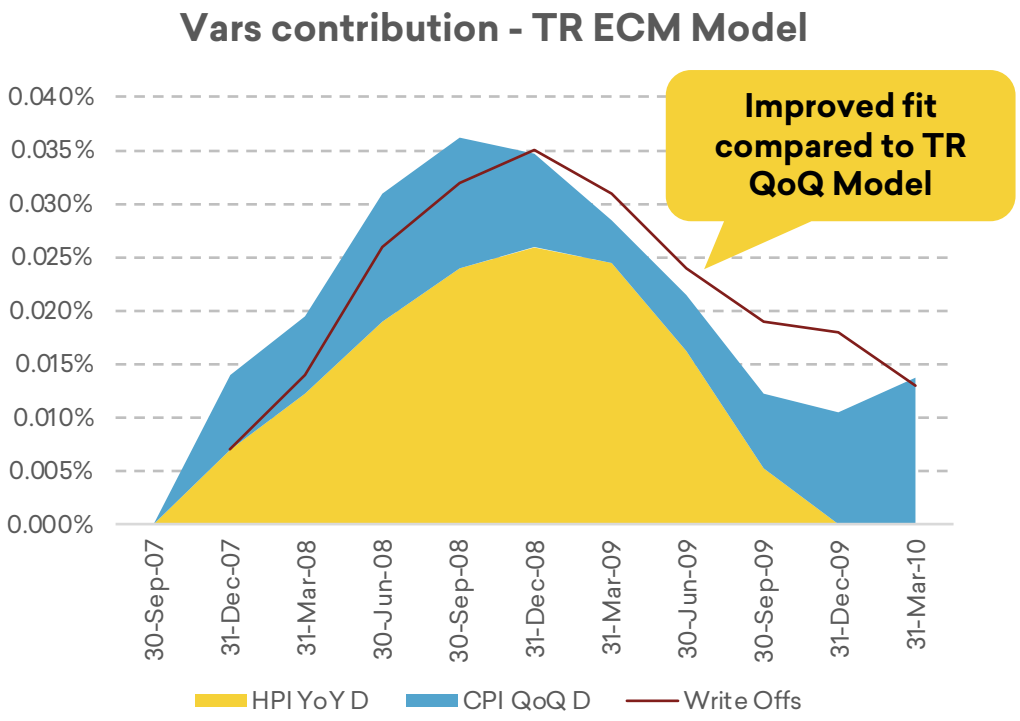
R-Squared 81.7%



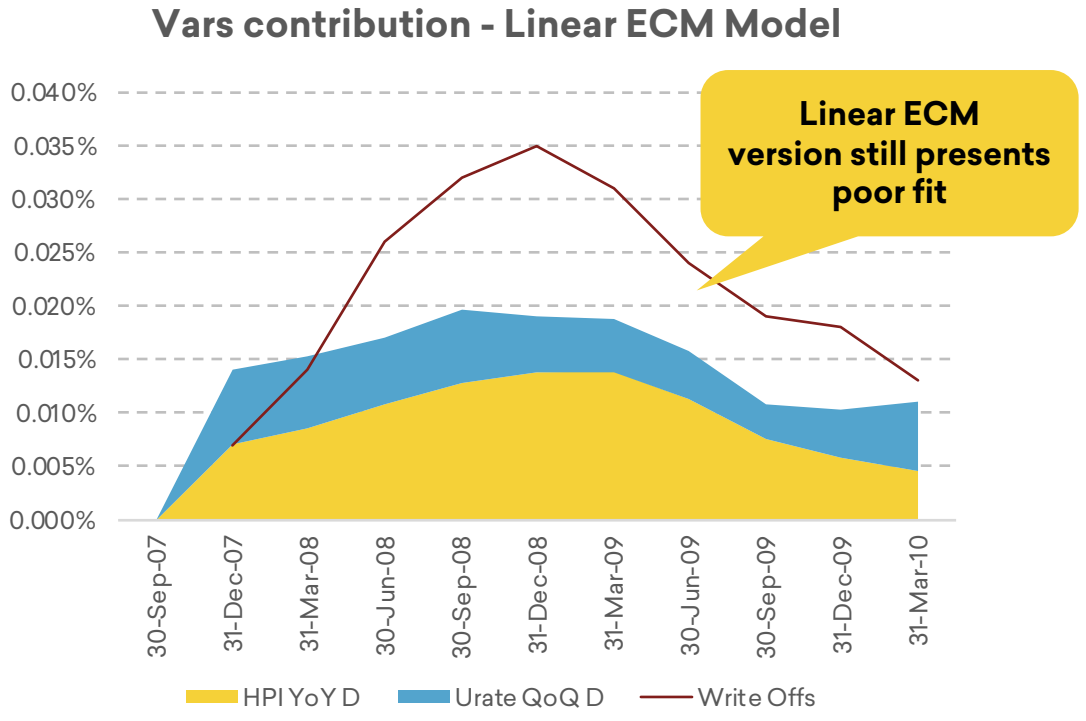
R-Squared 71.9%

TR Model – Model Fit

TR ECM Model vs Linear ECM Model over 2008 recession



R-Squared 86.1%



R-Squared 68.0%

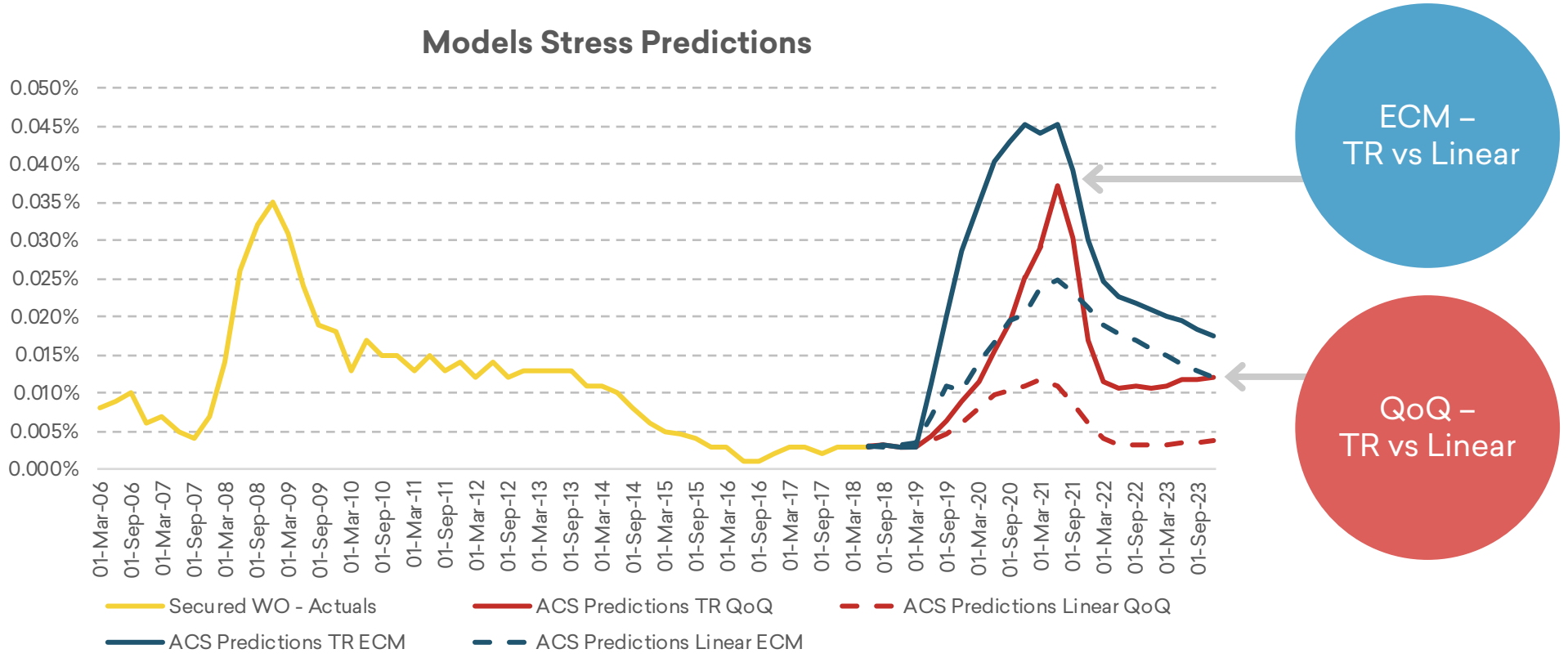
TR Model – Stress Scenario Response

TR ECM Model delivers the best fit and the strongest response under stress

