Financial Data Professional Institute

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Introductions

Kathryn Wilkens, Ph.D., CAIA
Founder,
Pearl Quest LLC

Harshdeep Ahluwalia
Head of Asset Allocation,
Americas Vanguard,
Investment Strategy Group

Today's Topic:
**The Best of Both Worlds:
Forecasting US Equity Market Returns Using a Hybrid Machine
Learning-Time Series Approach**

The Best of Both Worlds

Forecasting U.S. Equity Market Returns Using a Hybrid Machine Learning-Time Series Approach

Harshdeep Ahluwalia

Head of Asset Allocation, Americas
Vanguard, Investment Strategy Group
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Overview

- Forecasting equity market returns using the Shiller Regression
  - Valuation metrics such as the Shiller CAPE ratio are widely followed to forecast

  - Out-of-Sample forecast accuracy

  - Does using ML help substantially?

- Why does the regression fail?

- Our 2-step approach for forecasting returns
  - Traditional time series approach: Vector Auto-Regression (VAR)

  - ML-VAR approach

- Q&A

Long-run equity returns are time-varying…

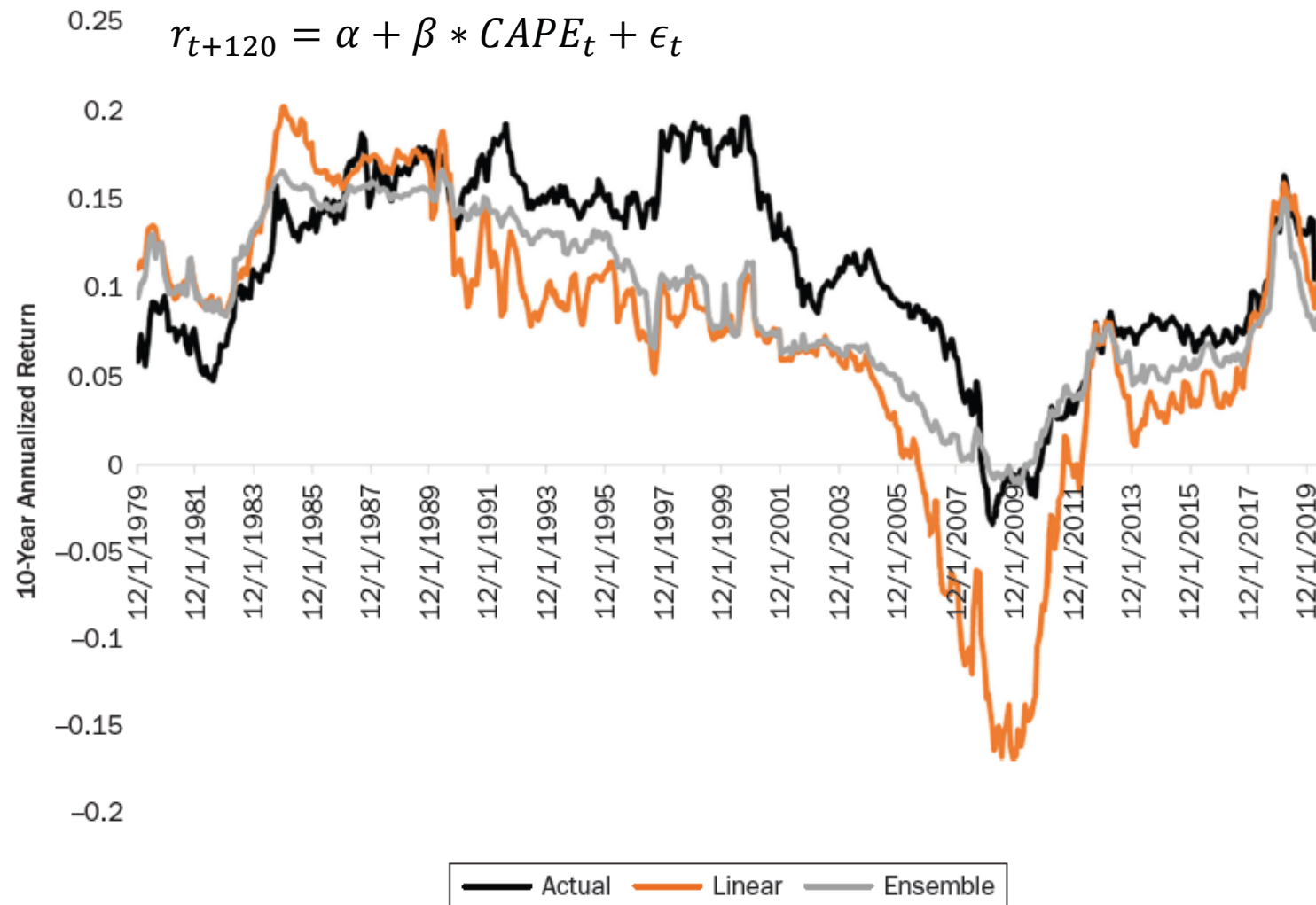… and are dependent on initial valuations
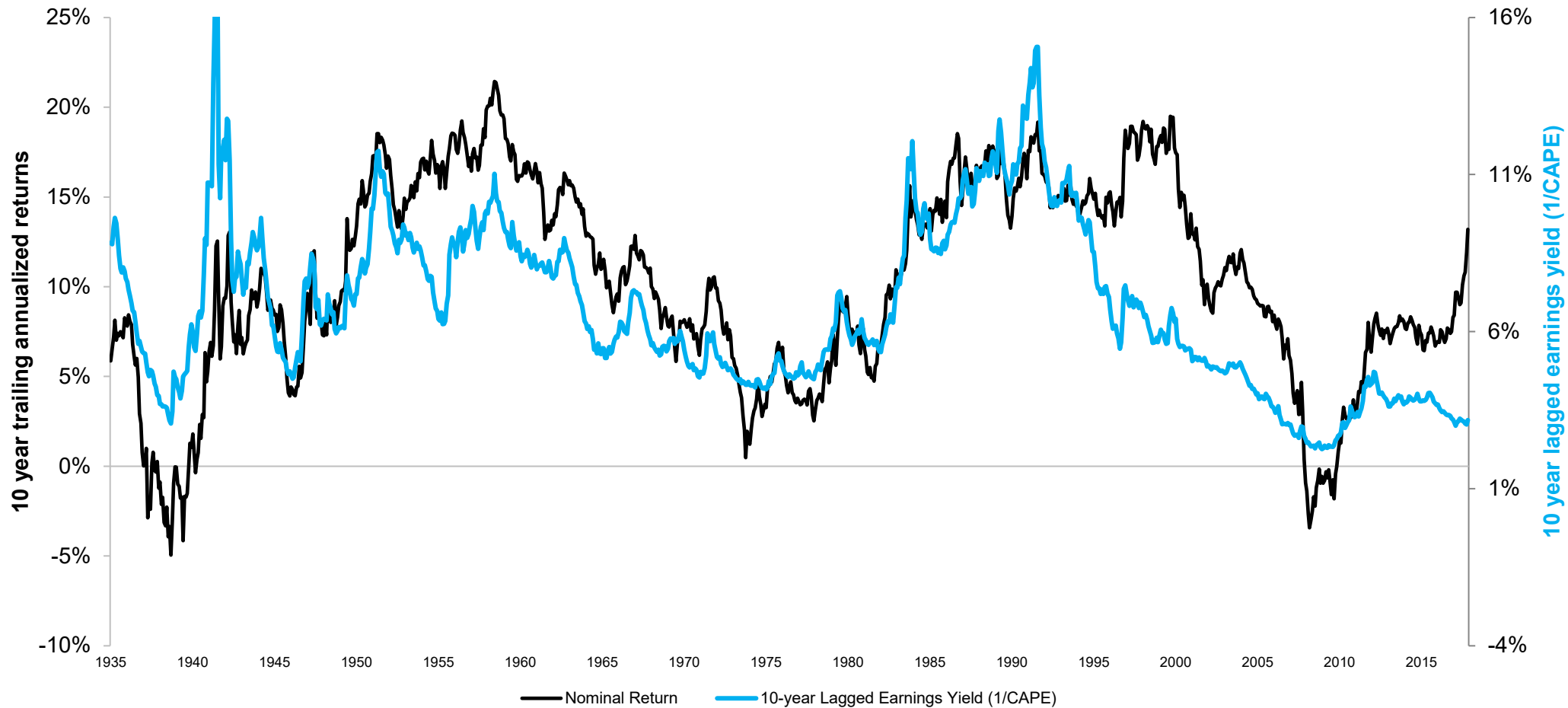
Note: The returns are the rolling 10-year trailing annualized returns of the S&P 500 index from January 1936 through October 2019. Source: Vanguard calculations, based on SBBI data from Factset and Robert Shiller's website, at aida.wss.yale.edu/~shiller/data.htm.

