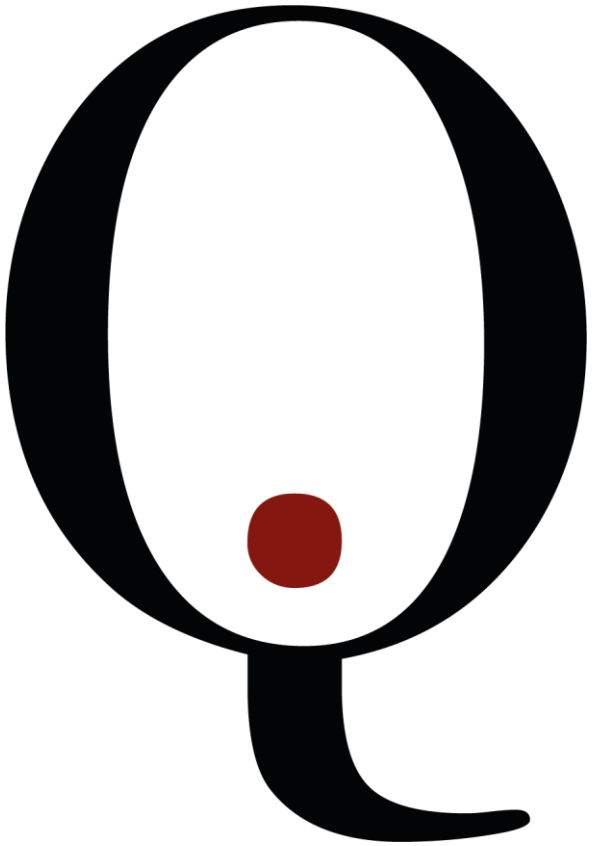
Putting Data into Context — How to Apply Macroeconomics in Finance



EPFL - Lausanne, November 2025
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Agenda for today

- Quantitative Risk Management
- Our Aim for Today
- Maneuvering in Macro Space
- Real GDP and Output Gaps
- Inflation and its Components
- The Neutral Rate of Interest (r*)
- Central Bank Policy Rate
- How to Apply Covered Theory in Practice

Quantitative Risk Management

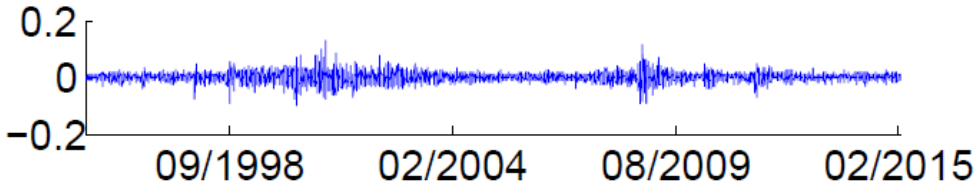
Your portfolio of knowhow… so far so good

Quantitative Risk Management
Your portfolio of knowhow… so far so good

Financial time series

- Stylized facts
- ARMA Processes
- GARCH models

Empirical Returns vs. Normal Returns vs. Student's t Returns



For the $GARCH(1,1)$ case, rewrite the volatility equation as:

$$\sigma_t^2 = \alpha_0 + (\alpha_1 Z_{t-1}^2 + \beta_1)\sigma_{t-1}^2$$

Estimating Parameters

We would like to compute the values of the parameters that maximize the likelihood function:

where we can write:

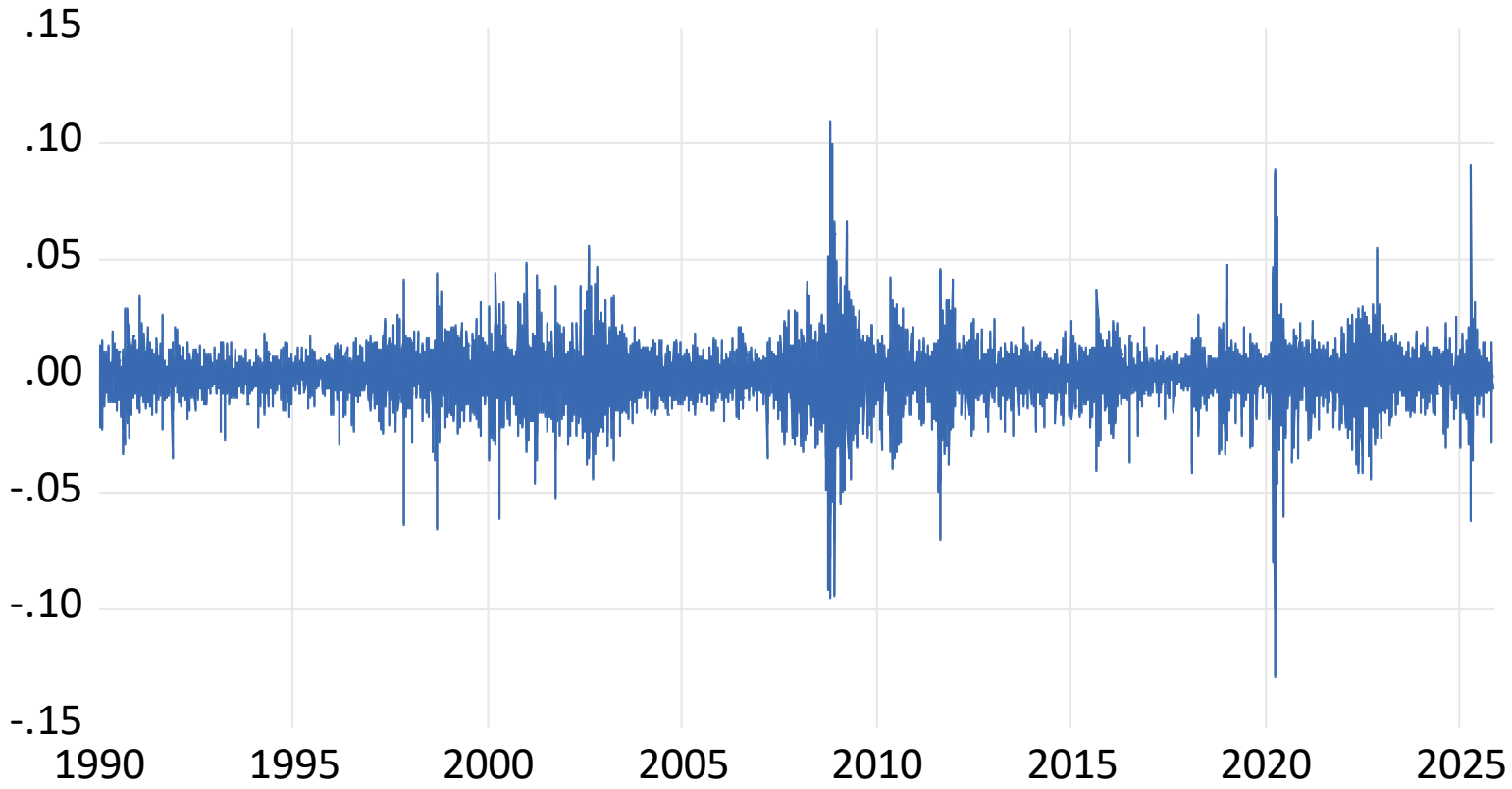
$$\log\Big(L(\alpha_0, \alpha_1, \beta_1; \boldsymbol{X})\Big) = \sum_{t=1}^{n} l_t(\alpha_0, \alpha_1, \beta_1)$$