Threshold models:

Pros:
- Better fit than a traditional linear model
- More responsive to stress

Cons:
- Complexity of modelling/ implementation
- Potentially introduce overfitting/bias



MODELS EXPLORED

Threshold Autoregressive (TAR) Model

TAR Model - Theory

The threshold is driven by the dependent variable

- The model assumes two forms depending on the dependent variables crossing a certain threshold at time *t-1*.

Model representation:

$$Write - Off\ Rate_t$$

$$= \alpha_1 + \beta_1 X_t + \epsilon_t$$

$$= \alpha_2 + \beta_2 X_t + \epsilon_t$$

Where

if $Write - Off\ Rate_{t-1} < T$

or $Write - Off\ Rate_{t-1} \geq T$

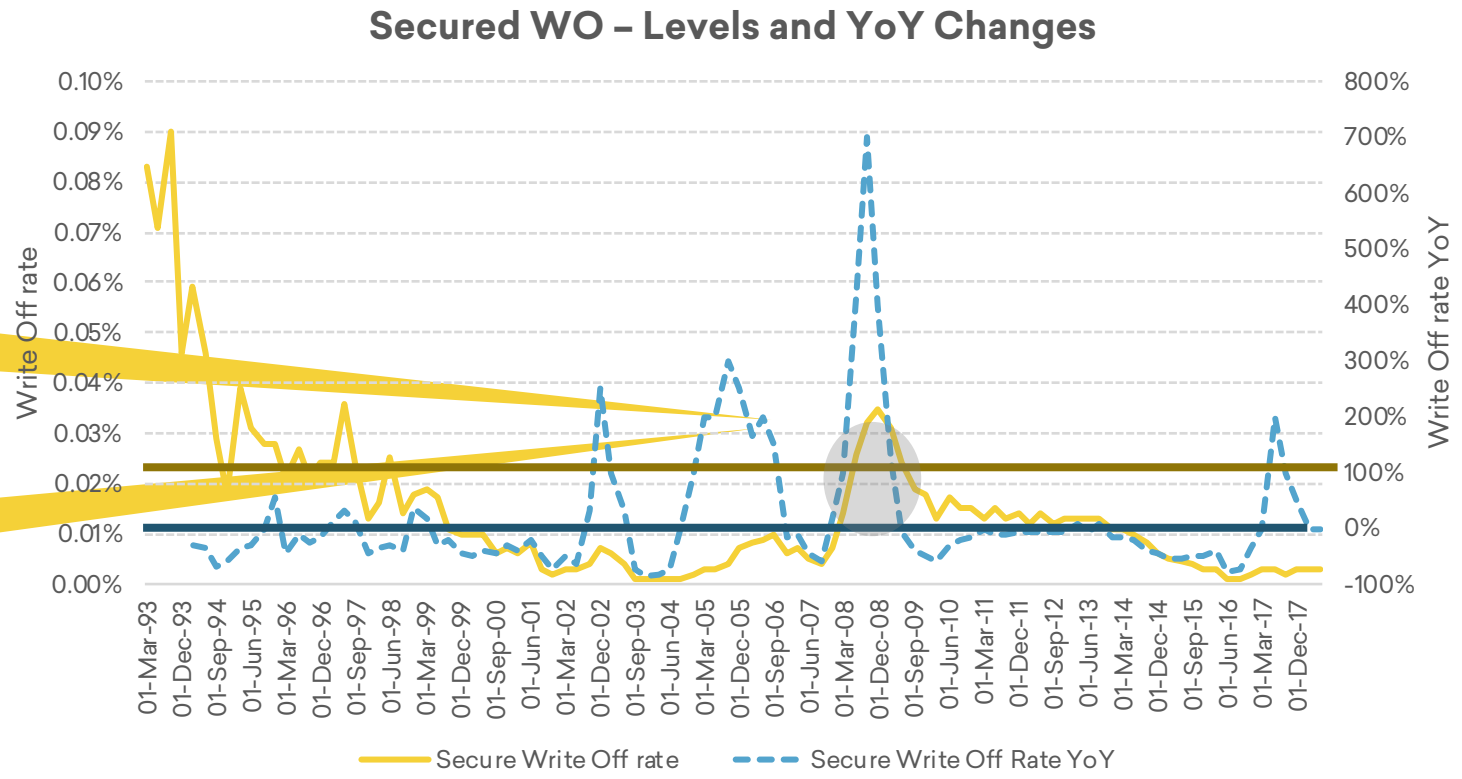
Where X_t is a matrix containing the macroeconomic variables and possibly AR (autoregressive) components.

