



# Adapting to the High Inflationary Environment: Stochastic Modelling Approaches and Challenges

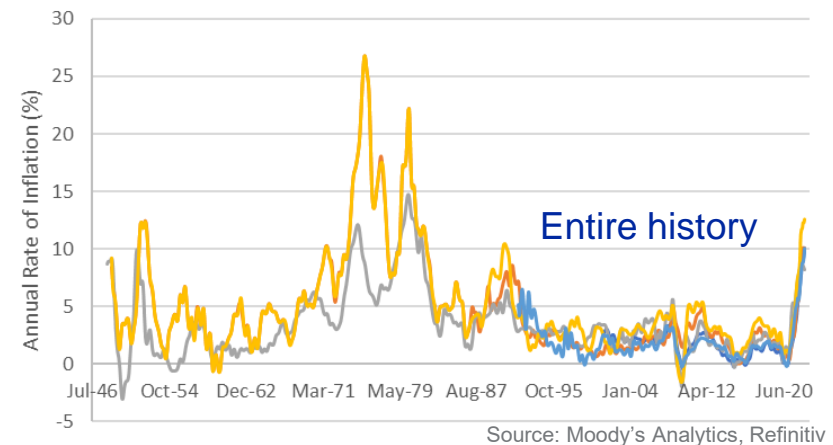
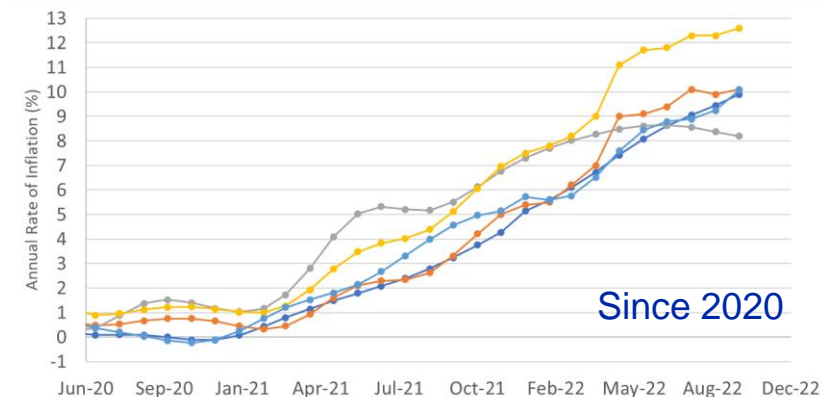
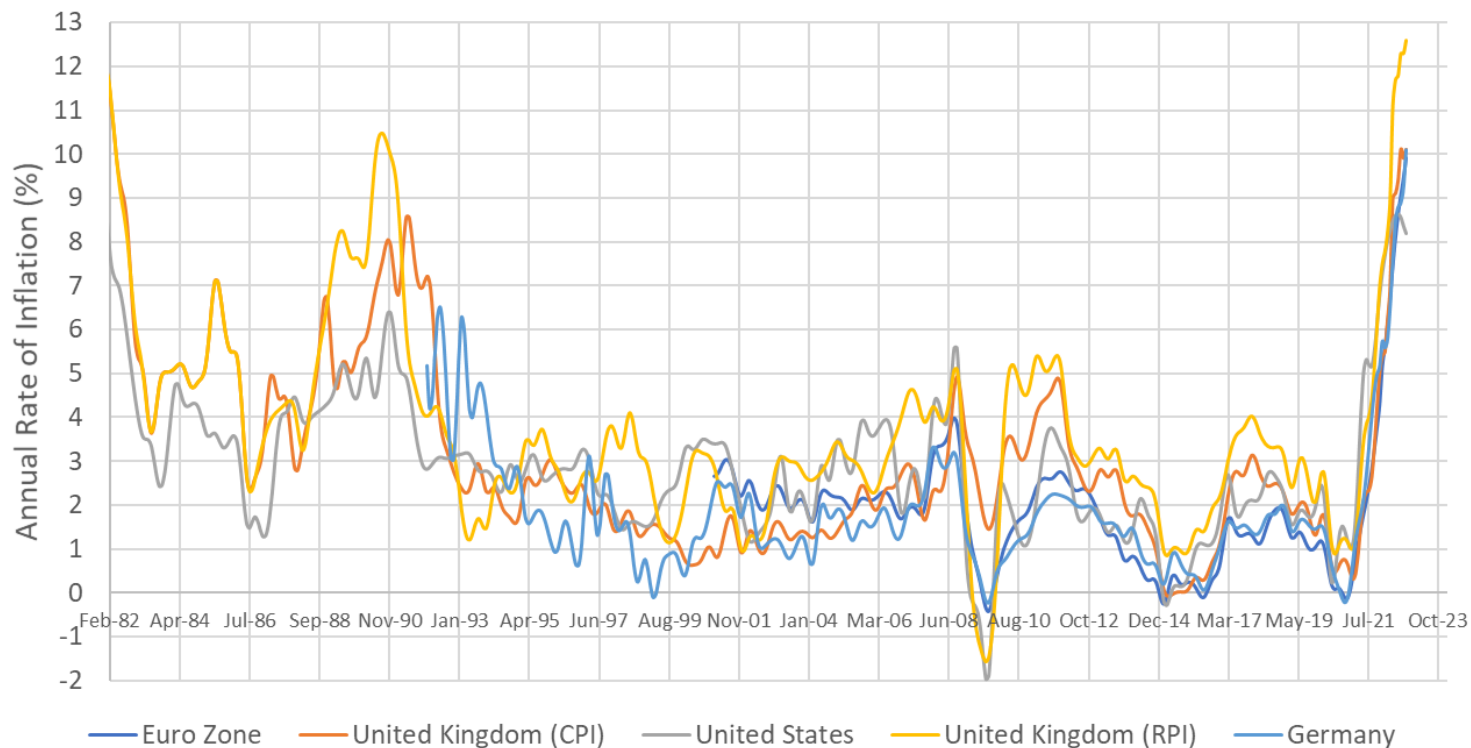
Greg Isted, Director, Modelling & Calibration Services  
Natasha Margariti FIA, Director, Solutions Specialist

22<sup>nd</sup> November 2022

# Agenda

- » Current global inflation environment
- » Structure of a stochastic inflation model
- » Setting a target path for inflation
- » Setting inflation distribution targets
- » Validating stochastic inflation models
- » Alternative inflation index modelling
- » Stress testing inflation models

