How Inflation and 10-year Bond Yield Forecasting with Computer Science (AI) Could Support Pension Funds

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allea Ltd. (Consultants and Actuaries)

EAA e-Conference on
Data Science & Data Ethics

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SUMMARY

Switzerland: Index of the 1st Pillar Pension vs. HCPI-Inflation Evolution over the Period 1985-2023 of the 2nd Pillar
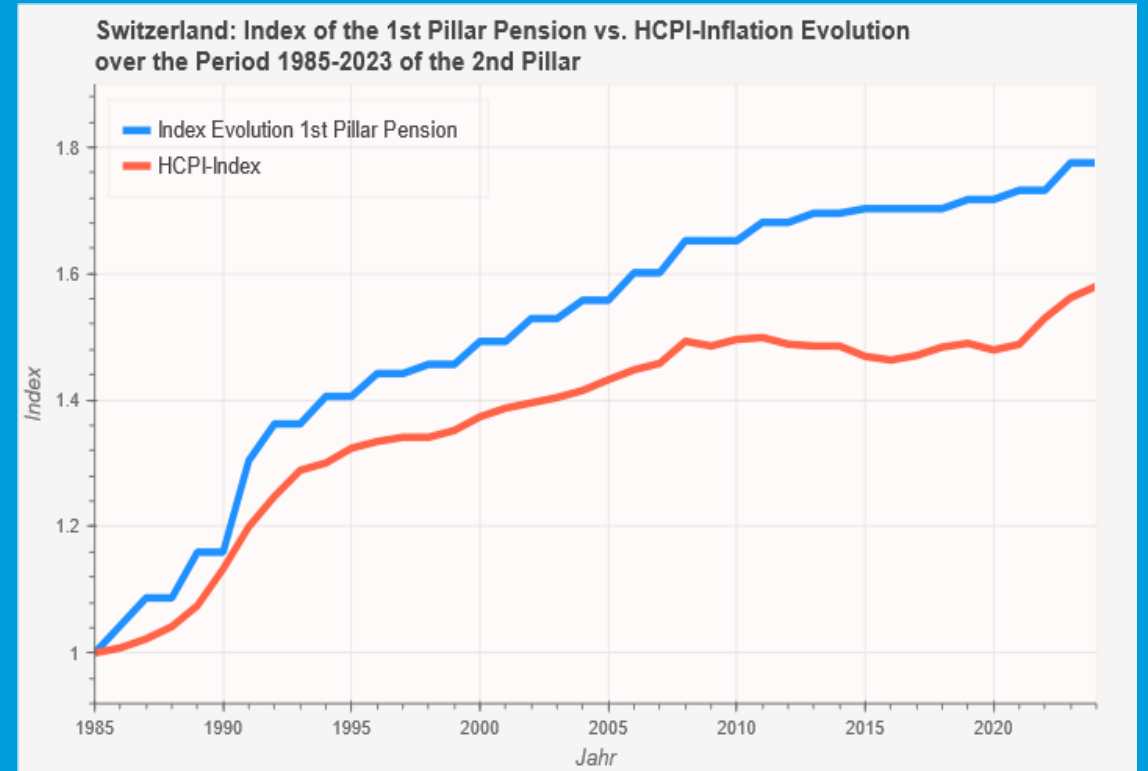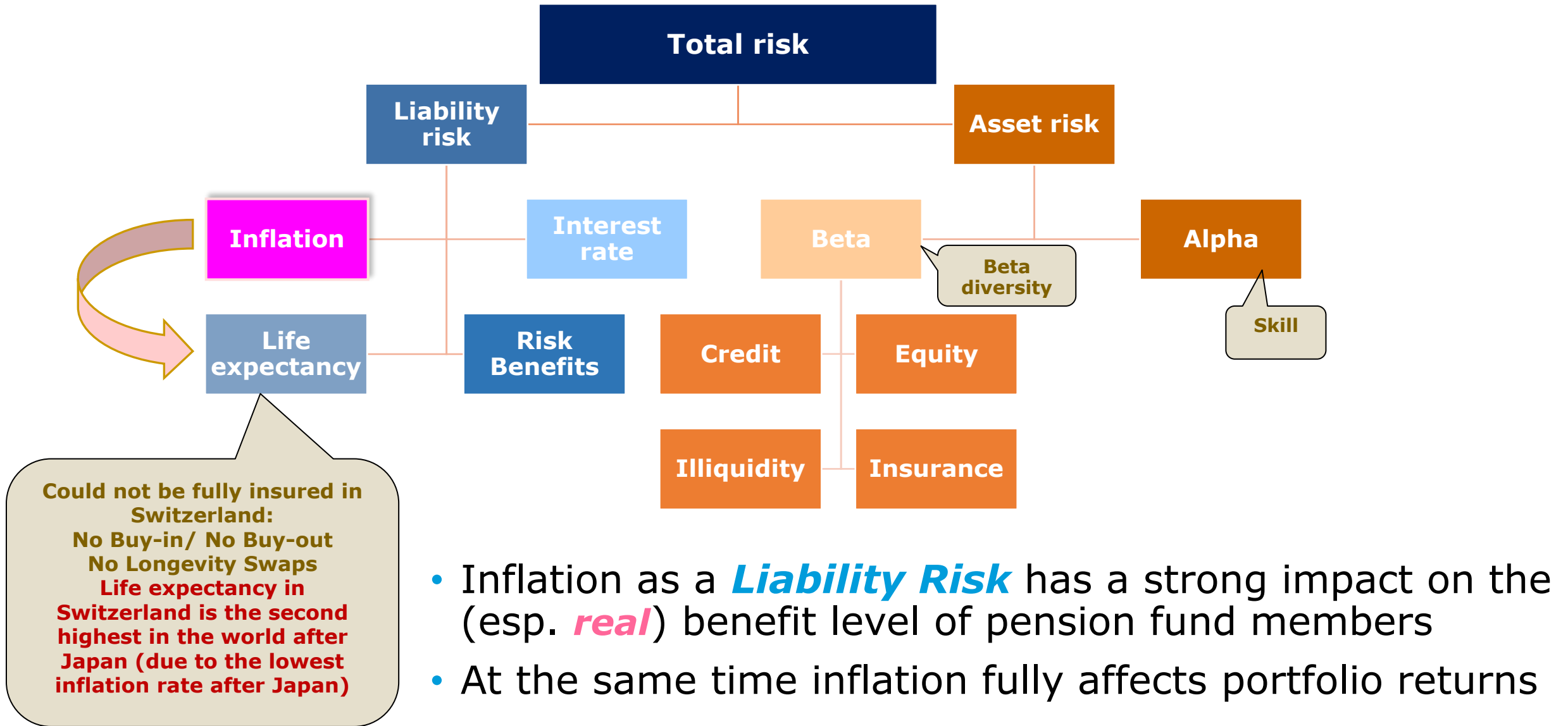
ROLE OF THE PENSION FUND'S BOARD OF TRUSTEES

- The pension fund board of trustees is responsible for the overall management of the pension fund (**Art. 51a para. 1 LPP/BVG**)
  - *Two of these tasks' examples*:
    - Setting of the financing system and
    - Determination of the **objectives** and **principles of asset management** as well as the **implementation and monitoring of the investment process**

- The management responsibility of the board of trustees with regards to the investment of assets
  - The board of trustees comprehensibly **designs**, **monitors** and **controls** the management of assets in a manner that is appropriate to earnings and risks
  - Interest credit (IC) level depends on the pension fund funding ratio and portfolio performance
    - Only high ICs help to reach high level of saving capital at retirement.