TAR Model – Choice of the Threshold T

Set up threshold based on both absolute level and relative changes of WO Rate

Threshold is set as: WO >0.010% and WO YoY >50%

Coincides with threshold identified for TR models



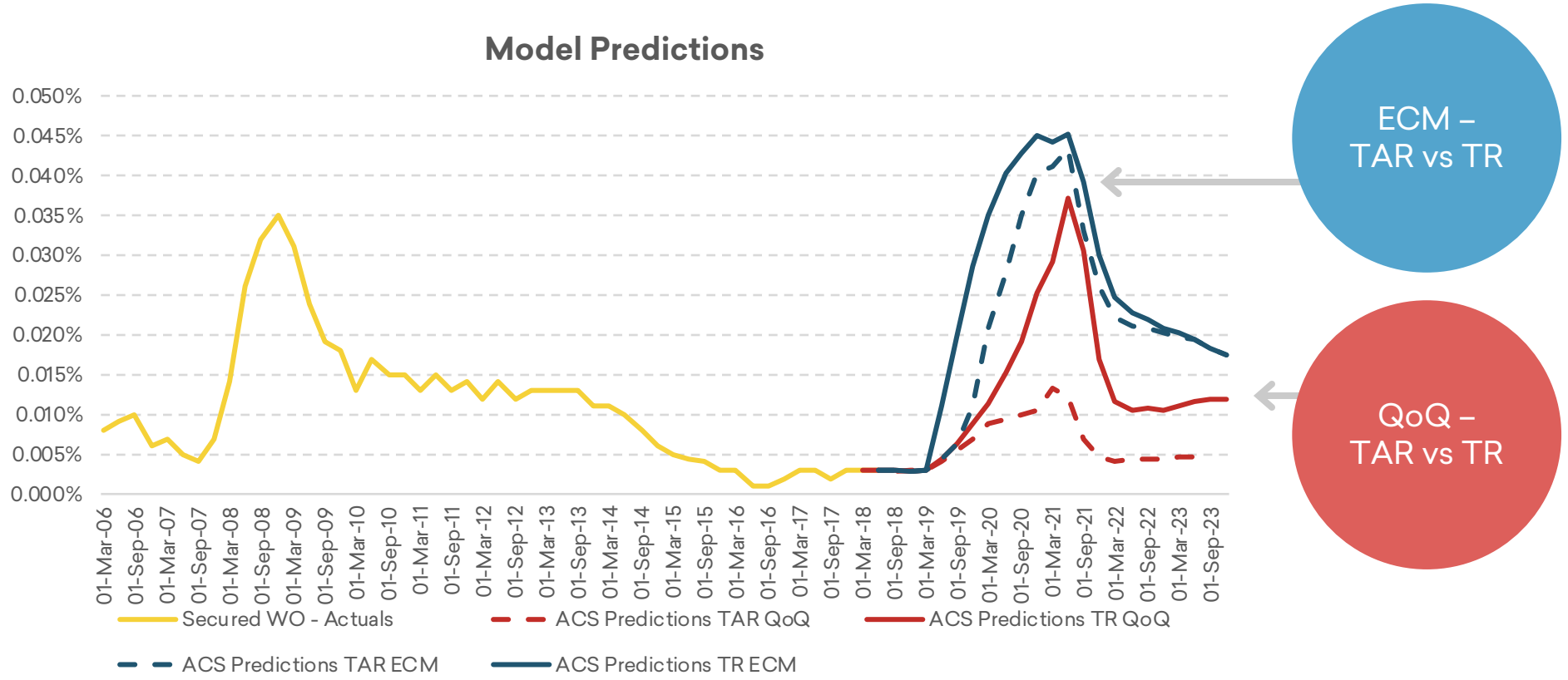
Use same models as TR but recalibrate stress forecasts