Past performance is no guarantee of future returns. The performance of an index is not an exact representation of any particular investment, as you cannot invest directly in an index.

Out-of-Sample forecasts under the Shiller Approach

Shiller CAPE regression forecasts are quite inaccurate

$$r_{t+120} = \alpha + \beta * CAPE_t + \epsilon_t$$

Legend: — Actual — Linear — Ensemble

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Past performance is no guarantee of future returns. The performance of an index is not an exact representation of any particular investment, as you cannot invest directly in an index.

Key points to remember while assessing forecast accuracy

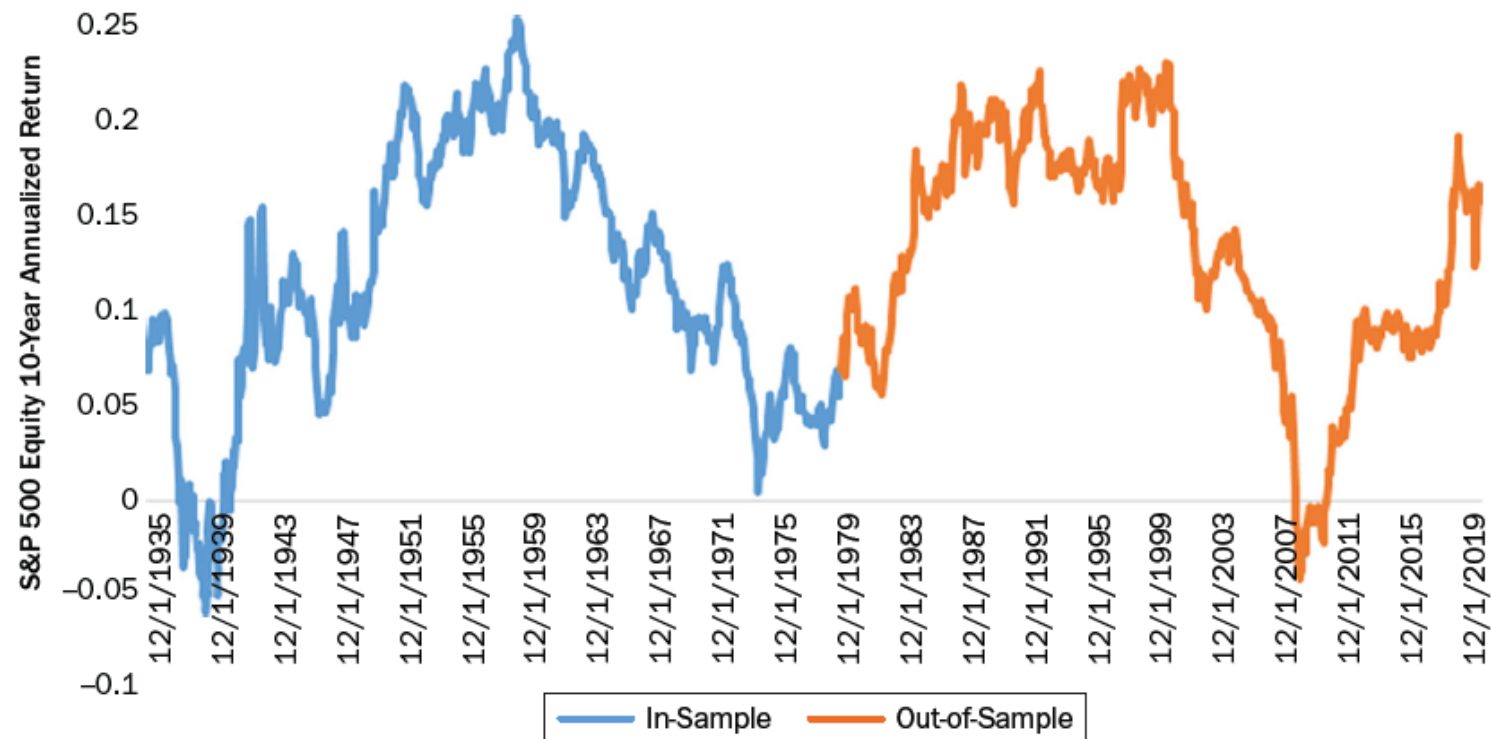1. **Avoid look-ahead bias**
   - Adjust hyper-parameters in-sample only and apply the best in-sample combination out-of-sample