# Current Inflation Dynamics: comparison to history



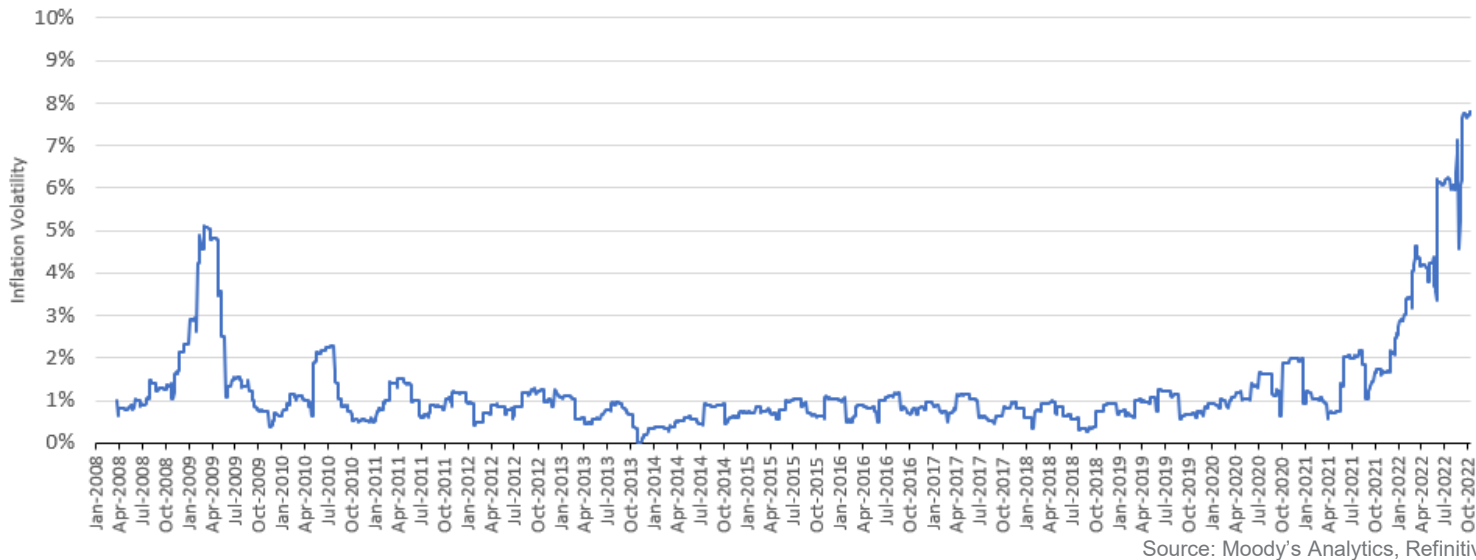
The recent dramatic increase in inflation is a very rare event:

- » An annual upward jump with a magnitude greater than those in recent months not observed in over 40 years in most major economies.
- » No. of larger jumps over entire history: UK CPI (30/879), UK RPI (22/879), US (7/885). Most in 1950s and 1970s.
- » No. of proportionally larger upward jumps over entire history: UK CPI (5/879), UK RPI (4/879), US (13/885), Germany (3/357).

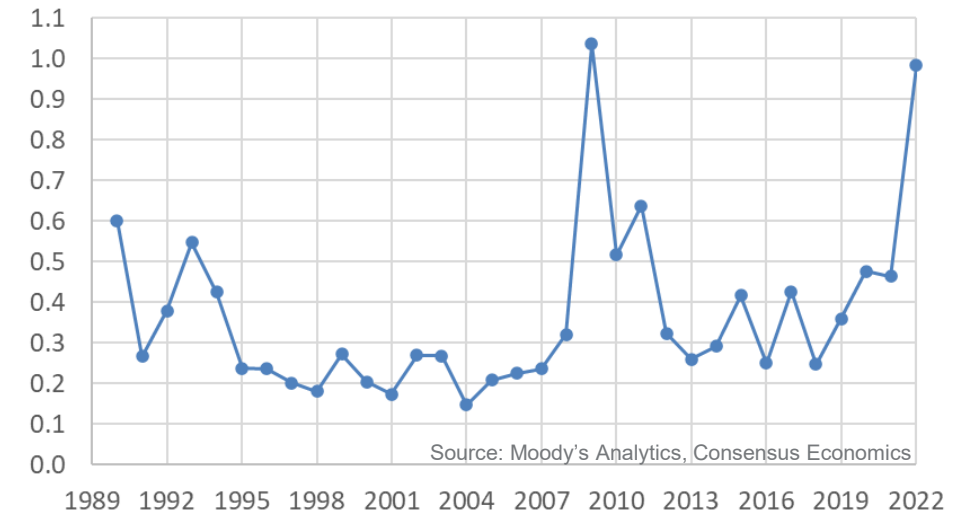
# Future Inflation Uncertainty is Current Very High

- » Future inflation uncertainty can be measured using various types of data/methods including:
  - **Economists' forecasts (survey-based):** e.g. standard deviation of 1-year ahead forecasts.
  - **Market data-derived volatility:** e.g. standard deviation of historic 1-month inflation swaps.

Volatility (annualised 60-day) of GBP (RPI) 1-Year Swap-Implied Inflation



Standard Deviation of Survey-Based Economists' UK RPI 1-Year-Ahead Inflation Forecasts (April-Based Surveys)



- » Important that insurers' stochastic inflation model/s reflect both:
  - The current high-level of inflation and the expected high-levels of inflation over the next few years.
  - The current high-degree of uncertainty about near-future inflation.



# Inflation Model Structure

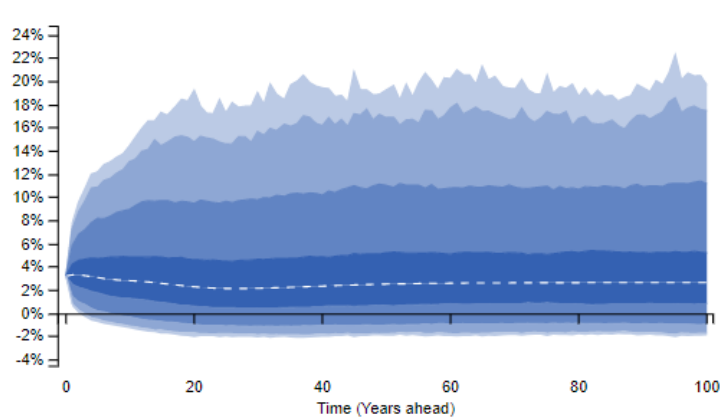
# Inflation Model Structure (part 1): modelling 'expected' inflation

» Fisher Equation:

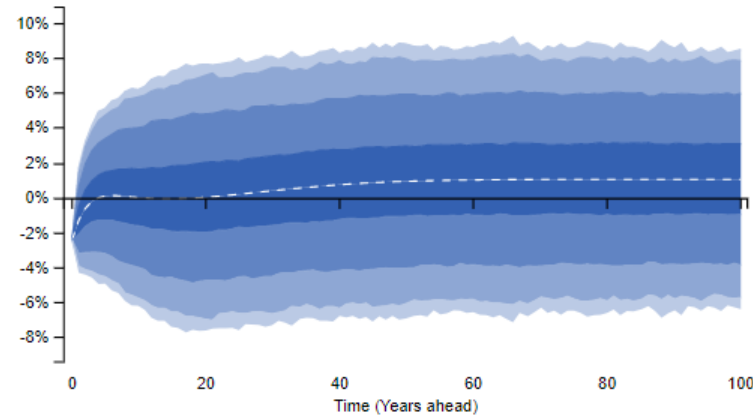
$$\text{nominal 1Y rate } (t) = \text{real 1Y rate } (t) + \text{expected 1Y inflation } (t)$$

» Typically 1-year nominal and real rates are explicitly modelled (possibly with different models) and 1-year expected inflation is 'backed-out'.

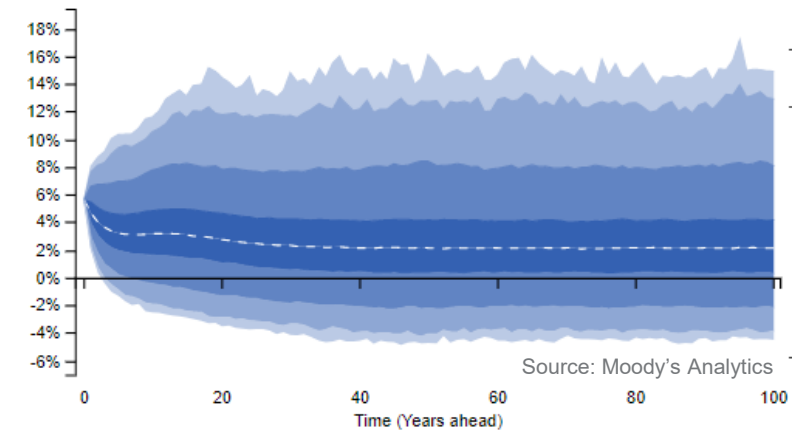
– End-Oct 2022 UK Example:



1Y nominal rate (modelled directly)



1Y real rate (modelled directly)



1Y expected inflation (modelled indirectly)

» The distribution of the derived variable (i.e. 1-year expected inflation) is dependent on:

- The **modelled distribution** of 1-year nominal and 1-year real rates.
- The **modelled correlation** between 1-year nominal and 1-year real rates.