HOW TO SUPPORT PENSION FUND BOARD OF TRUSTEES

- Forecasting inflation, government bond yields and AA corporate bond yields is useful for making forecasts of:
  - Local benefit obligations and liability positions for Swiss pension fund expert reports,
  - International accounting (IFRS, US GAAP, IPSAS),
  - Asset allocation

- To explain the projected results to the Board of Trustees (of pension funds) and to obtain their confirmation:
  - It is worthwhile to visualize these results and forecasting (for better understanding).

- Sometimes it would be important to present as a "second opinion" a comparison of the results produced by other consultancies

- Even though the prediction approach and the "second opinion" analysis are very complicated, it would be useful to find a simple, well-understood approach to confirm your results:
  - The Threshold Portfolio Return calculated based on the financial statements of existing pension fund helps to produce exacter assumptions for forecasting;
  - Analysis of historical personal data over last years helps for forecasting as well.
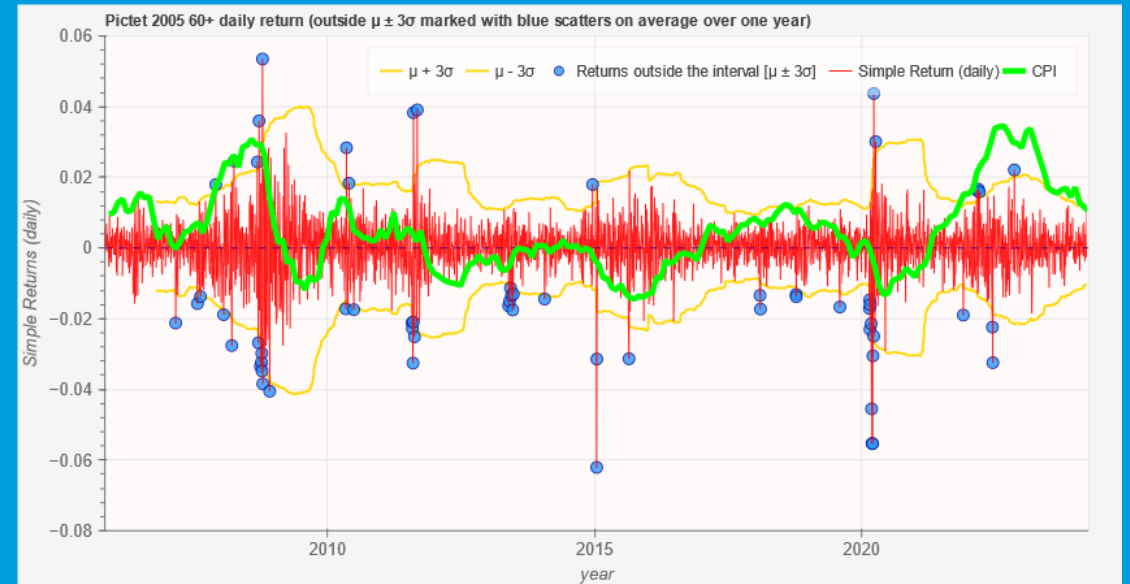
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                         ┌─────────────────┐
                         │   Total risk    │
                         └────────┬────────┘
          ┌───────────────────────┴───────────────────────┐
   ┌──────────────┐                                 ┌──────────────┐
   │   Liability  │                                 │  Asset risk  │
   │     risk     │                                 └──────────────┘
   └──────────────┘
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Total risk

Liability risk — **Asset risk**

Inflation

Interest rate

Beta

Beta diversity

Alpha

Skill

Life expectancy

Risk Benefits

Credit

Equity

Illiquidity

Insurance

Could not be fully insured in Switzerland:
No Buy-in/ No Buy-out
No Longevity Swaps
Life expectancy in Switzerland is the second highest in the world after Japan (due to the lowest inflation rate after Japan)

- Inflation as a *Liability Risk* has a strong impact on the (esp. *real*) benefit level of pension fund members
- At the same time inflation fully affects portfolio returns

THANKS FOR HISTORICAL DATA FOR FINANCE AND INSURANCE

- Our analyses are based on (free of charge) historical data produced by
  - **Swiss National Bank (SNB)** – government bonds Yield Curves parameters;
  - **Federal Statistical Office (FSO)/ Bundesamt für Statistik (BFS)** – Swiss Headline Inflation and Core Inflation rates & its components;
  - **The World Bank Data/ International Monetary Fund (IMF)** – world wide inflation and its components as well other economic data (like GDP, etc.), country life expectancies;
  - **Pictet Asset Management Bank** – typical Swiss pension fund Portfolio Indices (Pictet LPP/BVG 2005 plus, Pictet LPP/BVG 2000, Pictet LPP/BVG 2015).
- Visualisation and IT(AI)-analyses with ANACONDA.NAVIGATOR (Python) and **R-project** based on their free of charge libraries

EXAMPLE: EVOLUTION PORTFOLIO RETURN VS. CPI & Y10

Pictet 2005 60+ daily return (outside μ ± 3σ marked with blue scatters on average over one year)
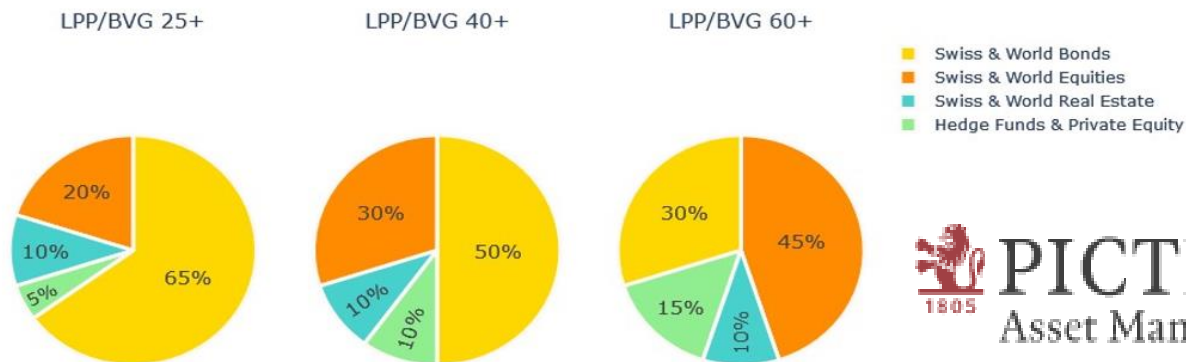
Composition of the Pictet LPP 2005 Indices
The table below shows the weightings of the three indices

INVESTMENT CATEGORIES	INDICES	LPP-25 PLUS 2005	LPP-40 PLUS 2005	LPP-60 PLUS 2005
BONDS		65	50	30
Swiss	Swiss Bond Index AAA-BBB	40	30	15
World	Bloomberg Multiverse (*)	25	20	15
EQUITIES		20	30	45
Swiss	Swiss Performance Index	7.5	10	15
World	MSCI AC World IMI	12.5	20	30
REAL ESTATE		10	10	10
Swiss	SXI Real Estate Funds	7.5	5	2.5
World	Dow Jones Global Select RESI	2.5	5	7.5
HEDGE FUNDS	HFRX Global Hedge Fund (*)	2.5	5	7.5
PRIVATE EQUITY	LPX50	2.5	5	7.5
Currency exposure		17.5	30	45

(*) hedged in CHF

Indices Pictet LPP/ BVG 2005 plus

LPP/BVG 25+   LPP/BVG 40+   LPP/BVG 60+

- Swiss & World Bonds
- Swiss & World Equities
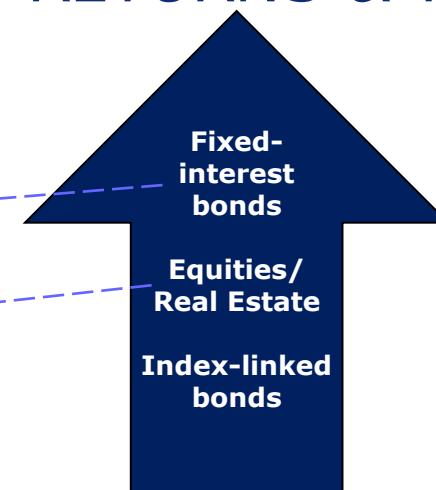- Swiss & World Real Estate
- Hedge Funds & Private Equity

- Pictet Asset Management bank prepared portfolio indices typical for Swiss pension funds
  - Pictet return data is generated monthly and daily and is very useful for all types of analysis
- **Pictet LPP/BVG 2005 plus** indices are very popular
  - **Pictet 40+ Index** used for the FRP4 Guidelines (Y10 historical returns over last year per Sept. 30 + 2.5%)
  - 2.5% corresponds to the difference of average Y10 and Pictet 2005 40+ returns over 20 years
  - FRP4 is the upper limit for the technical interest rate to valuate liabilities

INFLATION CAN "EAT AWAY" AT PENSION FUND INVESTMENTS

- ***Understanding the relationship between inflation and investments is essential to making informed investing decisions.***
  - Investments with lower interest rates are hit harder by the effects of inflation.
  - Inflation affects how much retirement savings are worth.