2. **Use a recursive (expanding) window**
   - This maximizes the use of historical data and is reflective to real time forecasting practice

3. **Limit the independent variables assessed based on sound economic rationale**
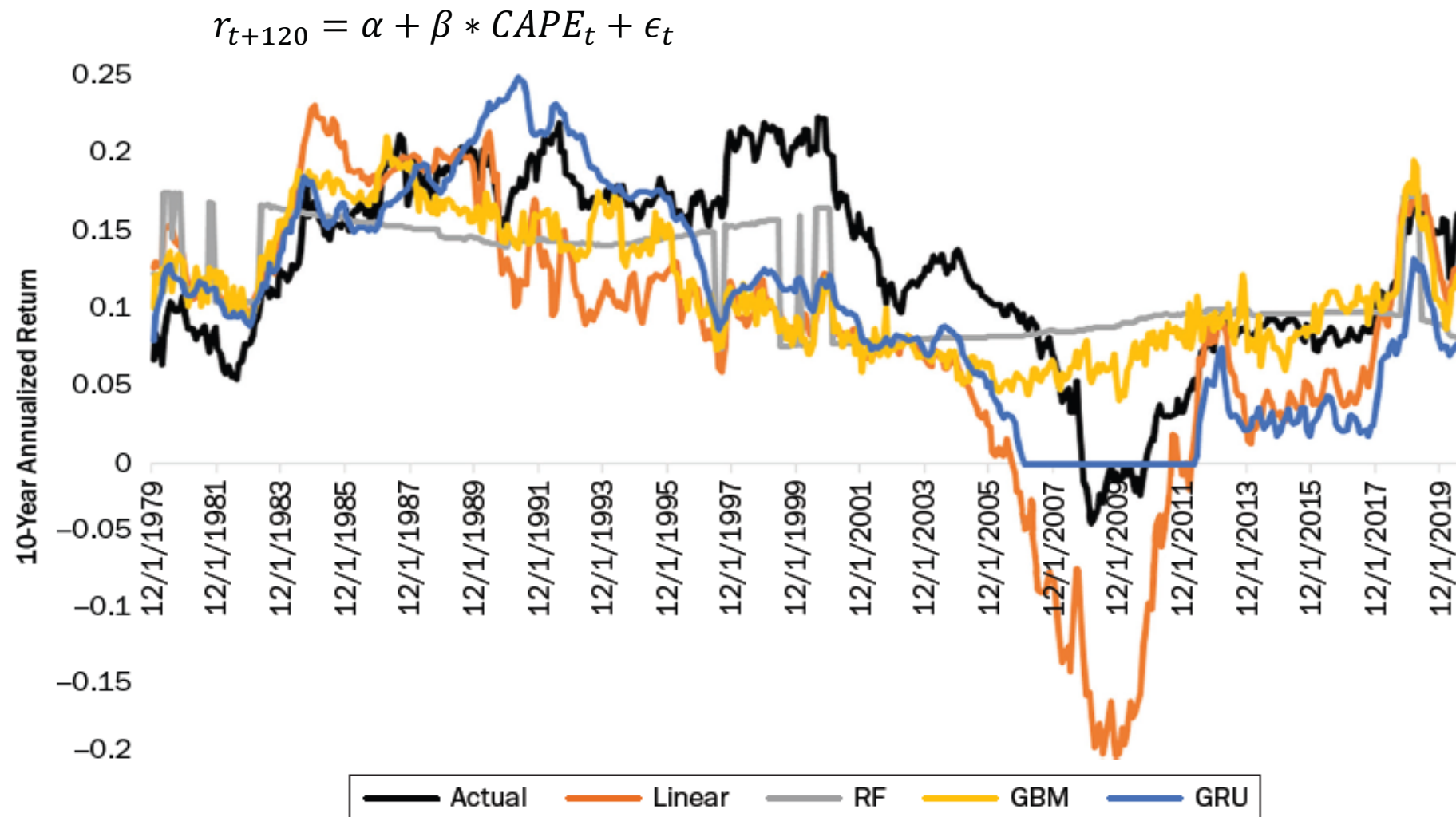   - Avoid a kitchen sink approach