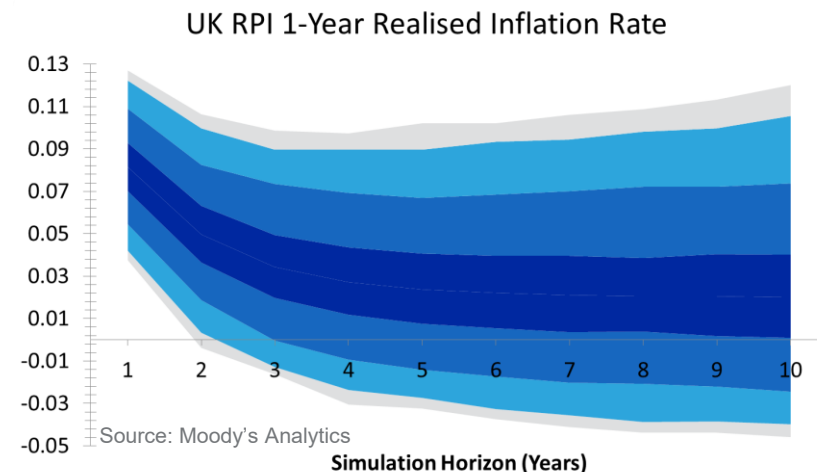
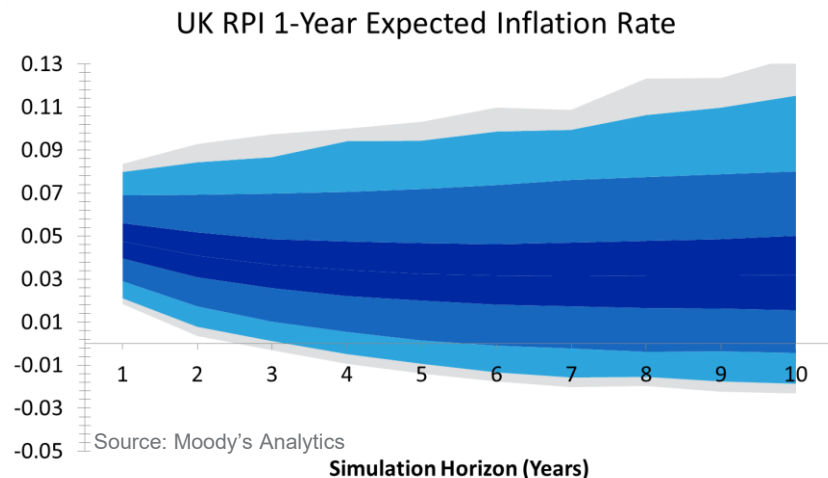
# Inflation Model Structure (part 2): modelling 'realised' inflation

- » The modelled inflation rate outputted from a stochastic simulation does not have to equal the modelled 1-year 'expected' inflation.
- » The modelled 1-year 'expected' inflation can be adjusted to give modelled 'realised inflation'. This could allow modelled inflation to:
  - Follow a target path of future inflation on average. We may want this to differ from market-implied inflation.
  - Exhibit an 'unexpected inflation shock'. We may want the distribution of modelled inflation to be different to expected inflation.
- » Structure of modelled 'realised inflation' model

$$\text{realised inflation}(t) = [ \text{expected 1Y inflation}(t-1) + x(t) ] + \text{stochastic shock}(t)$$

Can be chosen to capture a target path for average modelled inflation

The magnitude of this can be chosen to capture a target for the size of unexpected inflation shocks



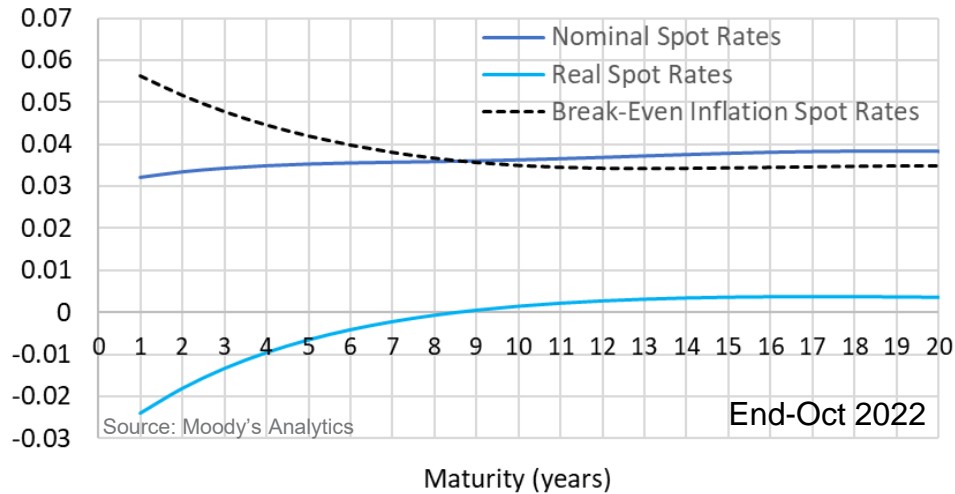


# Setting an Inflation Target Path



# Setting an Inflation Target Path: could break-even inflation be used?

- » The break-even inflation curve = nominal yield curve – real yield curve



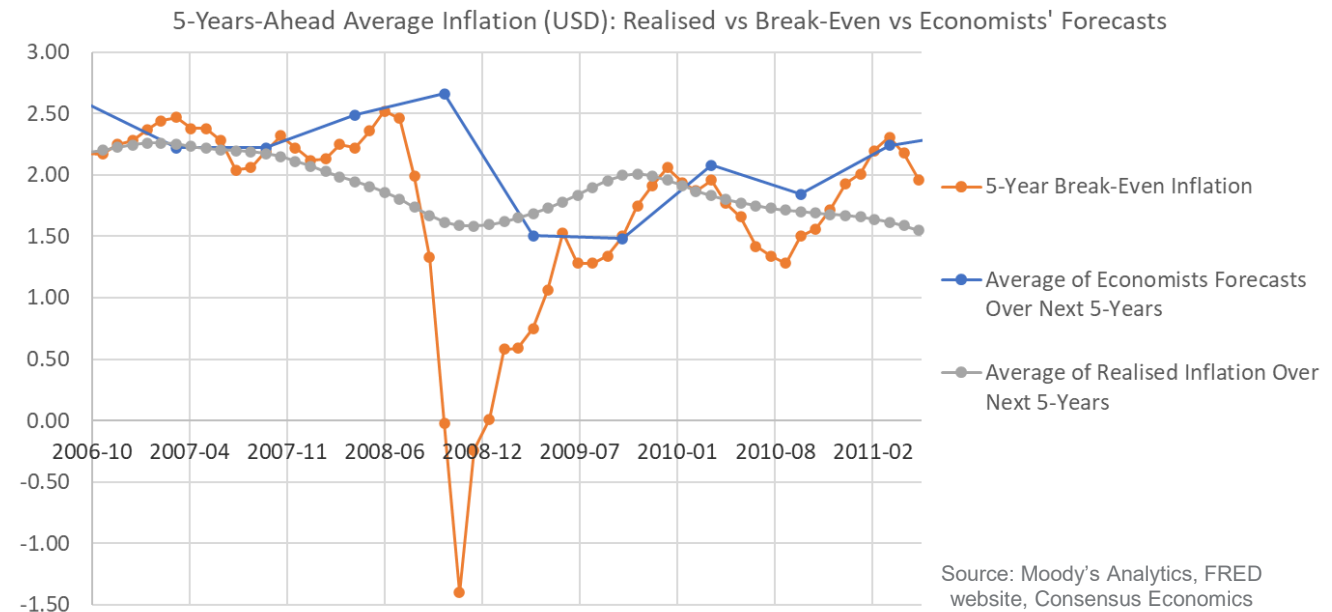
The X-year maturity break-even inflation spot rate