- Rising inflation has a negative effect on the returns of equities and bonds.

- Inflation and nominal equity returns are <u>negatively correlated</u>

- *Real assets*, such as commodities and real estate, tend to have a positive relationship with inflation. Commodities can help investors mitigate rising inflation
  - However, commodities have important drawbacks. They tend to be more volatile than other asset classes, do not produce any income, and have historically underperformed stocks and bonds over longer time periods.

- Diversifying portfolio with exposure to stocks and *real assets* may help shield money against inflation

CORRELATION OF THE INFLATION RATE WITH PORTFOLIO RETURNS & Y10

«R» Return	Headline CPI	10-year Bond Yield	R 2005 25+	R 2005 40+	R 2005 60+
Headline CPI	1	0.4	-0.35	-0.22	-0.13
10-year Bond Yield	0.4	1	-0.07	-0.09	-0.1
R 2005 25+ Bonds 65%	-0.35	-0.07	1	0.96	0.9
R 2005 40+ Bonds 50%	-0.22	-0.09	0.96	1	0.99
R 2005 60+ Bonds 30%	-0.13	-0.1	0.9	0.99	1

Fixed-interest bonds

Equities/ Real Estate

Index-linked bonds

	count	mean	std	min	5%	25%	50%	75%	95%	max
Headline CPI	304	0.62	1.04	-1.44	-1.01	-0.05	0.57	1.24	2.81	3.45
10-year Bond Yield	304	1.46	1.37	-0.98	-0.49	0.04	1.39	2.68	3.54	4.1
R 2005 25+	304	3.39	5.46	-14.06	-7.52	0.53	4.09	6.89	10.37	19.76
R 2005 40+	304	3.98	8.05	-21.64	-10.83	-0.29	5.42	9.21	14.99	27.28
R 2005 60+	304	4.84	11.8	-31.79	-15.55	-1.64	6.18	12.28	22.14	37.21

- *Pictet BVG 2005 plus* indices returns, inflation and 10-year Bond Yield (Y10) data monthly over *December 31, 1998-March 31, 2024*

- Inflation has an impact on the portfolio return: When inflation rises, portfolio returns fall (the correlation is negative).

- Correlation between inflation and Y10 is positive

- The nominal returns were 3.39%, 3.98%, 4.84% and real returns: 2.77%, 3.36% and 4.22%

Evolution Pictet nominal Indices (vs. real) based on Inflation & Y10
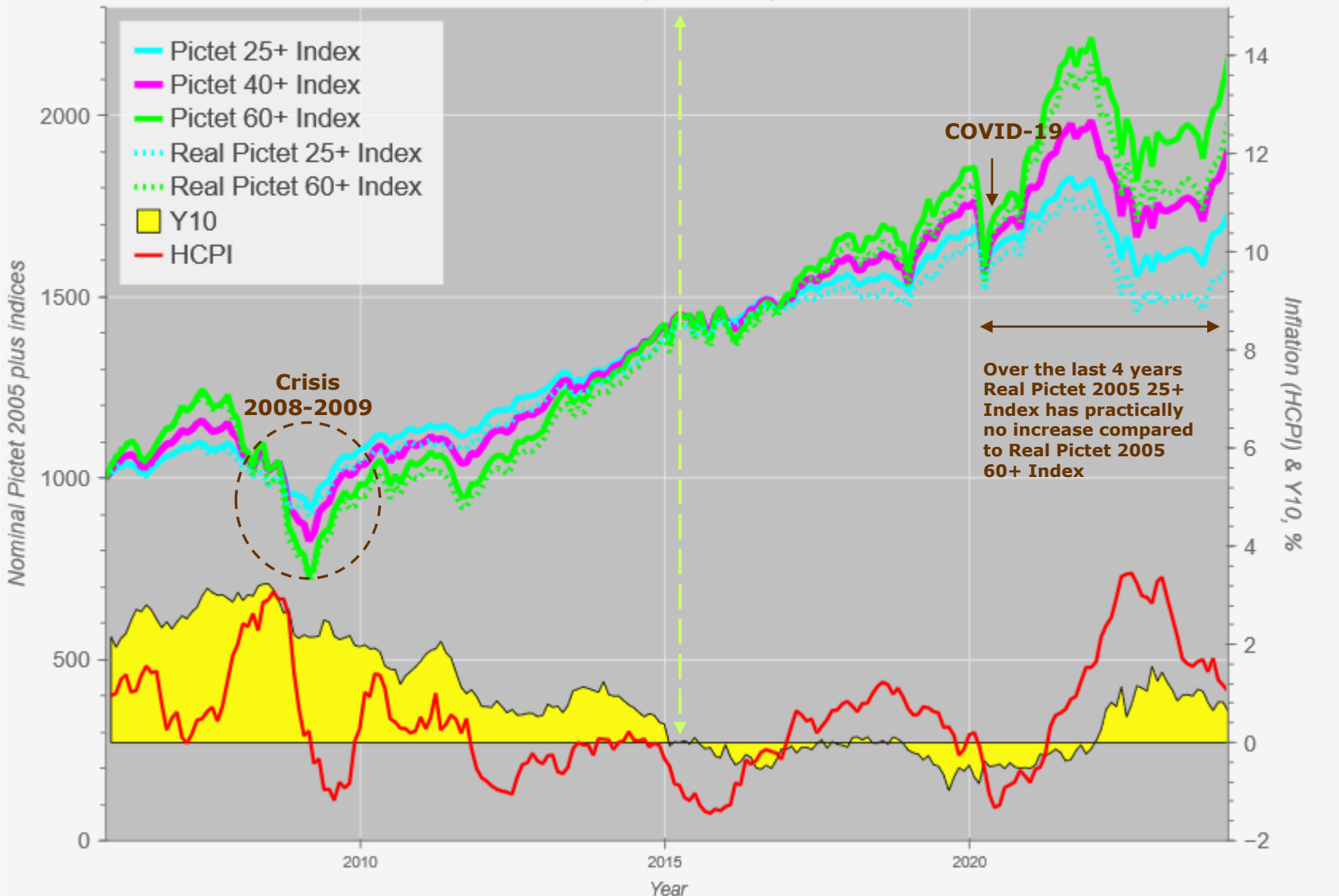
- Inflation (HCPI) and Y10 evolutions have an impact on portfolio returns.
- Since January 2015 the Y10 was negative:
  - Returns of **Pictet Index 2005 60+** strongly increased due to this Y10 position
  - Positive Y10 (in 2022) was lower than in the period 2005-2014
- Real indices reduced to a greater extent from May 2021
  - **Real Pictet Index 2005 60+** nearly on **Nominal Pictet Index 2005 40+**