TAR Model – Stress Scenario Response

TAR Models are less responsive to stress than TR models but limit bias

Threshold autoregressive models advantages:

- Still ensure better fit and more responsiveness to stress (at least ECM) then linear models.
- Limit overfitting /bias potentially introduced by TR models.



MODELS EXPLORED

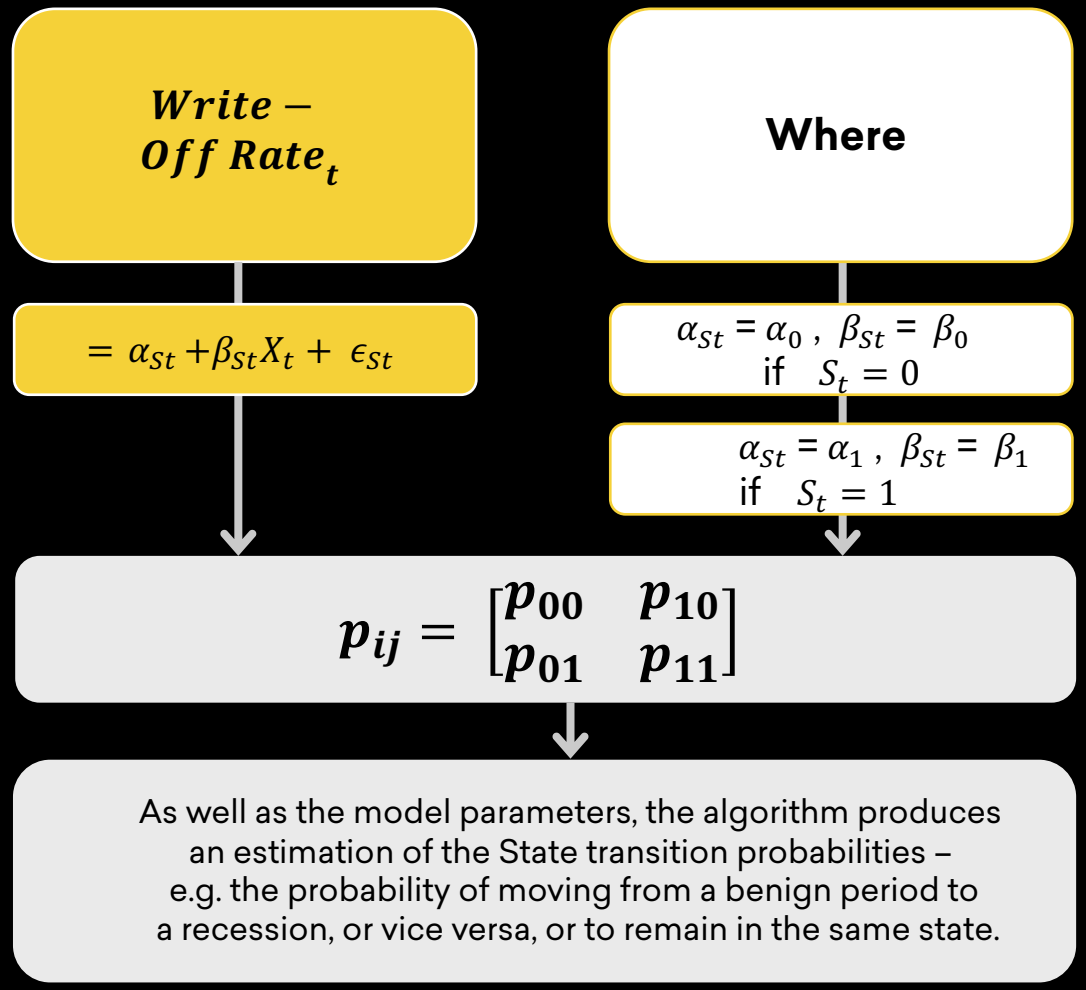
Markov Switching Regime (MSR) Model

MSR Model - Theory