=

The market's prediction of average annual inflation over the next X years

## Is break-even inflation a good predictor of future inflation?

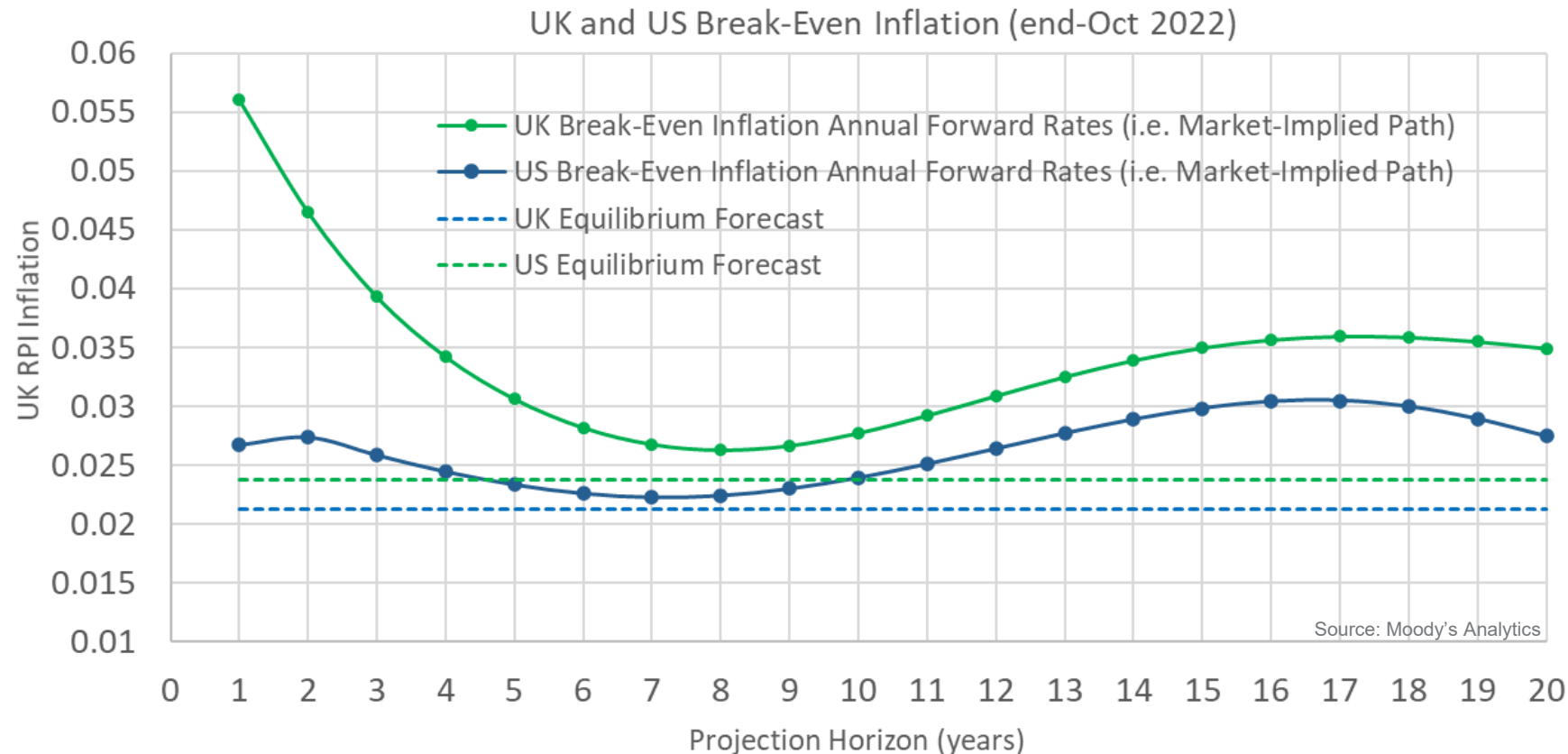
- » Risk premia in government and index-linked bond curves can distort the market-participants inflation expectations.
  - 'Flight-to-quality' in crises magnify this effect.
- » Market-implied inflation in US 2008 suggested inflation over the next 5 years would be negative on average.
  - Economists' believed it would be between 1.5–2.6%.
  - Realised inflation average 2008-2013: about 1.5%



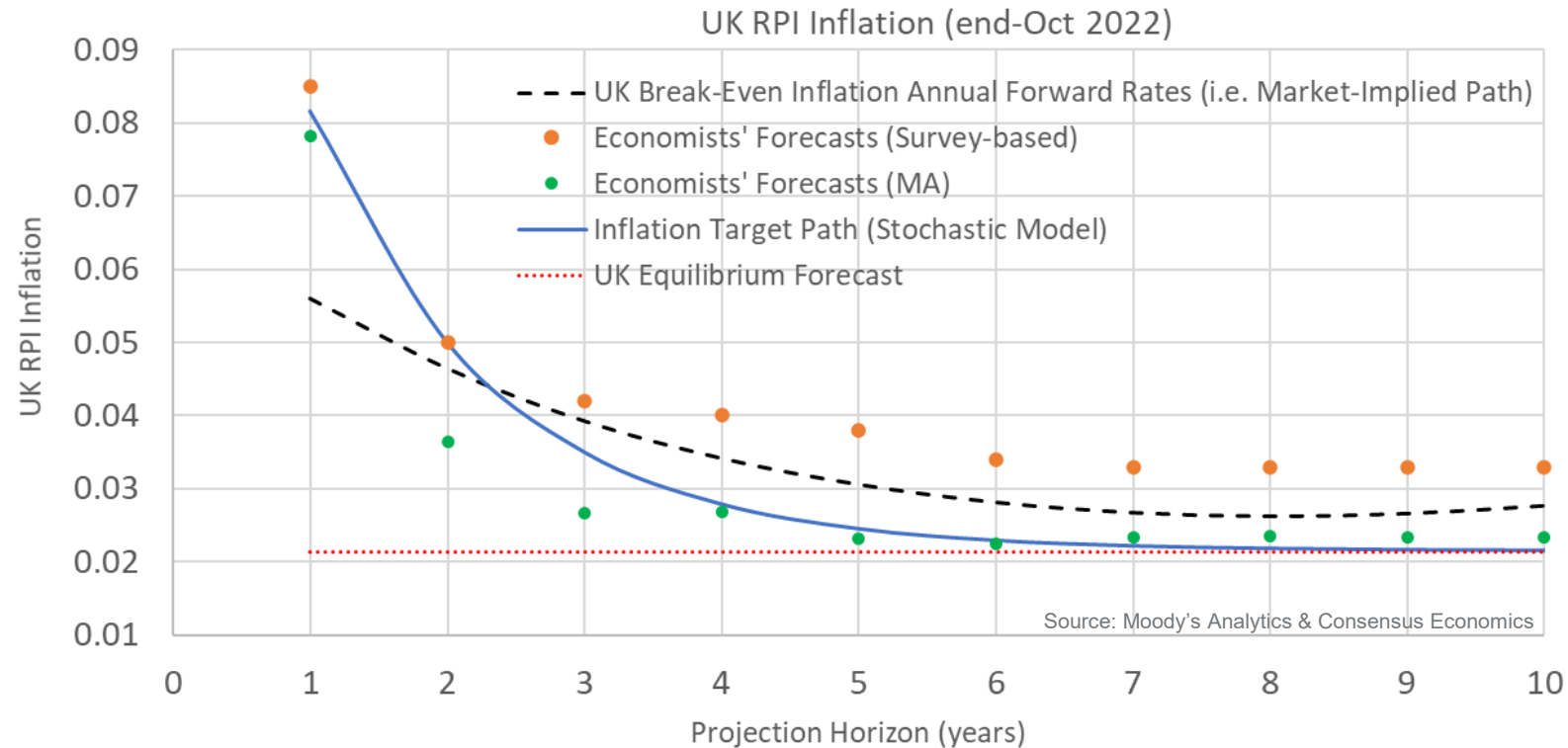
**Inflation forecasts are likely to be better predictors of inflation over the next few years than market-implied inflation**