MODELS FOR FORECAST INFLATION & Y10
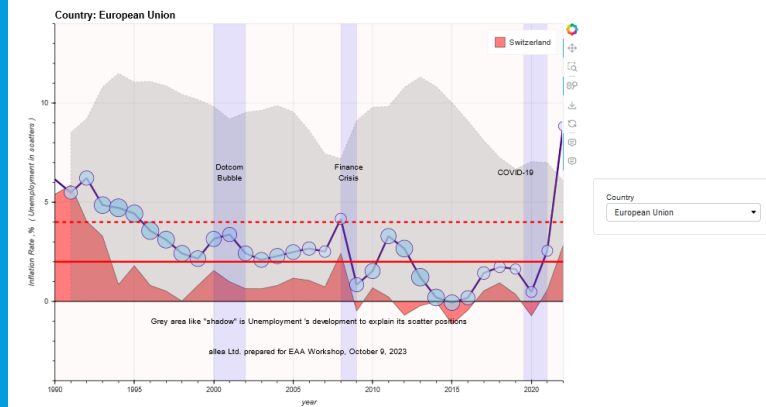
«BEST» APPROACH FOR INFLATION FORECASTING ? - 1

- Determining the «best» approach for inflation forecasting depends on various factors:
  - Including the context of the forecast,
  - Data availability,
  - The forecast horizon, and
  - The specific characteristics of the economy being analysed

- Here some common approaches used in inflation forecasting:
  - Econometric Models (relationships between inflation and its determinants (money supply, GDP growth, unemployment, etc.)
  - Time Series Analysis (z.B. ARIMA oder SARIMA) and Vector Autoregression (VAR) Models
  - Machine Learning (ML) Algorithms (z.B. neural networks, random forests, support vector machines)
  - Survey-Based Forecasts (surveys of businesses, consumers, or professional forecasters can provide valuable insights into inflation expectations)
  - Central Bank Models (central banks often develop their own models for inflation forecasting, which may incorporate a combination of econometric techniques, macroeconomic theory, and judgmental adjustments)
  - Hybrid Approaches (for example, combining econometric models with machine learning algorithms or incorporating judgmental adjustments into statistical models)

«BEST» APPROACH FOR INFLATION FORECASTING ? - 2

- There is no universally «best» approach for inflation forecasting, as the effectiveness of each method can vary depending on the specific context and data available

- In practice, forecasters often use a combination of approaches and continually evaluate and update their models to improve forecast accuracy over time

- At the moment, we use the following approaches in inflation forecasting – with monthly updated results to verify the forecasting

- Time Series Analysis (z.B. ARIMA oder SARIMA, i.e. seasonal ARIMA) - *affine*
  - Time series analysis focuses on historical inflation data to identify patterns, trends, and seasonality. Techniques like ARIMA (Auto Regressive Integrated Moving Average) or SARIMA models are commonly used by many consultants in time series analysis
- Machine Learning Algorithms (neural networks, NN)
  - NN algorithm can be employed to forecast inflation by learning from historical data patterns
  - NN technique is useful for capturing nonlinear relationships and complex interactions among variables

| Bottom (Input) layer	Hidden layer	Top (Output) layer
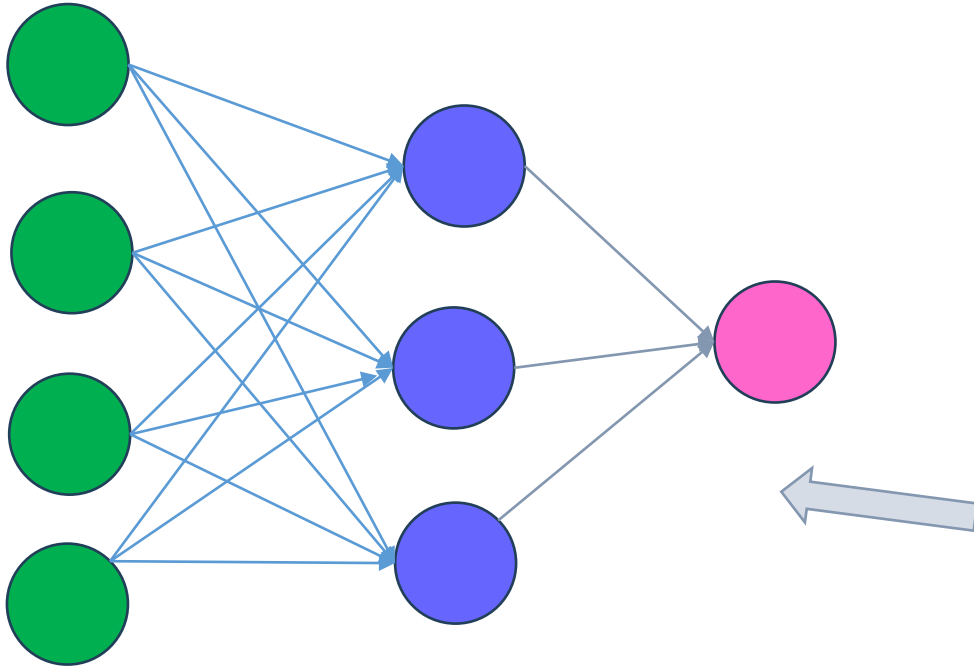
$$z_j = \beta_j + \sum_{i=1}^{n} W_{i,j} X_i$$

z_j - the value of output node j, β_j – constant for node j, $W_{i,j}$ – the weight from the input node i to output node j, X_i is the inputs, n is number of input variables.

- Artificial neural network (ANN) methods rely on mathematical models in a similar pattern as 'neurons' in the brain.

- ANN models help design complex non-linear associations between the dependent variable and its predictors (Hyndman and Athanasopoulos 2018).

- The simplest ANN models would only have predictors (independent variables or *inputs*) in the bottom layer and the dependent variable (*output*) in the top layer, which would be equivalent to a linear regression model.

- After adding the hidden layer(s) in-between bottom and top layers, the ANN structure becomes non-linear.

- This type of ANN is called multi-layered feed-forward network, where each layer of neurons (● nodes) receive inputs from the previous layer.
  - The inputs to each node are estimated using a weighted linear combination
  - In the hidden layer **z** is transformed into non-linear function using sigmoid *s(z) = 1/(1+exp(-z))* to give the input for the next layer.
  - Parameters β_j and $W_{i,j}$ are «learned» from the training data

- With time series data such as inflation, Y10, portfolio returns, etc. , lagged values of the time series can be used as inputs in the ANN structure, just as it's used lagged values in a linear autoregression model
  - That is why this model is called **neural network autoregression** or **NNAR**
- NNAR(**p**,**k**): **p** lagged inputs and **k** nodes in the hidden layer
 - Number of lagged inputs, and the number of nodes in each hidden layer, must be specified in advance.

FORECASTING APPROACH NNAR VS. ARIMA

ARIMA(p,d,q)

d

AR (p)   MA (q)
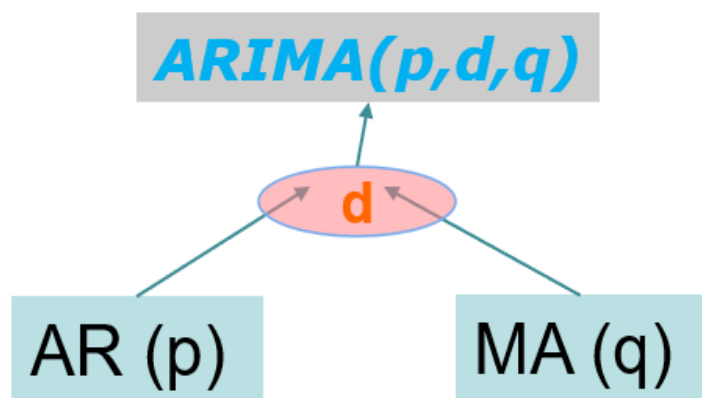
Box & Jenkins (1976) introduced the concept of **AutoRegressive Integrated Moving Average** (ARIMA) time series models.
This **is a linear (affine), stationary** AR(p) and MA(q) model. The ARIMA-Variance and -Mean increase linearly (NNAR is not linearly).