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Out-of-Sample forecasts under the Shiller Approach

ML forecasts

$$r_{t+120} = \alpha + \beta * CAPE_t + \epsilon_t$$

Comparison of Out-of-Sample forecast accuracy

- The forecast accuracy of the traditional Shiller Regression is worse than historical average!

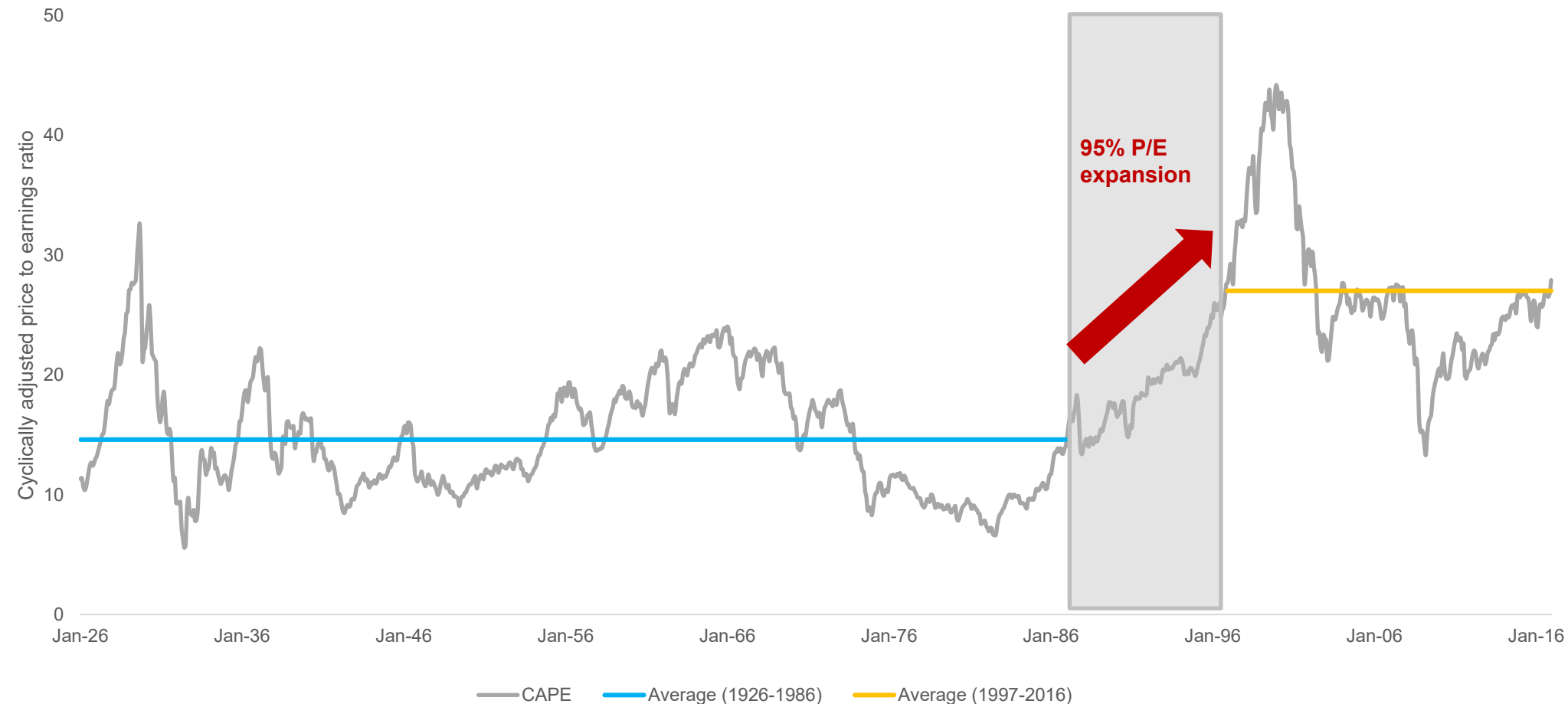- ML techniques improve accuracy, but only marginally