# Setting an Inflation Target Path: could break-even inflation be used?

- » The break-even inflation curve is likely to be a poor predictor of inflation at long time horizons (10+ years).
  - Risk/term premia embedded with nominal and index-linked bonds can become significant for long-maturity instruments.



# Setting an Inflation Target Path: using economists' forecasts

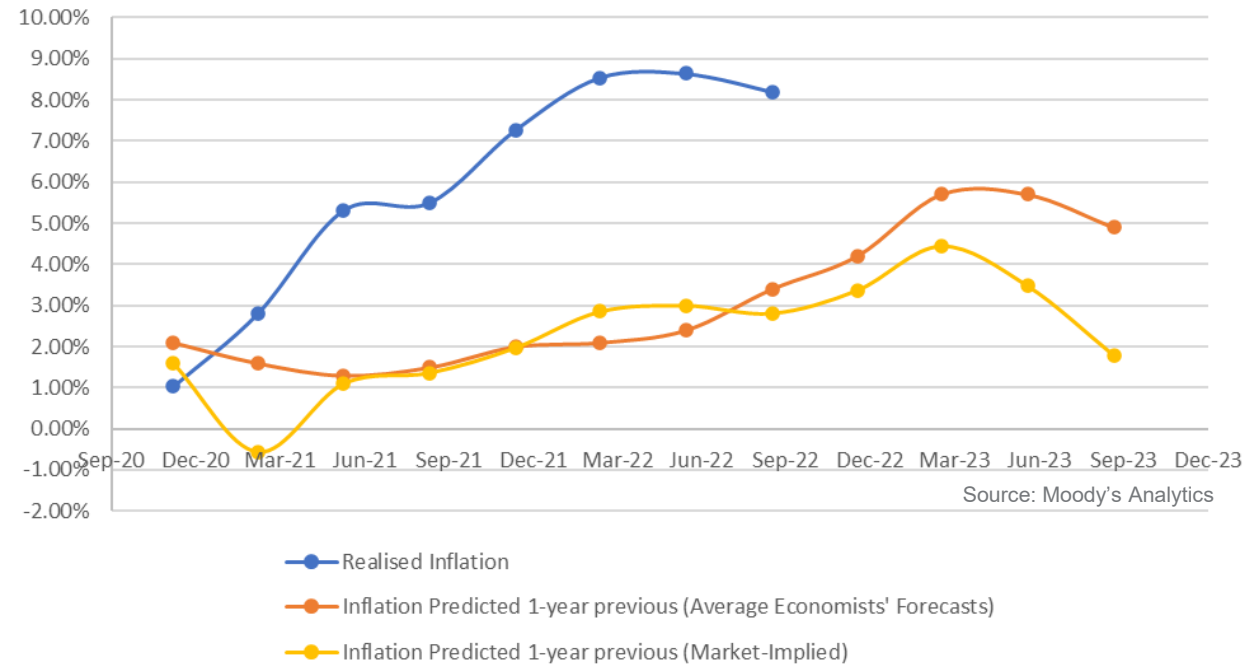


- » One approach to setting a target path for inflation is to fit a smooth function to a range of forecasts.
  - This allows any differences in forecast dates (and approaches) to be smoothed out.

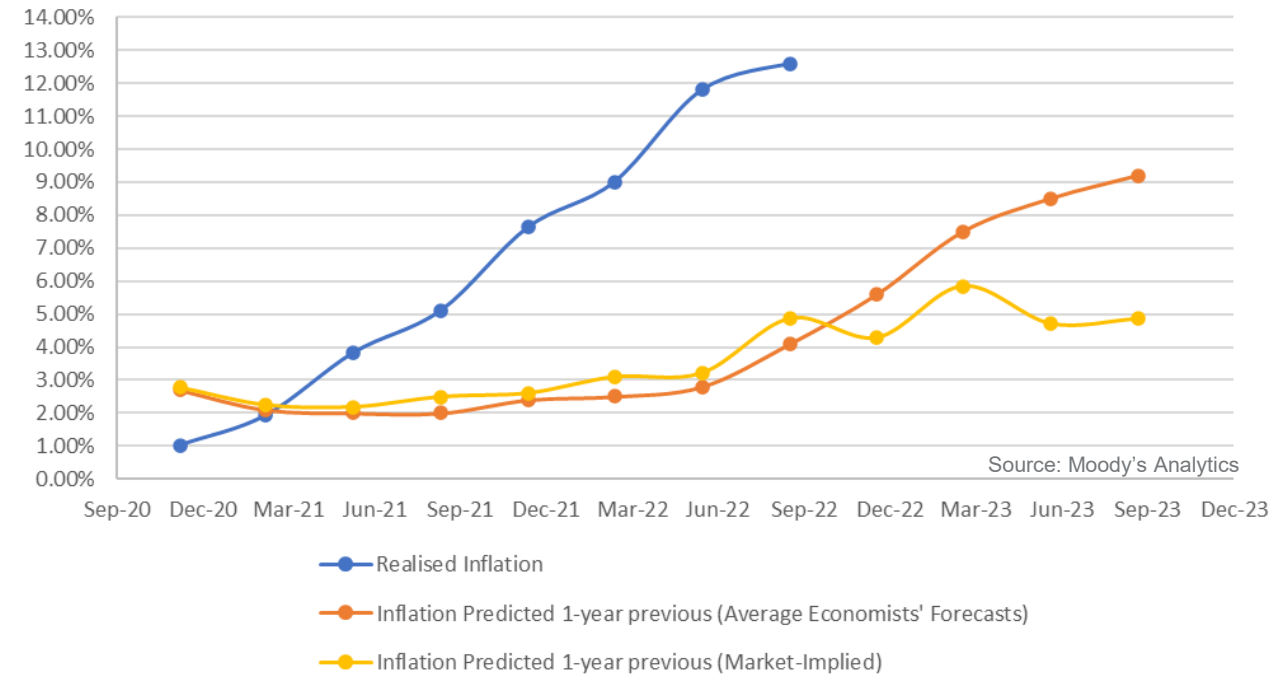
- » In this example the Rebonato function (blue curve) is fitted to:
  - Average of survey-based forecasts from Consensus Economics (orange circles).
  - Econometric model-based forecasts from Moody's Analytics (green circles).