State classification is not pre-defined but determined by the data

- Different equations depending on the ‘state’ of the economy.
- The threshold is not pre-defined, but instead the probability of being in a certain state (e.g. benign vs recession) is estimated on the data.
- The ‘state’ of the economy is unobserved (an hidden Markov chain) and can take values of 0/1.

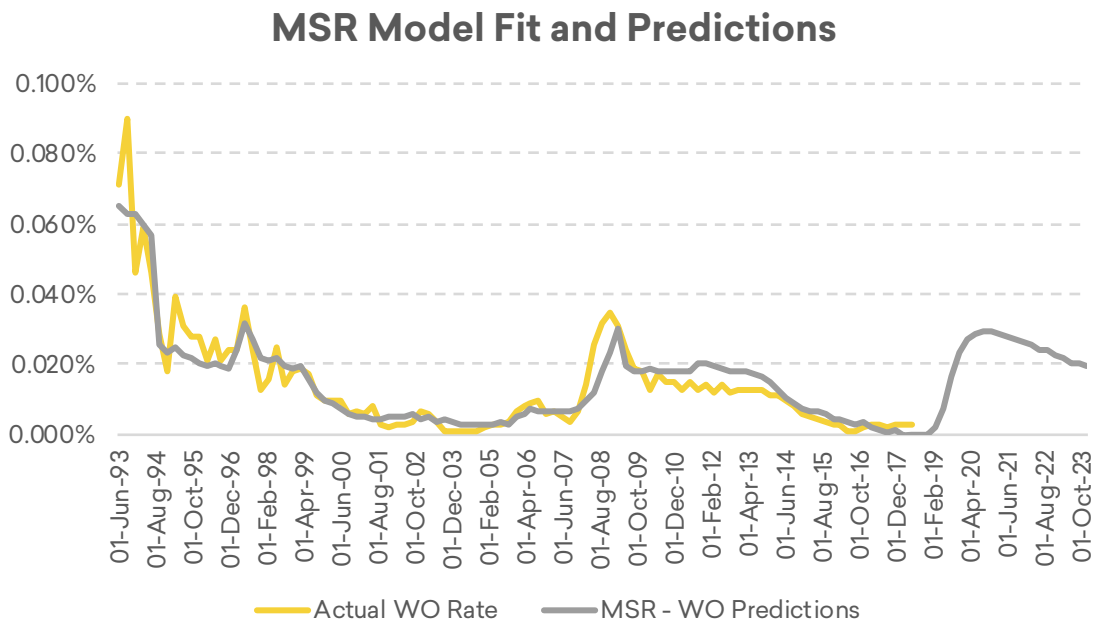
Model representation (example):