	Average Forecast Error (RMSE)	Correlation of Predicted Returns with Actual	Model Forecast Error Relative to Error of Using a Naïve Historical Mean Forecast
Historical Mean	5.3%	−6%	
Linear	6.3%***	77%	Higher
RF	4.4%***	56%	Lower
GBM	4.5%***	58%	Lower
rnn	4.3%***	80%	Lower
Ensemble	3.9%***	78%	Lower

NOTES: For the real-time analysis, the predictions (with the exception of GRU) are determined recursively at a monthly frequency, starting with December 1935–November 1979. Asterisks next to the RMSE refers to the significance (Newey–West adjusted) of the Diebold–Mariano test (Diebold and Mariano 2002) of whether the forecast is statistically better or worse than the historical mean. ***Significant at the 99% level.

SOURCE: Authors' calculations.

Which mean will the CAPE revert to?

- CAPE mean has nearly doubled since the mid 1980's!
- Why? - Periods of low interest rates correspond to periods of high CAPE

95% P/E expansion

Legend: CAPE — Average (1926-1986) — Average (1997-2016)

Y-axis: Cyclically adjusted price to earnings ratio (0, 10, 20, 30, 40, 50)

X-axis: Jan-26, Jan-36, Jan-46, Jan-56, Jan-66, Jan-76, Jan-86, Jan-96, Jan-06, Jan-16

Why do traditional models fail?

- They don't account for economic environment
- High inflation and high real yield = high earnings yield
- VAR is a better way to capture linkages with the economy