# Recent Inflation Spike: anticipated by economists or the markets?

USD CPI Inflation



GBP RPI Inflation



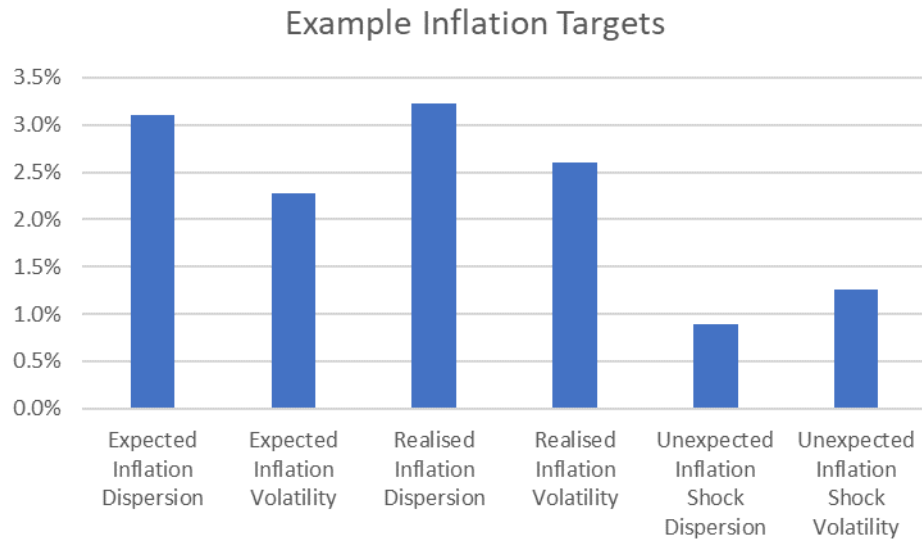
- » 1-year-ahead market-implied and economists' forecasts significantly underestimated/missed the recent dramatic inflation increase.
  - Illustrates that the energy crisis and Ukraine/Russian war and its impact were unexpected (an economic 'tail event').
- » We should expect recent stochastic inflation model projections to have captured the recent spike in the upper tail of their distribution.
- » How can inflation models be calibrated to capture a reasonable level of risk?



# Modelling Inflation Distributions

# Setting Targets for the Distribution of Inflation

- » It is reasonable to set distributional targets for inflation using historical data. Several considerations:
  - What length of history of should be used?
  - Should all periods of history be included?
  - Should all points in history be weighted equally?
  - Should index-specific or global targets be set?
  - Targets for ‘expected’ and ‘realised’ inflation may need to be set (dependent on model structure).
  - Targets based on the ‘volatility’ and ‘dispersion’ of inflation should be considered.
    - › Definitions: standard deviation of level (i.e. the dispersion’) and in change in the inflation rate (i.e. volatility).



## Example targets:

- » All available history used: maximises information used.
- » All periods of history used: difficult to justify what to remove/keep.
- » Exponentially-weight history: more recent history weighted higher.
- » Global targets: maximises information; rare events in one economy’s history may be possible in others; limited history available for some economies.

# Calibrating an Inflation Model to Distribution Targets

$$\text{realised inflation}(t) = [ \text{expected 1Y inflation}(t-1) + x(t) ] + \text{stochastic shock}(t)$$



Modelled correlation between nominal and real rates models could be calibrated to capture expected inflation targets



Standard deviation of this could be calibrated to better capture realised inflation targets or unexpected inflation shock targets

## Considerations:

- » All targets may not be perfectly captured – decision on which targets to best capture may depend on application/projection horizon.
- » Expected inflation targets could be captured by adjusting nominal/real rate calibrations - may lead to sacrificing fit to related targets.
- » Can conditionality be introduced?
  - If nominal rate model exhibits a realistic rate level/volatility relationship then this will feed into the expected inflation distribution.
  - If the standard deviation of the stochastic shock could vary through time it could be initialised at current inflation volatility levels.
- » How could conditional volatility targets be set?
  - Utilise the distribution of 1-year horizon inflation forecasts from economists. **Challenge: limited data; not available for all economies.**
  - Measure historic data (weighting more recent most heavily). **Challenge: backward looking; weighting scheme/window size is subjective.**