- ARIMA is effective as a representative model of traditional time series models for forecasting. Machine learning models generally achieve better prediction accuracy.

- The forecast based on the **affine** model (like ARIMA) produces higher bandwidth of inflation rates and 10-year government bond yields

- The accuracy of the forecasts is measured by the root-mean-square error (RMSE)
  - RMSE with NNAR was always smaller than RMSE with ARIMA in our forecasts

- Due to higher RMSE with ARIMA much wider bandwidths of forecasted inflation and 10-year bond yields, Y10, were observed.
  - Additionally, other parameters based on these forecasted inflation and Y10 were realised (esp. compared to NNAR)

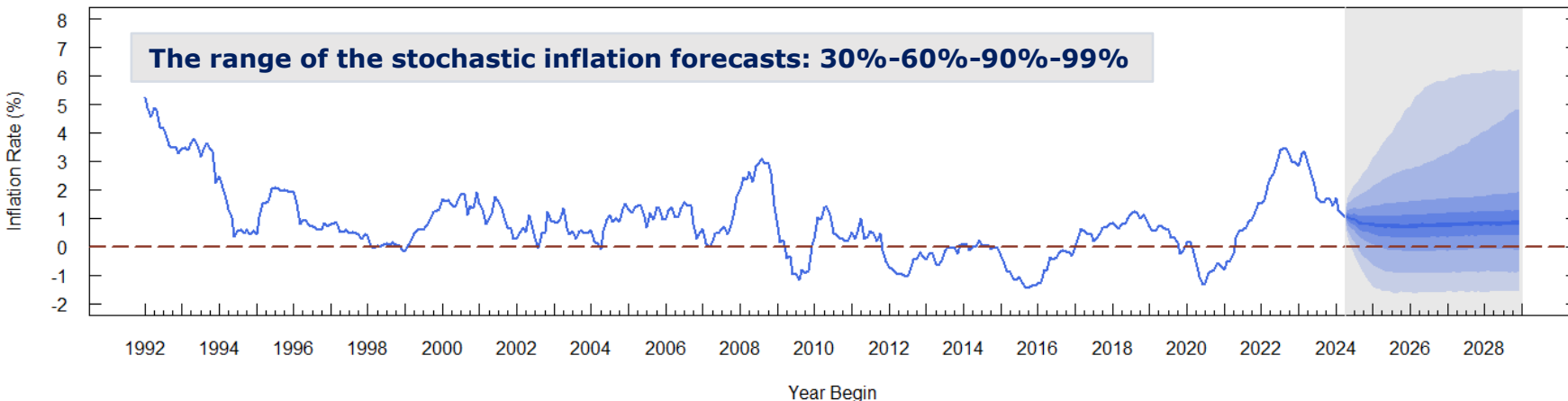## *EXAMPLE: FORECASTING APPROACH NNAR VS. ARIMA*
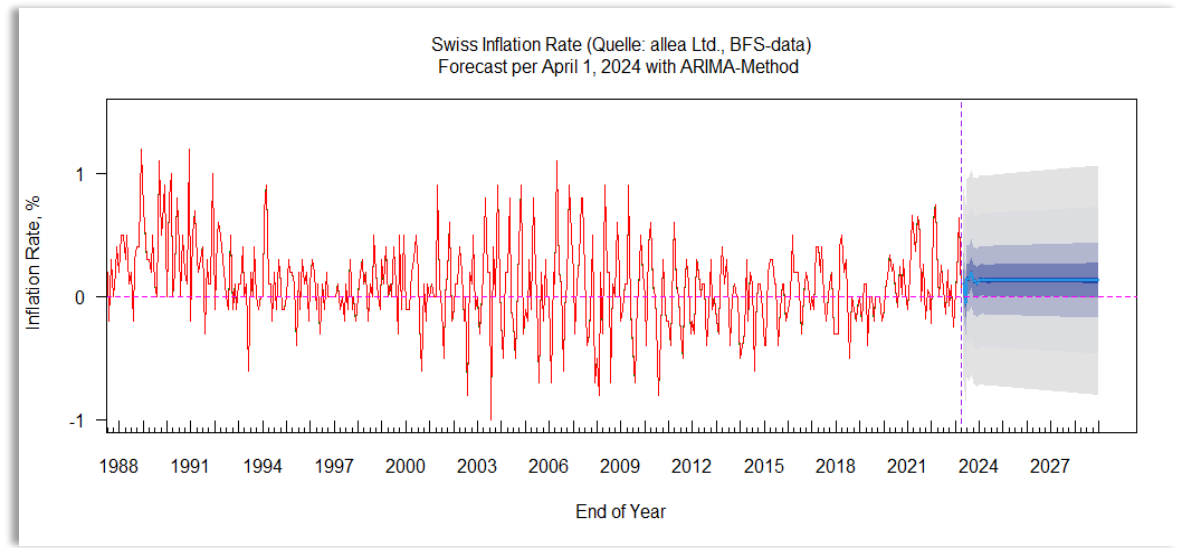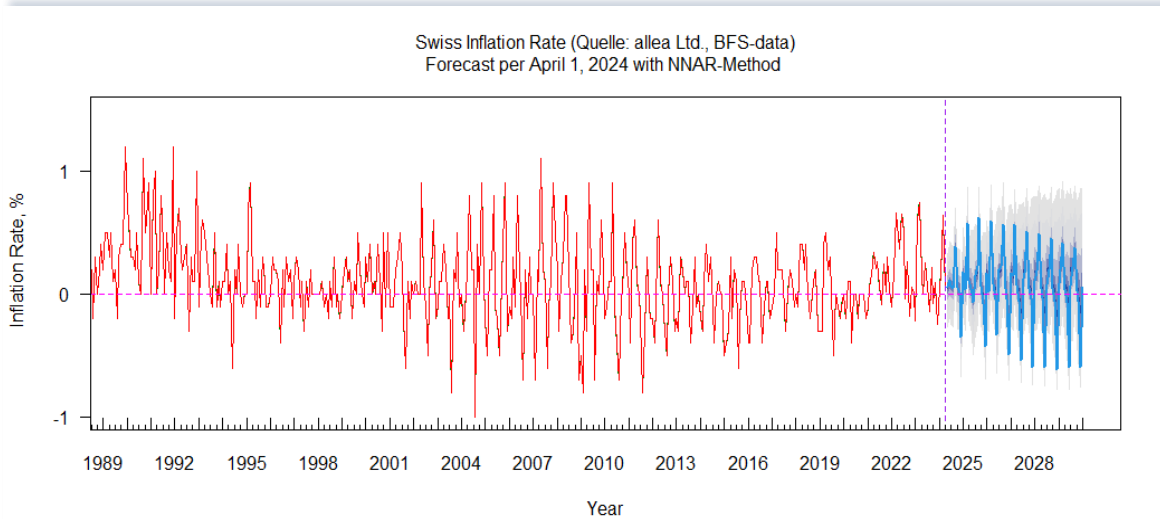
- Inflation rate forecast produced with NNAR (left) vs. ARIMA (right) per April 1, 2024, shows that the volatility (bandwidth of forecasted values) with ARIMA is much higher compared to the NNAR approach.