Quantitative Risk Management

Use know-how to estimate the conditional variance

Financial time series

- Observed raw return data over time
- Observed VIX index over time



Quantitative Risk Management

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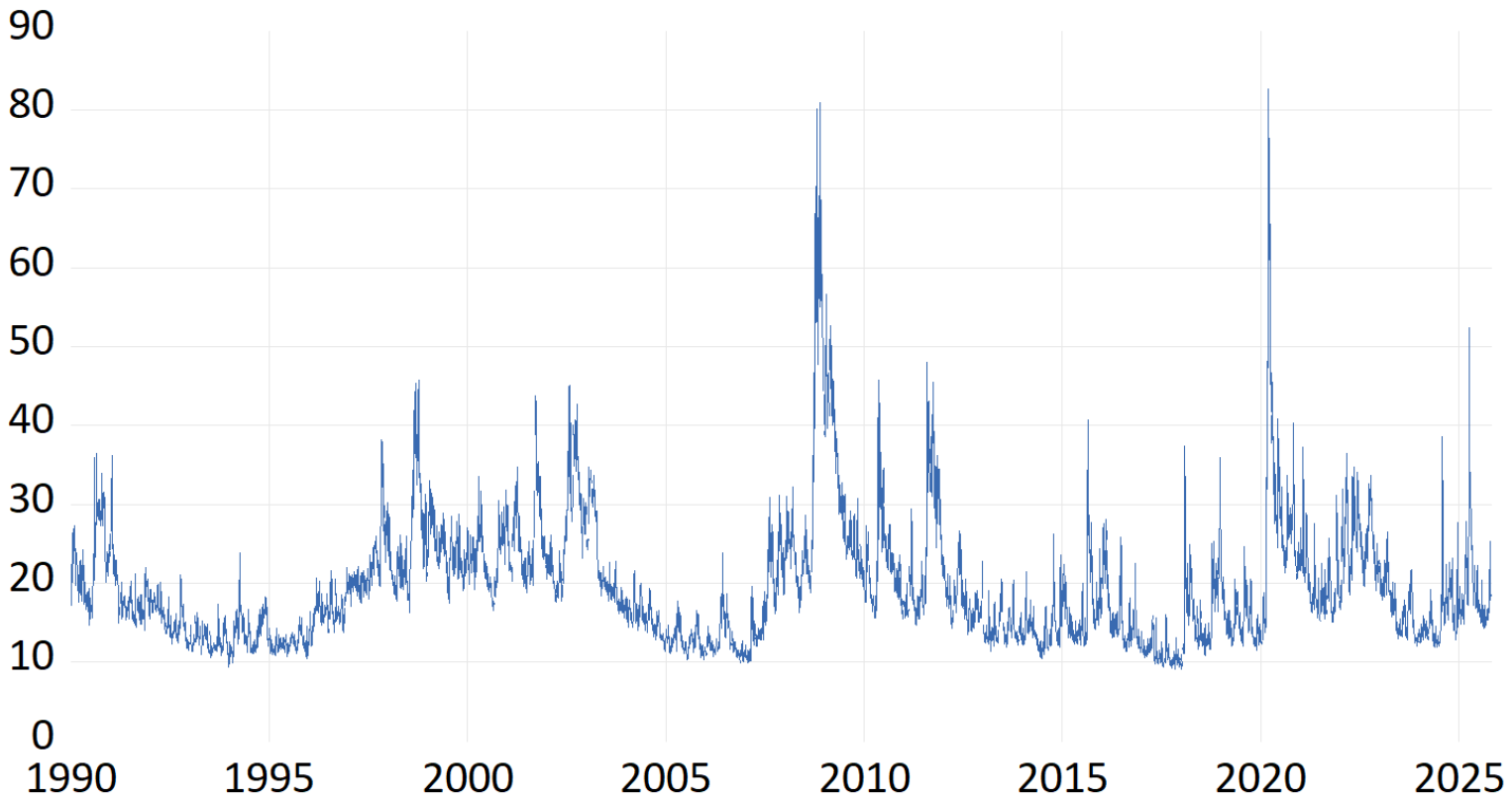
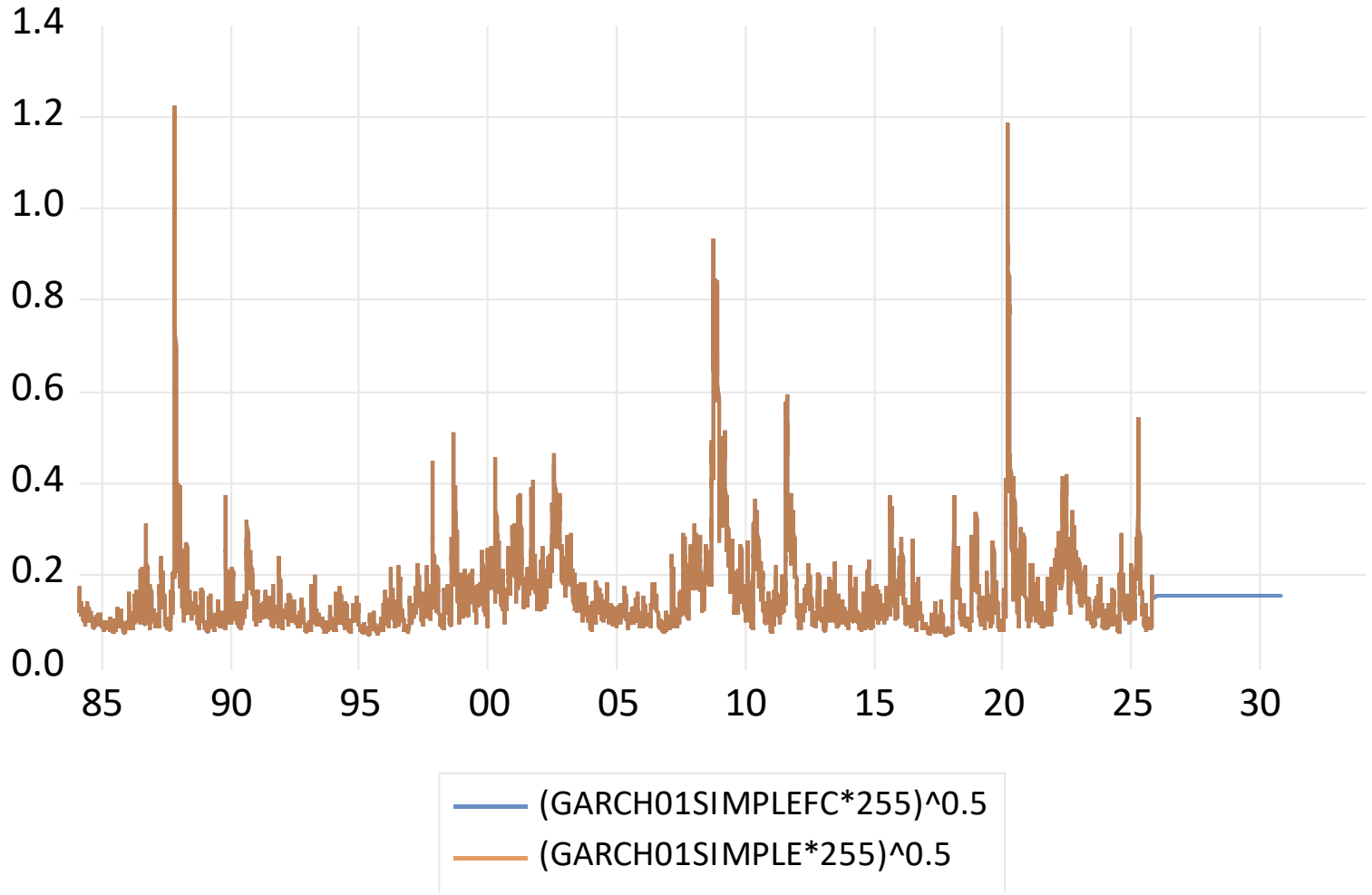