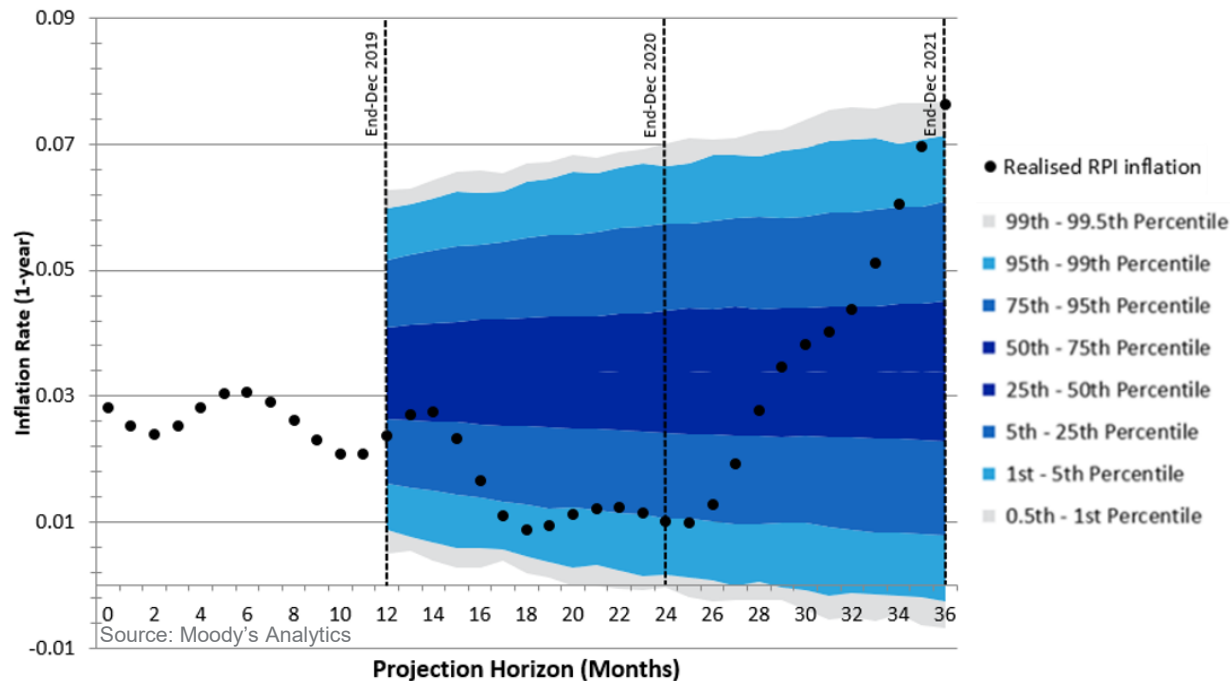


# Validating Inflation Models

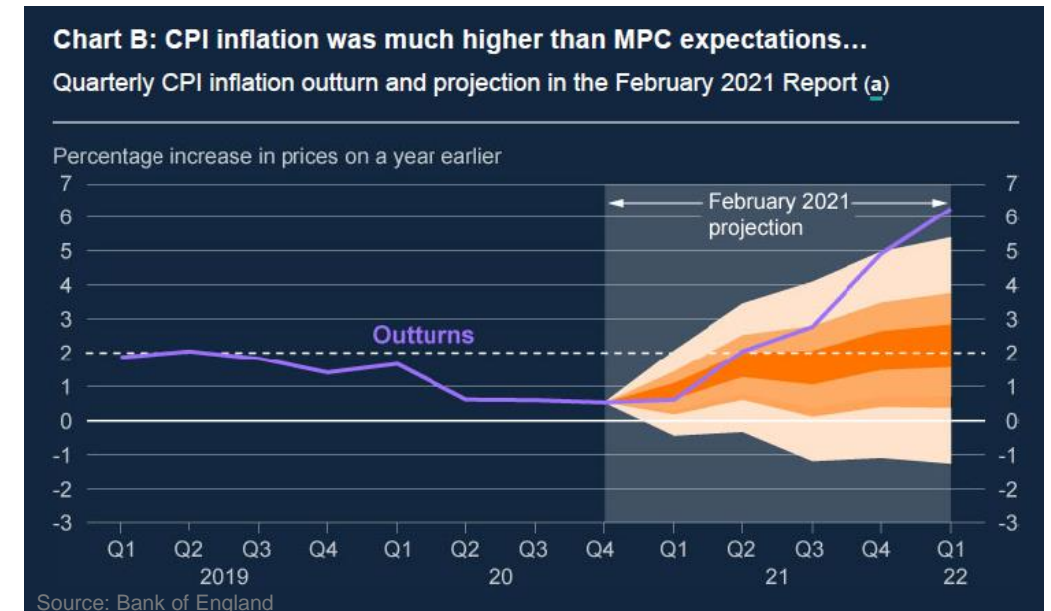


# Inflation Modelling Validation: backtesting

- » Model can be calibrated/initialised at a historic date to see if it captures realised rare/tail events.
- » Considerations:
  - At what point in time before a tail event should the model be initialised? Assigned model probability likely to be dependent on this.
  - Where in the tail should tail events sit? May be difficult to justify given limited history of data.
- » Backtesting can be a good qualitative sense-check of model suitability but can be difficult to draw strong quantitative conclusions from.
- » Example: UK RPI end-Dec 2018 projection.

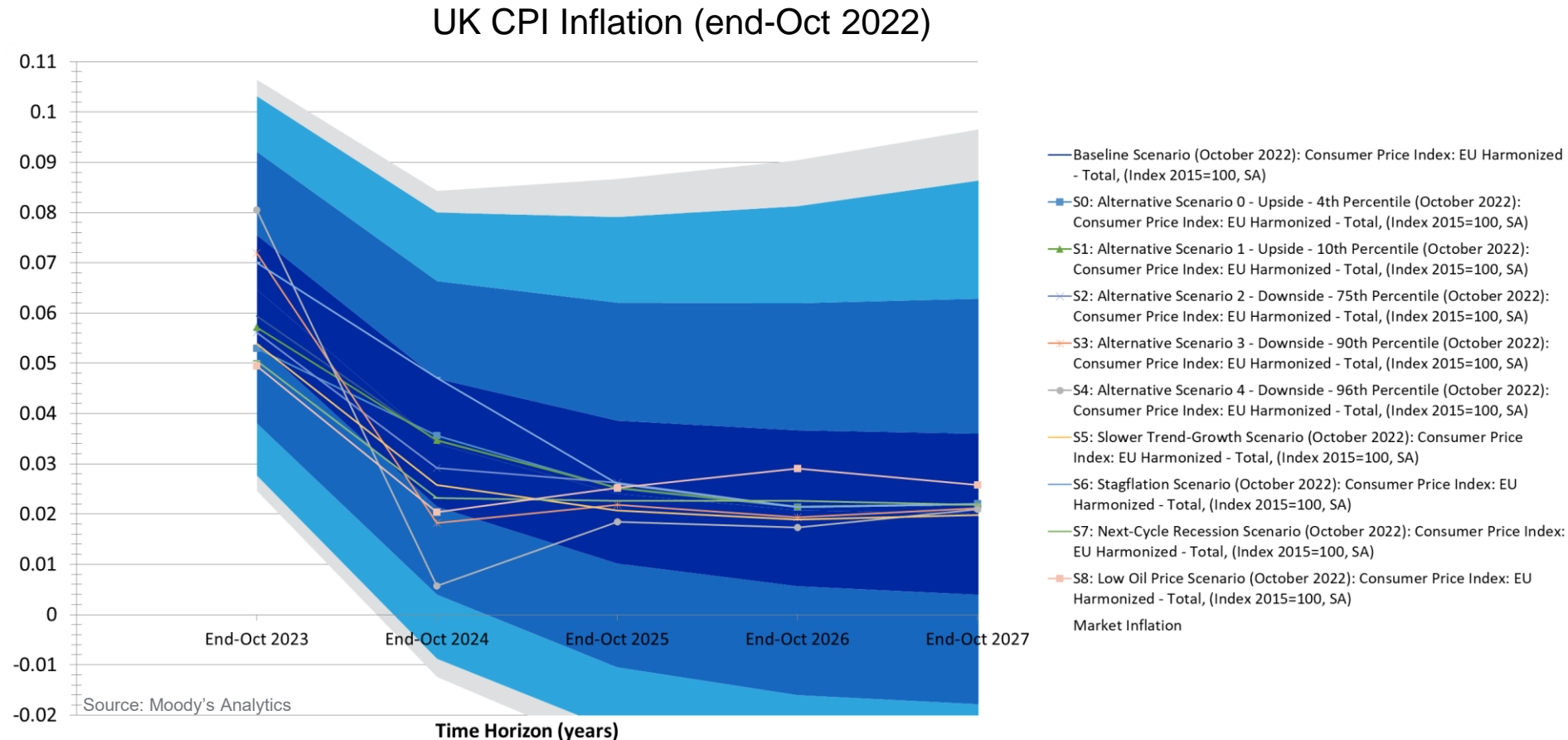


- » The Bank of England often publish backtesting results:



# Inflation Modelling Validation: using economists' narrative scenarios

- » Forward-looking validation analysis could be performed using a range of current narrative forecasts from economists.



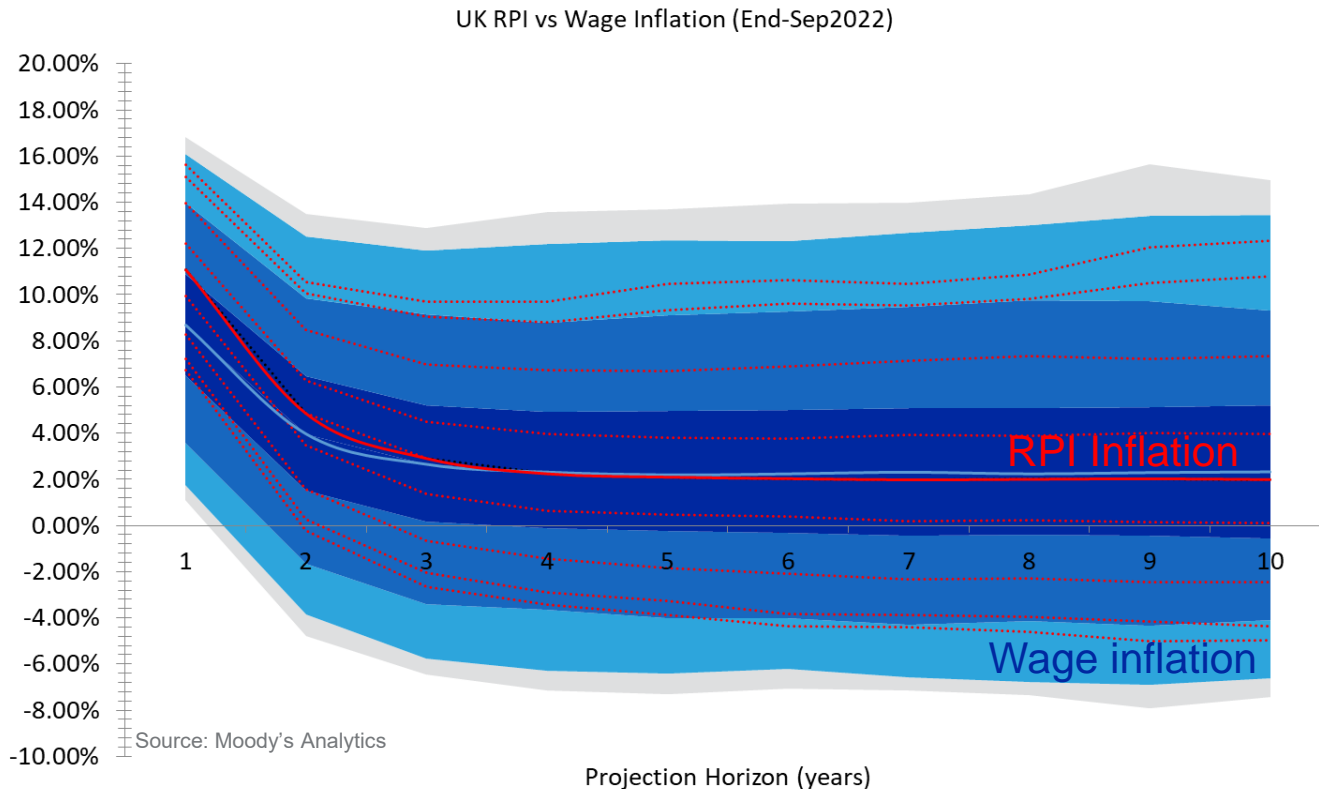
- » Another good qualitative sense-check: does the median/mean align with baseline narrative? Does the distribution capture all narratives?
- » Difficult to draw qualitative conclusions unless the narrative scenarios have associated probabilities.