- RMSE with NNAR is 0.1258 compared with RMSE with ARIMA is 0.3036
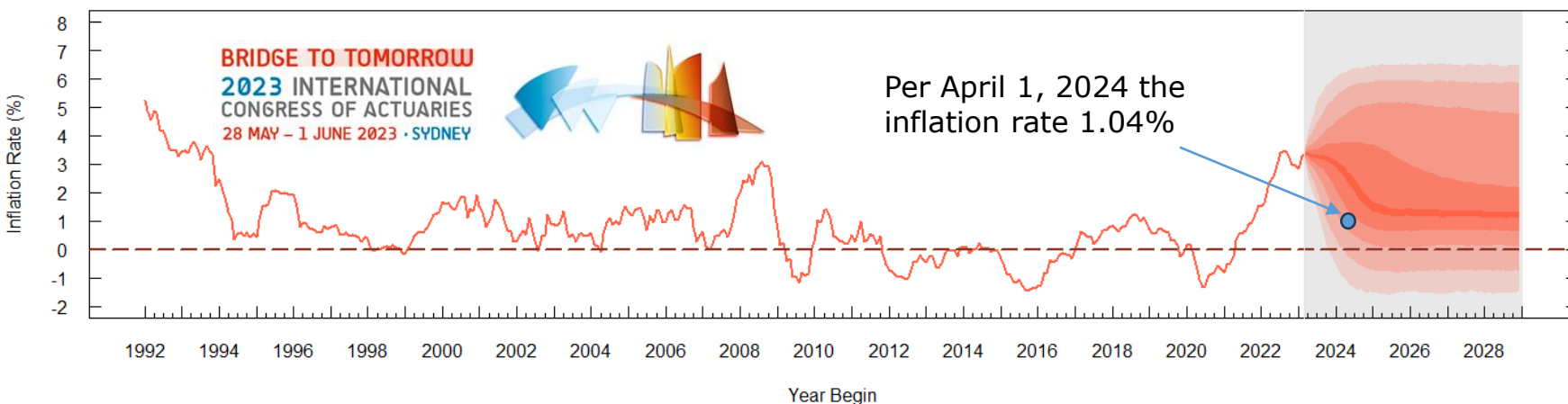
FORECAST INFLATION & Y10
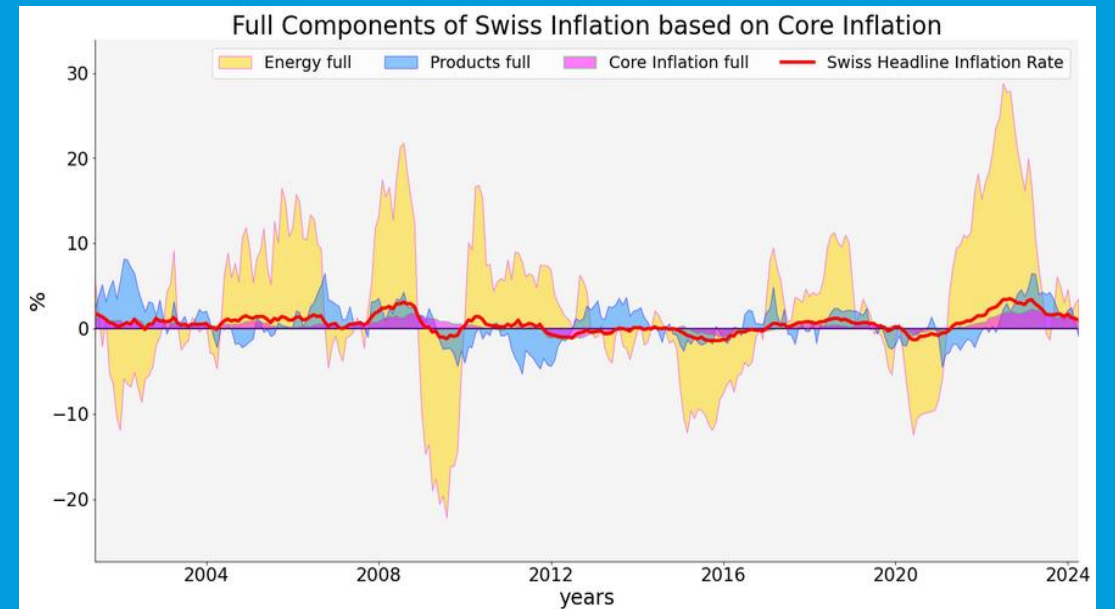
Full Components of Swiss Inflation based on Core Inflation

allea Ltd.: Forecasted inflation rate previous year's month: as of April 1, 2024

The range of the stochastic inflation forecasts: 30%-60%-90%-99%

allea Ltd.: Forecasted inflation rate previous year's month: as of March 1, 2023

Per April 1, 2024 the inflation rate 1.04%

- The forecast per March 1, 2023, was presented at ICA2023

- The inflation forecast is prepared monthly based on all inflation data prepared by Federal Statistical Office (FSO)/ Bundesamt für Statistik (BFS)

- For pension funds it is important to get the inflation forecast on average over 2-3 years

Swiss Inflation density and its average values over periods 1960 - 2022, 1980-2022, 1990-2022 and 2000-2022

The inflation forecast prepared based on monthly data Jan 1988 - March 2024

Legend: 1960-2022, 1980-2022, 1990-2022, 2000-2022
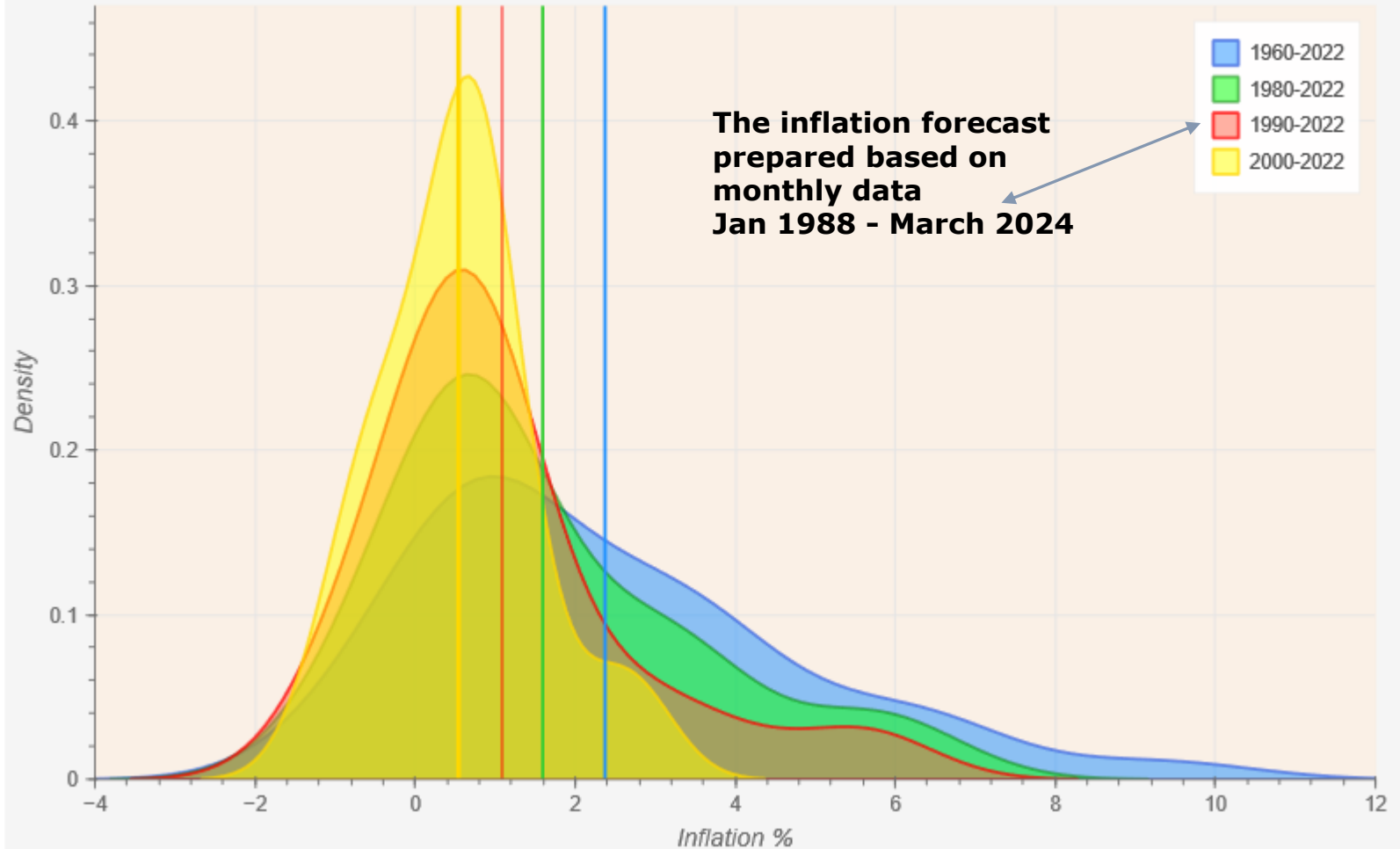
- Density of inflation based on historical data (The World Bank) over different periods

- The structure of inflation density based on historical data supports to understand the forecasted structure with NNAR model

  - The inflation density is not symmetric.