MSR Model - Results

MSR model on WO rate with switching mean and Unemployment

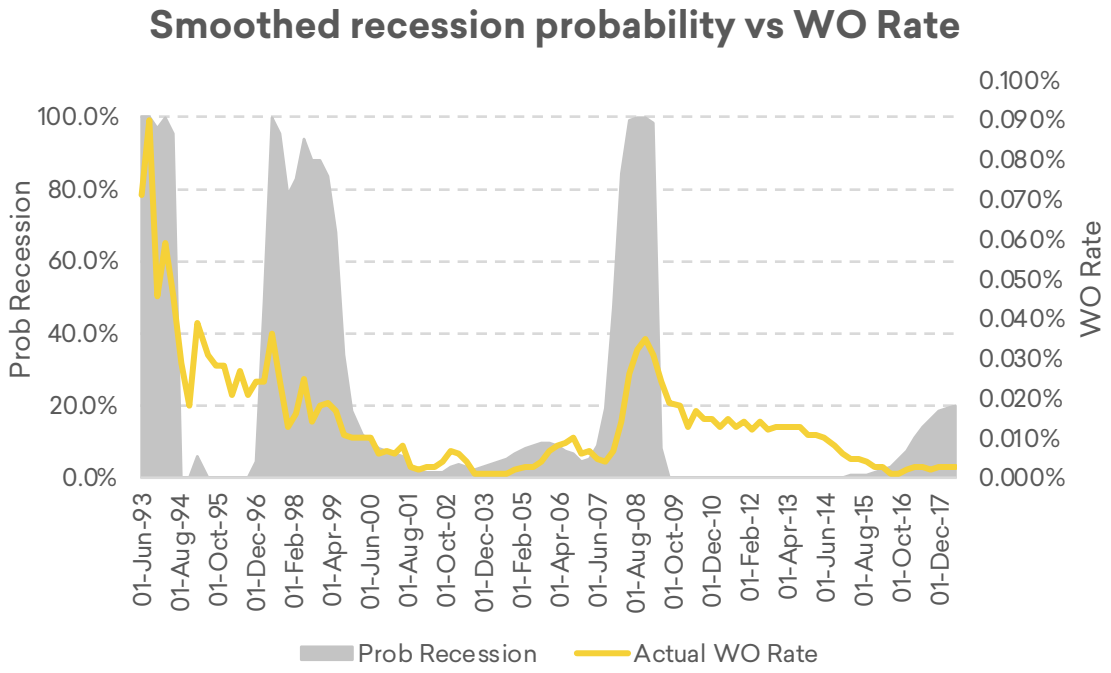
- Estimated MSR model on WO rate.
- The estimation allowed only for switching mean.
- Unemployment was introduced as the only Exogenous variable.
- The model estimates the probability of Recession/Benign period at each observation.
- Model's response under stress is in line with the 2008 recession. Stronger than TAR QoQ, but weaker than TAR ECM.