# Alternative Index Inflation Modelling

# Modelling Granular / Alternative Inflation Measures

- » Wage, construction, medical, legal inflation etc. could be modelled using a simple stochastic 'wedge'/spread model above core inflation.
- » Distributional qualities of the 'wedge' model could be determined by analysing the history of the index relative to core inflation.
  - For example can establish 'excess' inflation volatility, long-term level and mean reversion speed to calibrate a simple 1-factor model.
- » Initialisation of wedge model determined from current level of specific inflation index.



- » It may be challenging to set a target inflation path for the alternative index, however if a path is set then this could be captured by:
  - Allowing the wedge model to have time-varying parameters (e.g. mean reversion level) and calibrating these appropriately.
  - A separate inflation model altogether (derived using an index-specific real yield curve) could be used.

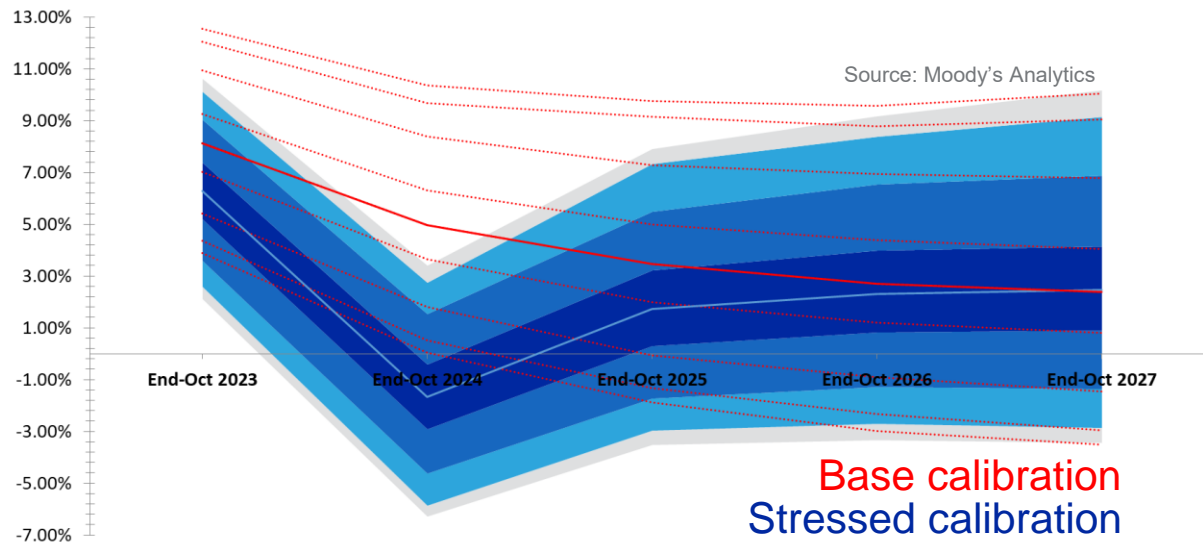


# Stress-Testing Inflation Models

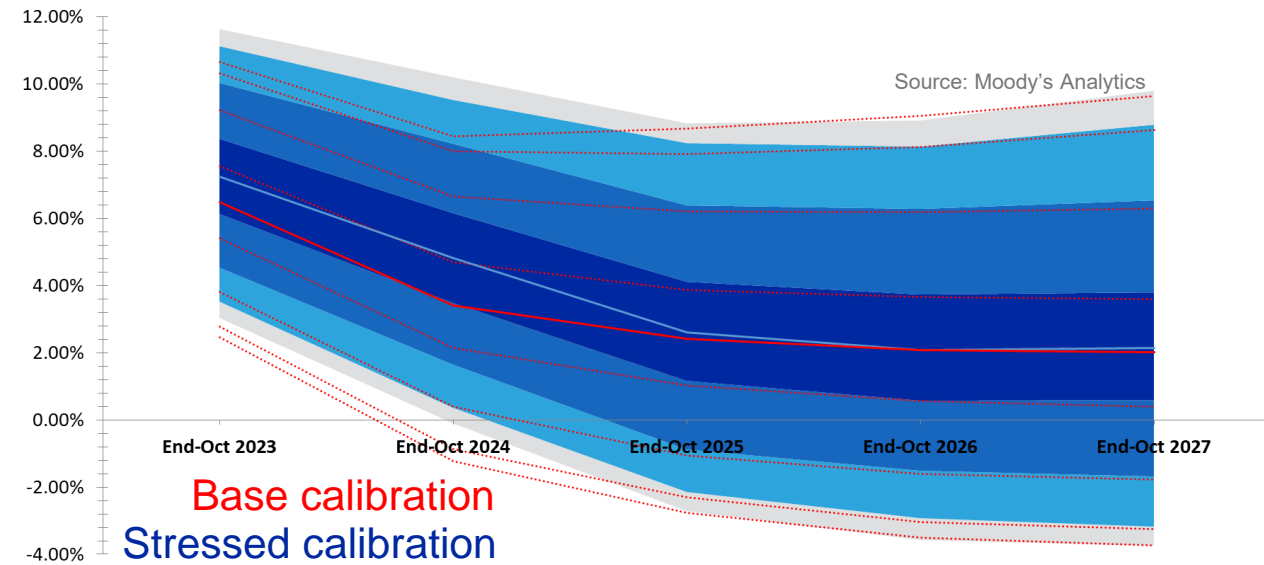
# Stressing Inflation Using Economists' Narrative Scenarios

- » The central path of inflation (and other economic variables) can be calibrated to extreme deterministic narrative paths from economists.
- » More justifiable stressing approach than arbitrarily increasing/decreasing inflation levels.

UK RPI: Stressed Recessionary Scenario vs Best Views (end-Oct 2022)



UK CPI: Stagflation Scenario vs Best Views (end-Oct 2022)



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Greg Isted  
Greg.Isted@moodys.com

Natasha Margariti FIA  
Natasha.Margariti@moodys.com

moodysanalytics.com



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