  - That is why it is not to expect that the stochastic forecasted inflation should be symmetric (like with ARIMA)

allea Ltd.: Forecasted CPI based on Y10: per March 1, 2023

Per April1, 2024 the inflation rate 1.04%
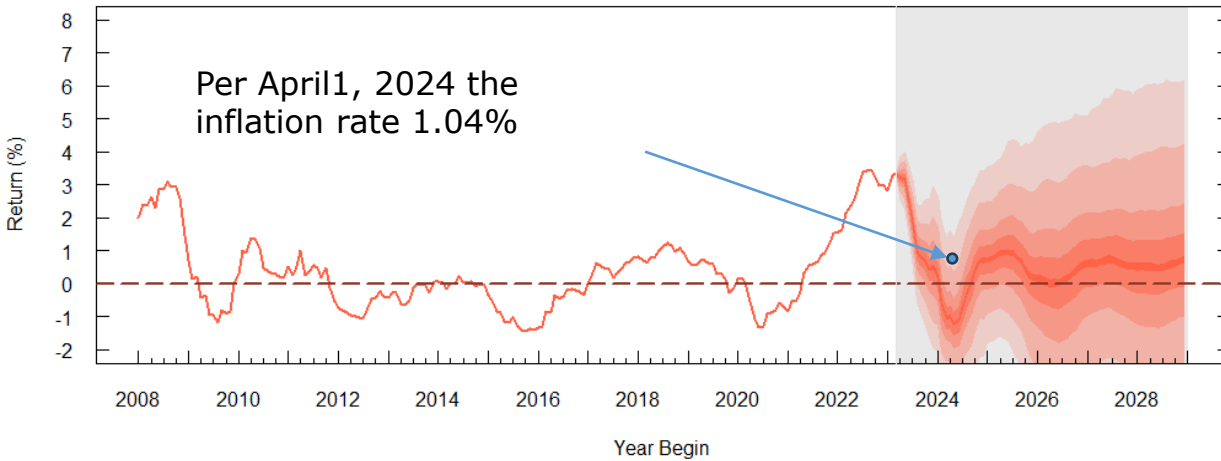
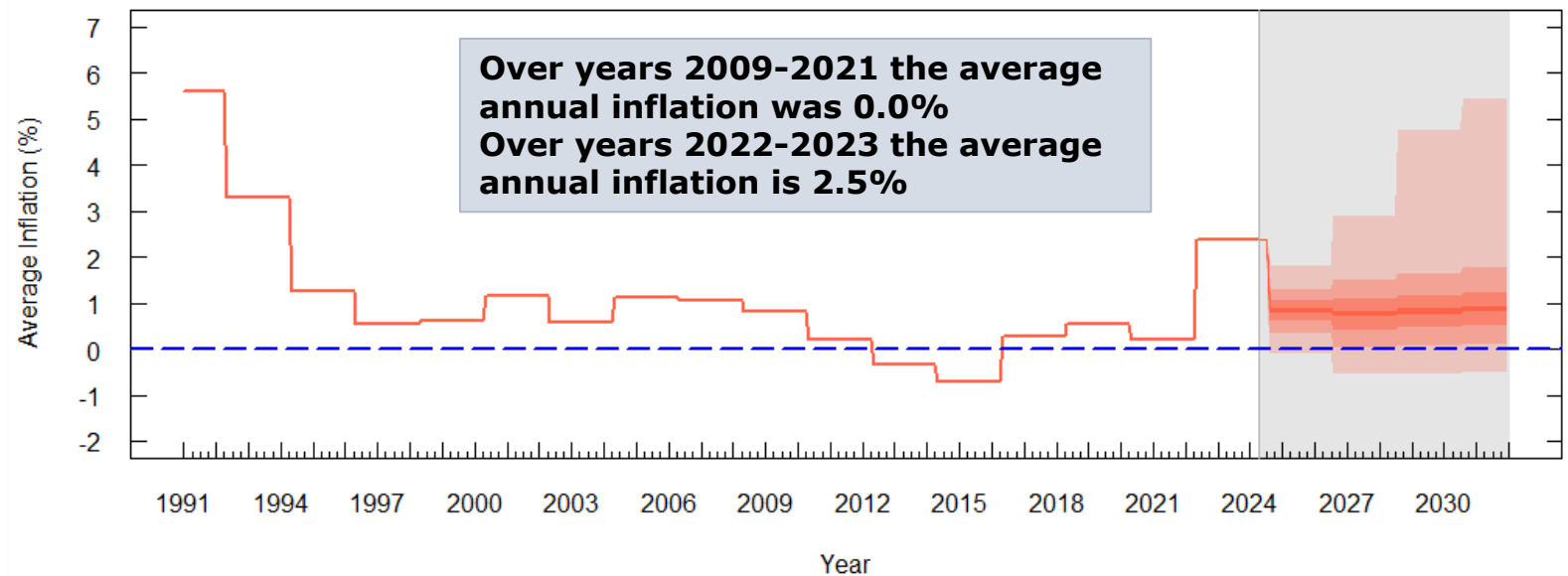allea Ltd.: Forecasted CPI based on Y10: per April 1, 2024
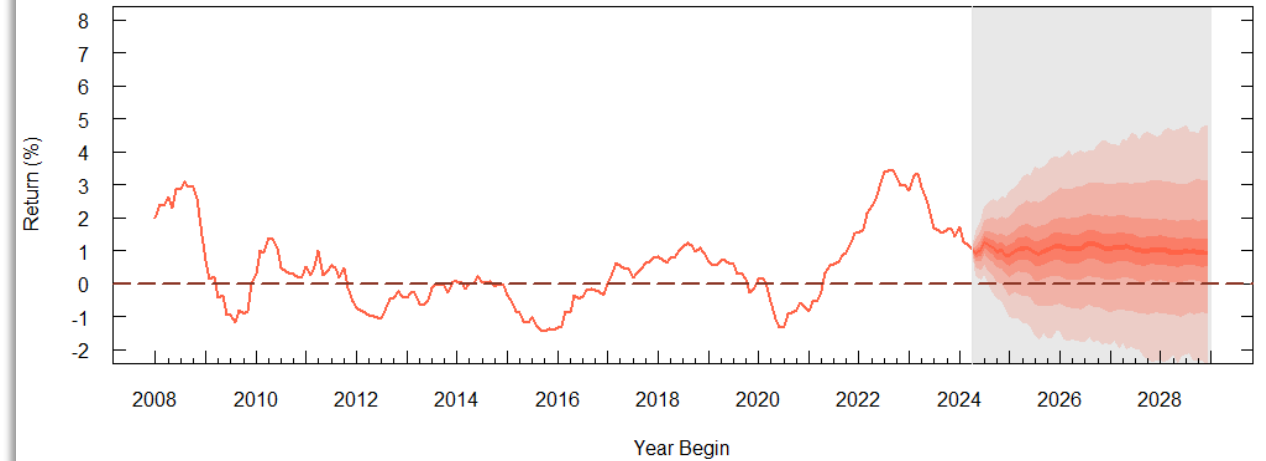
- Inflation forecasting can be prepared as well based on Y10 real and Y10 nominal returns