MSR Model - Results

Limitations of adopted approach

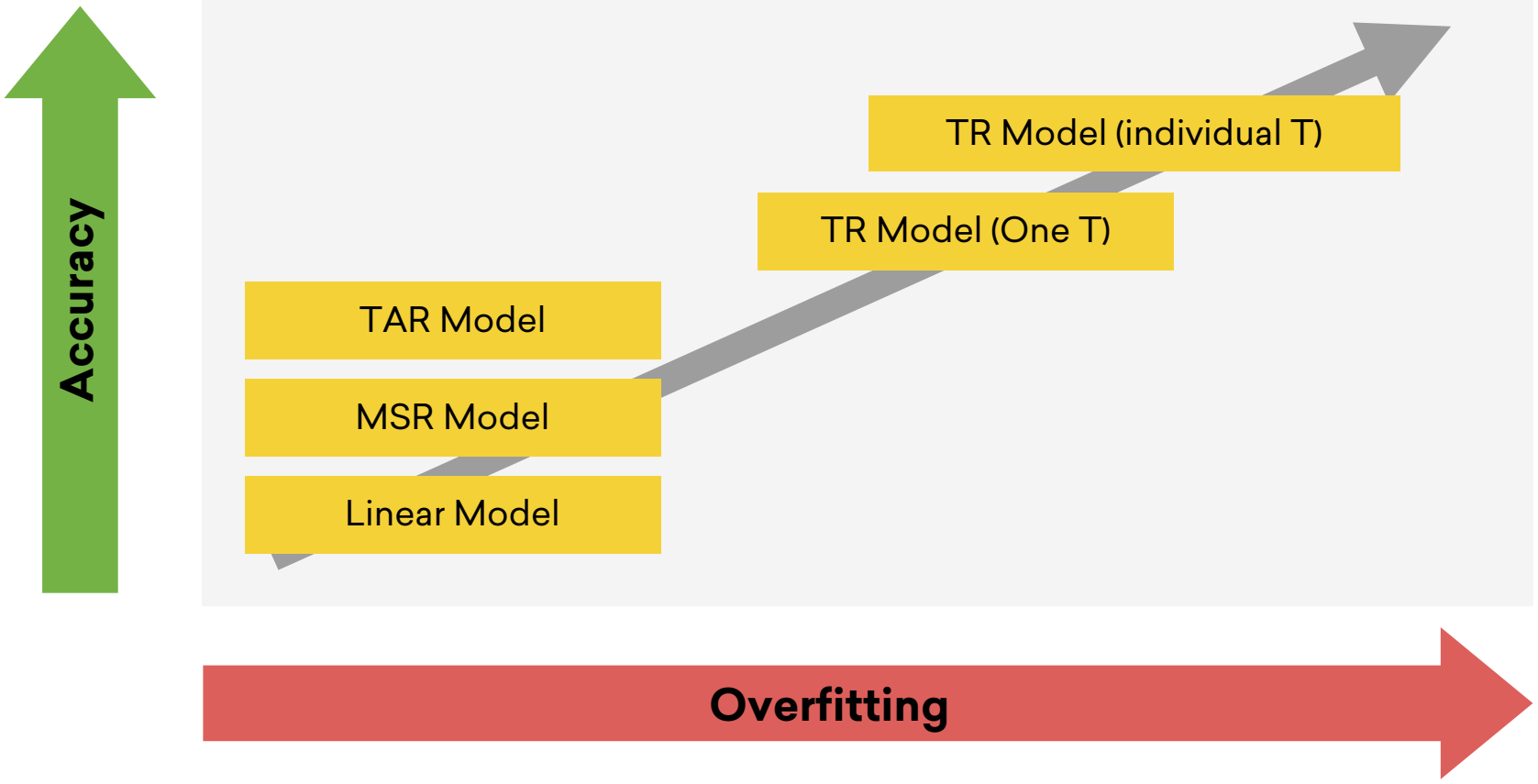
- The chart represents the recessionary times estimated by the MSR model.
- The expected duration of a recession is about 2 years (5 years for a benign period).
- Late ‘90s is identified as a period of recession as the WO level was on higher levels.
- Model estimated on WO QoQ would be best, but presented high volatility of transitions and weaker stress response.
- Can explore further improvements of WO QoQ model adding switching variances or the option of time-varying transition probabilities.



CONCLUSIONS

Non-linear Models

Pros and Cons of the different solutions



- **TAR and MSR models still provide better accuracy than linear models, while containing overfitting.**
- **TR Models could be used with robust governance and challenge.**

CONCLUSIONS

The importance of capturing non-linearity of economic effects on losses

Regulators expect financial institutions to be able to predict the impact of an economic downturn on portfolio losses, to ensure they could withstand another recession, both in impairment calculation and stress testing.

The incorporation of asymmetric effects in Economic Response Models should be considered for different reasons:

1. It would limit the need to deploy significant economic overlays as models would be more reactive under stress.
2. The adoption of non-linear economic models could facilitate the integration between IFRS 9 and stress testing models.
3. Regulators expect firms to continuously refine their forecasting capabilities, and would look favourably at a more robust and scientific approach to estimating the impact of economic scenarios on losses.

Thank you

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