An improved two-step model

1. Eliminate the return regression by using an identity

Return =   Dividend yield   +   Valuation expansion   +   Earnings growth
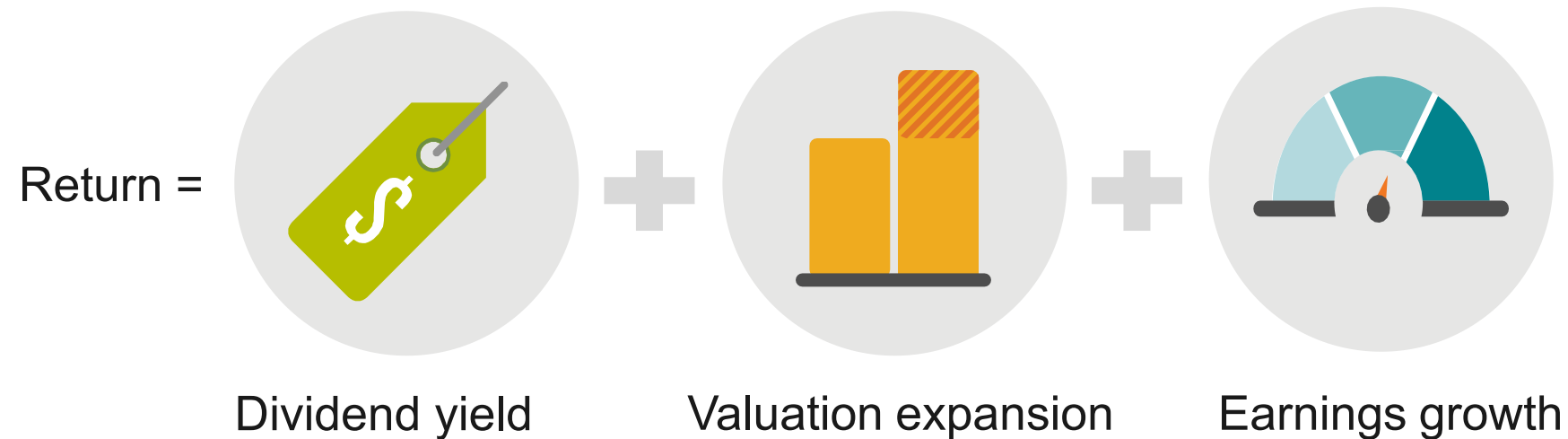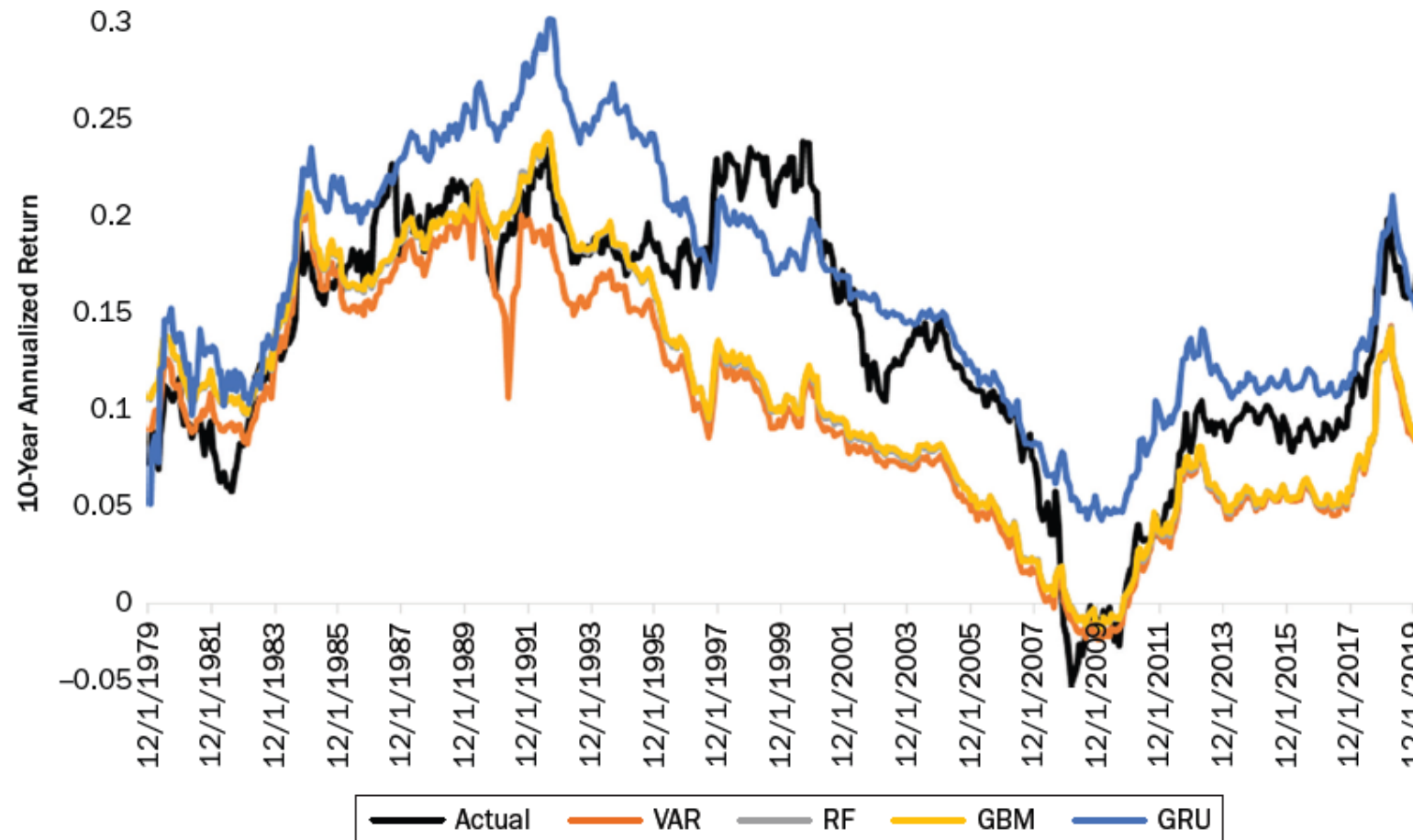
2. Forecast CAPE using Vector Auto-Regression (VAR)