- Inflation = Y10 nominal – Y10 real
  - Published by Elke Eberts, Raimond Maurer (Uni Mannheim) in „Der Aktuar" 7 (2001) Heft 3 to make the forecast of the German inflation

- The inflation forecast based on Y10 historical returns corresponds to the inflation forecast prepared based on inflation (HCPI) historical data

HOW INFLATION FORECAST SUPPORTS PENSION FUNDS

- Indexation of pensions in payment (or offering bonus annuity) is made (as a rule) based on the average inflation level over the last 2-3 years
  - The board of trustees decides if the indexation or bonus annuity should be offered based on the inflation evolution

- 2009-2021 per year 0.0%

- 2022-2023 per year 2.5%

- Jan-March 2024 1.2%

- Median forecasted inflation is ca. 1%

- It would be useful to valuate potential costs to support the real benefits and decide how to finance.

Forecasted Swiss Inflation on average over 2 years

Over years 2009-2021 the average annual inflation was 0.0%
**Over years 2022-2023 the average annual inflation is 2.5%**

HOW 10-YEAR BOND YIELD FORECAST SUPPORTS PENSION FUNDS

- FRP4 Guidelines defines the upper limit for technical interest rate (to valuate liabilities) based on the 10-year government bond yield valuated on average per year based on the monthly values (for example: per Sept 30, 2023, decided for actuarial reports per 31.12.2023. The next valuation per Sept 30, 2024).

- In years 2018-2022 the upper limit was between 2.0%-2.1% - now high but goes down.
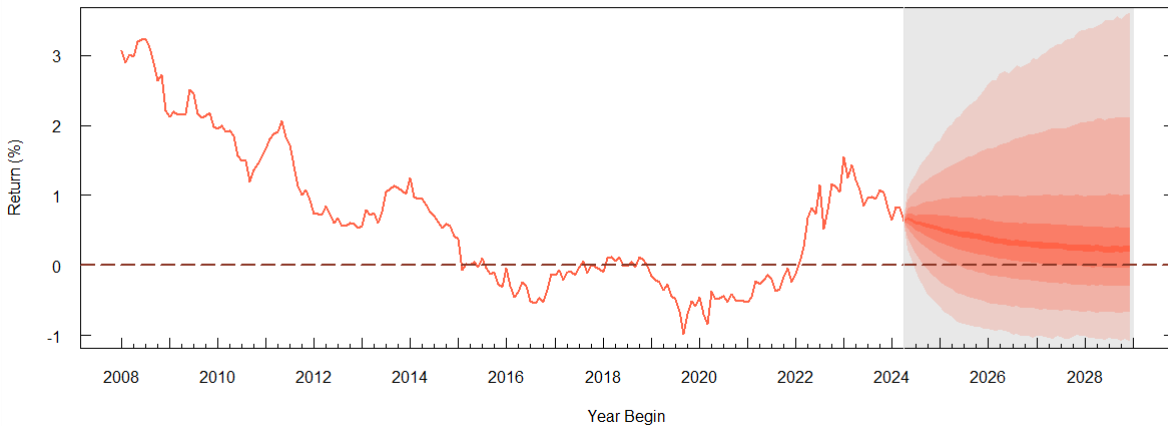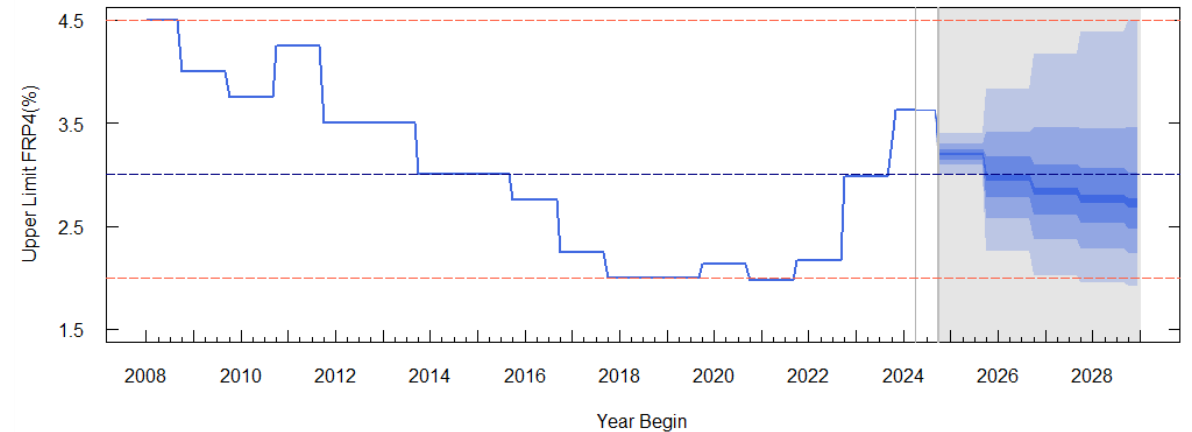
- The upper limit = average Y10 over last 12 month per Sept 30, 202X + 2.5%
  - 2.5% corresponds to the average difference between the portfolio return Pictet LPP/BVG 2005 40+ and Y10 over 20 years

- Inflation and bond yields forecasting helps to regularly communicate with pension fund membership about future benefits compared to the future costs of living.

- Inflation as a Liability Risk has a strong impact on liabilities and benefit levels of active membership and pensioners as well as on interest rates. Additionally, the direction of interest rates has a big influence on the pricing of assets (esp. bonds, equities, and real estate). It means inflation has an impact on the pension fund's Total Risk.

- In Switzerland, the inflation level after the finance crisis 2008 had been stable (on average over the period 2009-2021: the inflation rate was zero, 0%). Therefore, its current development has a strong impact on the "real" benefits of pension funds for active members and for pensions in payment.

- It would be very useful to investigate how active members and pensioners can be treated equally in terms of inflation and to make forecasts for these potential costs based on the prediction of inflation and 10-year government bond yields in advance.

- Scientific publications showed that forecasts for inflation, exchange rates, spot interest rates and other yields using Artificial Neural Network methods, provide very good predictions. Our forecasting results are based on Neural Network Autoregressive (NNAR) forecasting model (introduced by Prof. Hyndman and Prof. Athanasopoulos in 2018). The NNAR model is best suited for financial forecasting compared to the Autoregressive Integrated Moving Average (ARIMA) model

PhD Ljudmila Bertschi is a qualified member of the Swiss actuarial association (SAV/SAA) and an accredited pension actuary of the Swiss chamber of pension fund experts (SKPE).

She has a PhD in phys.-math. from the MSU and has worked in pension fund consulting for about 20 years in different Swiss and international consulting firms. She conducted a research study for the Federal Office of Social Security (2015), prepared many publications for international conferences as well as made presentations for Swiss chamber of pension fund experts (SKPE)

ABOUT ME

PhD. Ljudmila Bertschi

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Dr. Mauro Triulzi is a qualified member of the Swiss actuarial association (SAV) and has a Dr. sc. math. ETH.

He has worked for about 20 years as a developer of actuarial tools and implemented the nested stochastic modelling for pension fund liabilities including mortality rates for ALM studies. Currently he develops different actuarial tools for local and international accounting valuations as well as pension fund administration services.

Ljudmila Bertschi and Mauro Triulzi prepared and presented the EAA-Workshop on Oct 9, 2023, to this topic

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Thank you very much for your attention

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