– Capturing the long-run relationship of earning yields (1/CAPE) with rates, inflation, equity and bond volatility

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Out-of-Sample forecasts under the hybrid ML-VAR Approach

Improved forecasts

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Out-of-Sample forecasts under the hybrid ML-VAR Approach

Improved forecasts

Out-of-Sample forecasts under the hybrid ML-VAR Approach

- Improved accuracy with ML-VAR based approach
- Ensemble approach is the best

	Average Forecast Error (RMSE)	Correlation of Predicted Returns with Actual	Model Forecast Error Relative to Error of Using a Naïve Historical Mean Forecast
Historical Mean	5.3%	−6%	
VAR	4.3%***	83%	Lower
RF	3.9%***	81%	Lower
GBM	3.8%***	81%	Lower
GRU	3.2%***	89%	Lower
Ensemble	3.1%***	85%	Lower

NOTES: For the real-time analysis, the predictions (with the exception of GRU) are determined recursively at a monthly frequency, starting with December 1935–November 1979. Asterisks next to the RMSE refers to the significance (Newey–West adjusted) of the Diebold–Mariano test (2002) of whether the forecast is statistically better or worse than the historical mean. ***Significant at the 99% level.
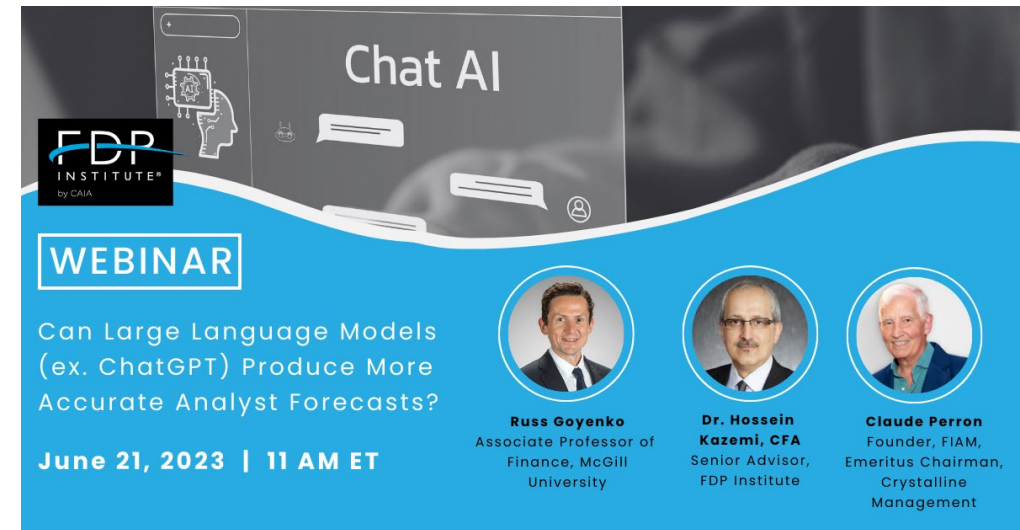
SOURCE: Authors' calculations.

Conclusion

- Valuation metrics such as the Shiller CAPE ratio are widely used to forecast returns

- However, forecast accuracy of the Shiller regression is poor
  - Why? Lack of mean reversion in CAPE ratio
  - CAPE reverts to a mean that is conditional on the economy (real rates, inflation and financial volatility)

- ML techniques only help marginally improve forecast accuracy of the Shiller approach

- The two-step approach
  - Forecast CAPE ratio conditional on the economy in a VAR setting (using traditional VAR or hybrid ML-VAR)
  - Calculate equity returns using "Sum of Parts" identity using CAPE ratio forecasted

- Forecast accuracy improves significantly using hybrid ML-VAR, especially the ensemble technique

All investments are subject to risk, including the possible loss of the money you invest.

Q & A

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June 21st @ 11 AM ET
Register Here

Thank You

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🌐 fdpinstitute.org

✉️ info@fdpinstitute.org

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