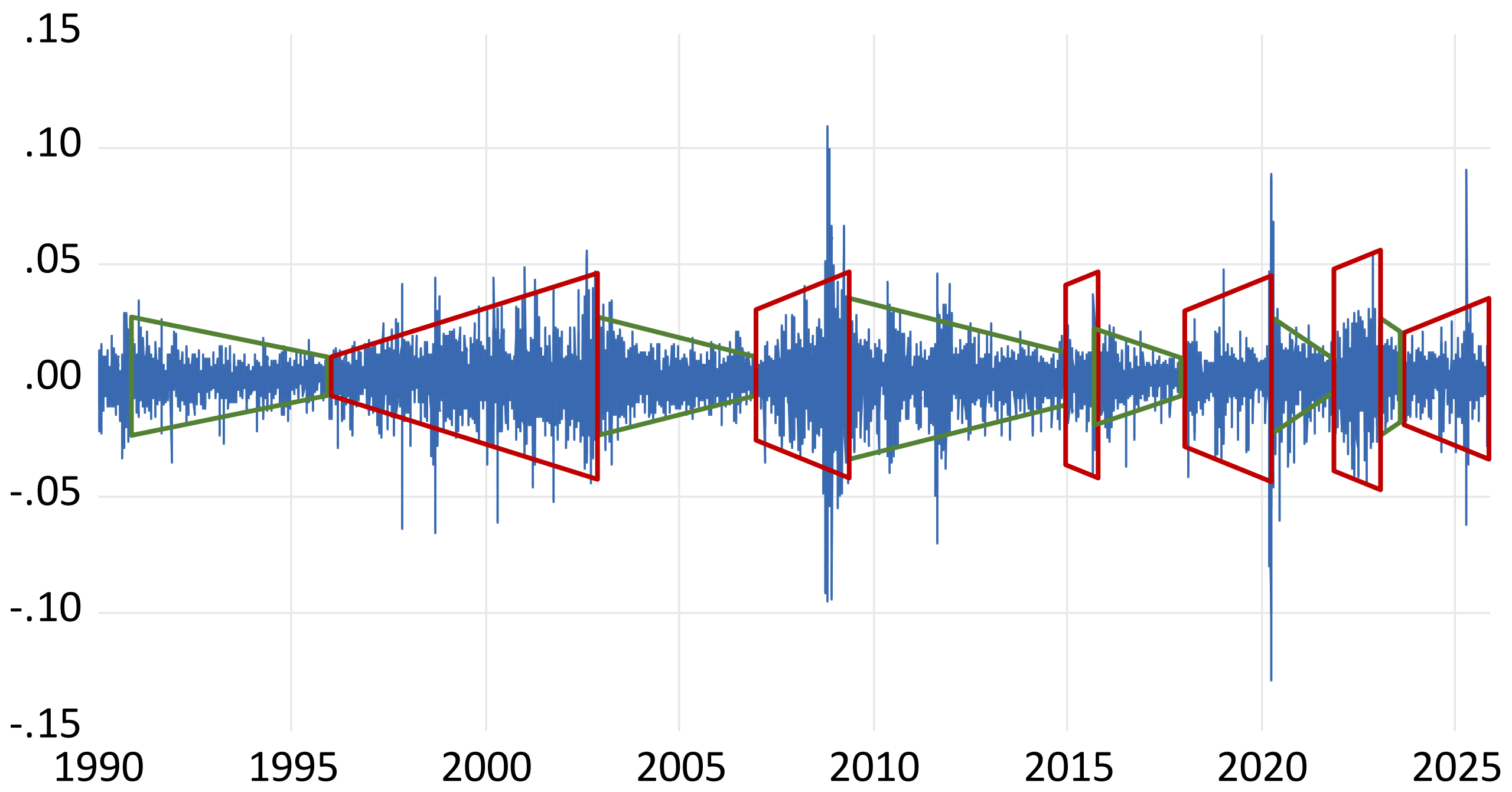
Quantitative Risk Management

And you can do some forecasts…

Financial time series

- GARCH (1,1) conditional variance^2
  - Full sample
  - Red sample
  - Green sample




.15
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1990
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2010
2015
2020
2025

Our aim for today:
Macro data and quantitative risk management

We want you to learn how macroeconomic data can help you better understand (i.e. model) measures that are relevant for quantitative risk management

Our aim for today:
Macro data and quantitative risk management

And we will do this by particularly focusing on the idea to cluster data according to regimes.

Our aim for today:
Macro data and quantitative risk management

Or put differently, we want to learn how to give a macroeconomic context to observed data in quantitative risk management.

Our aim for today:

Macro data and quantitative risk management

Growth (GDP) and *potential growth*

Inflation and its variants

Neutral Rate of interest

Central Bank **Policy Rate**

Form Regimes

Estimate Returns

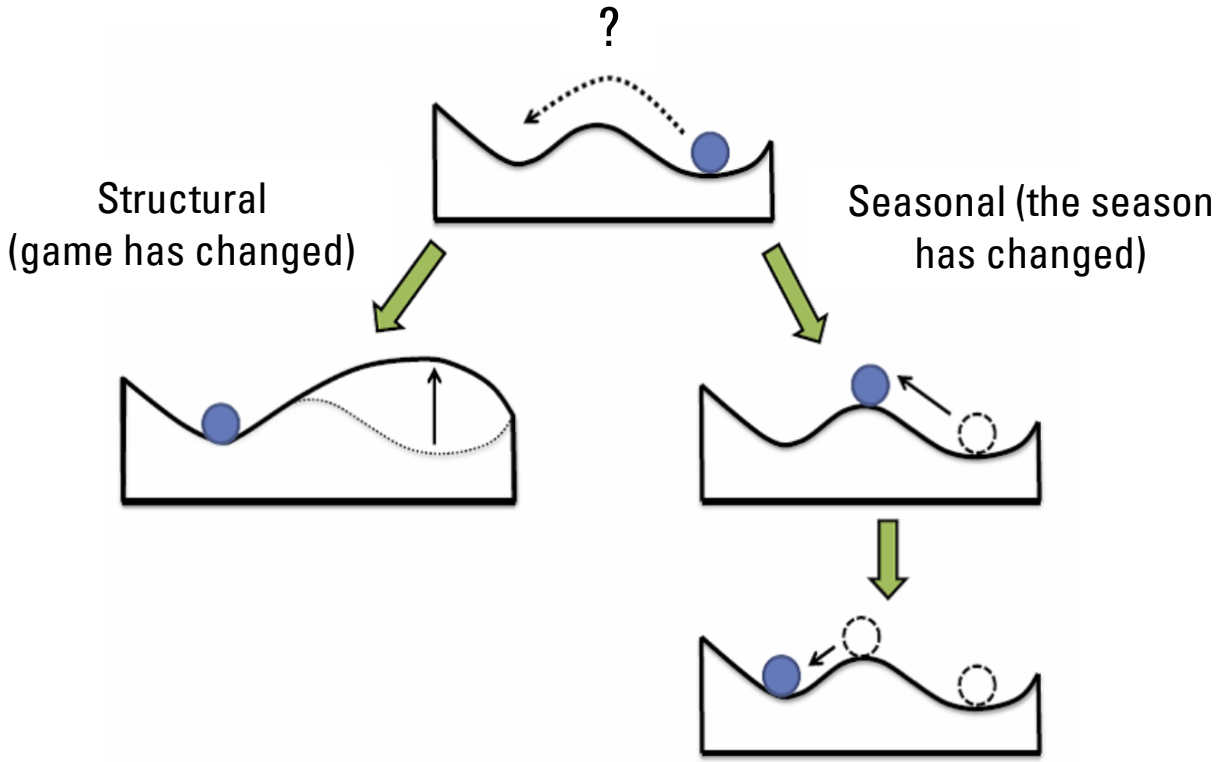
Estimate Risks

Maneuvering in Macro Space

Basic concepts and interdependencies

How to define macroeconomic space?
Let's start first by thinking about regimes

Structural vs. Seasonal Regimes



How to define macroeconomic space?
Let's start first by thinking about regimes

Personality driven political regimes...

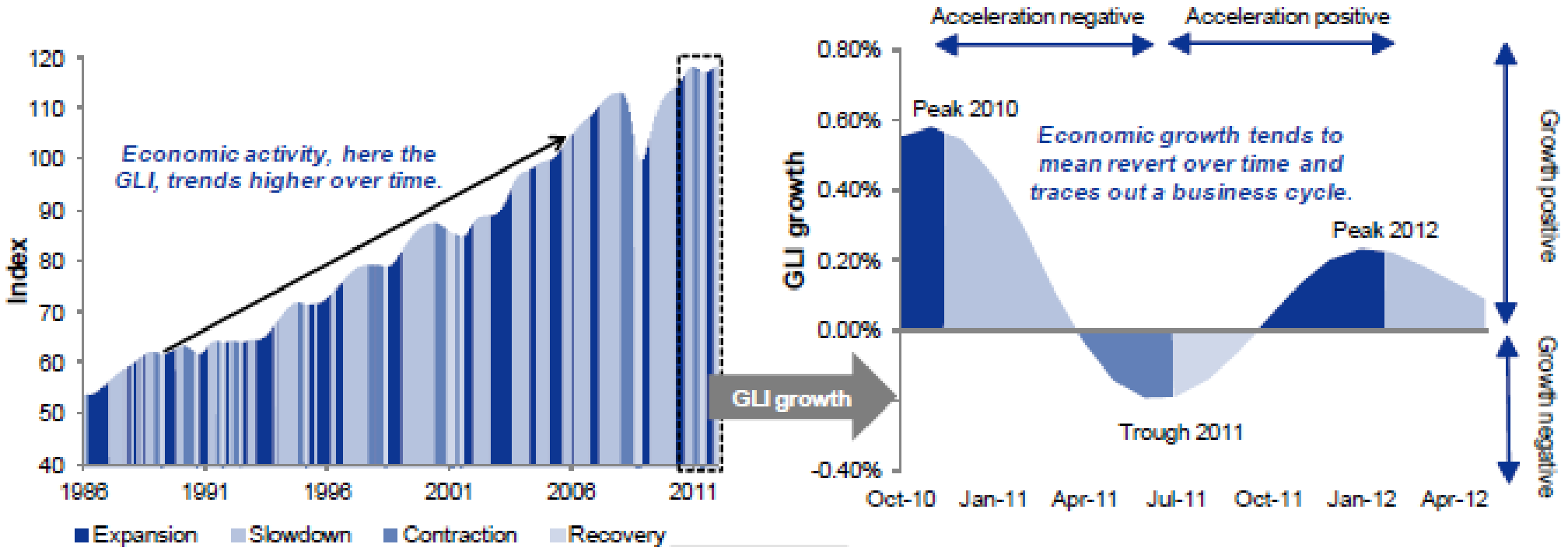




How to define macroeconomic space?

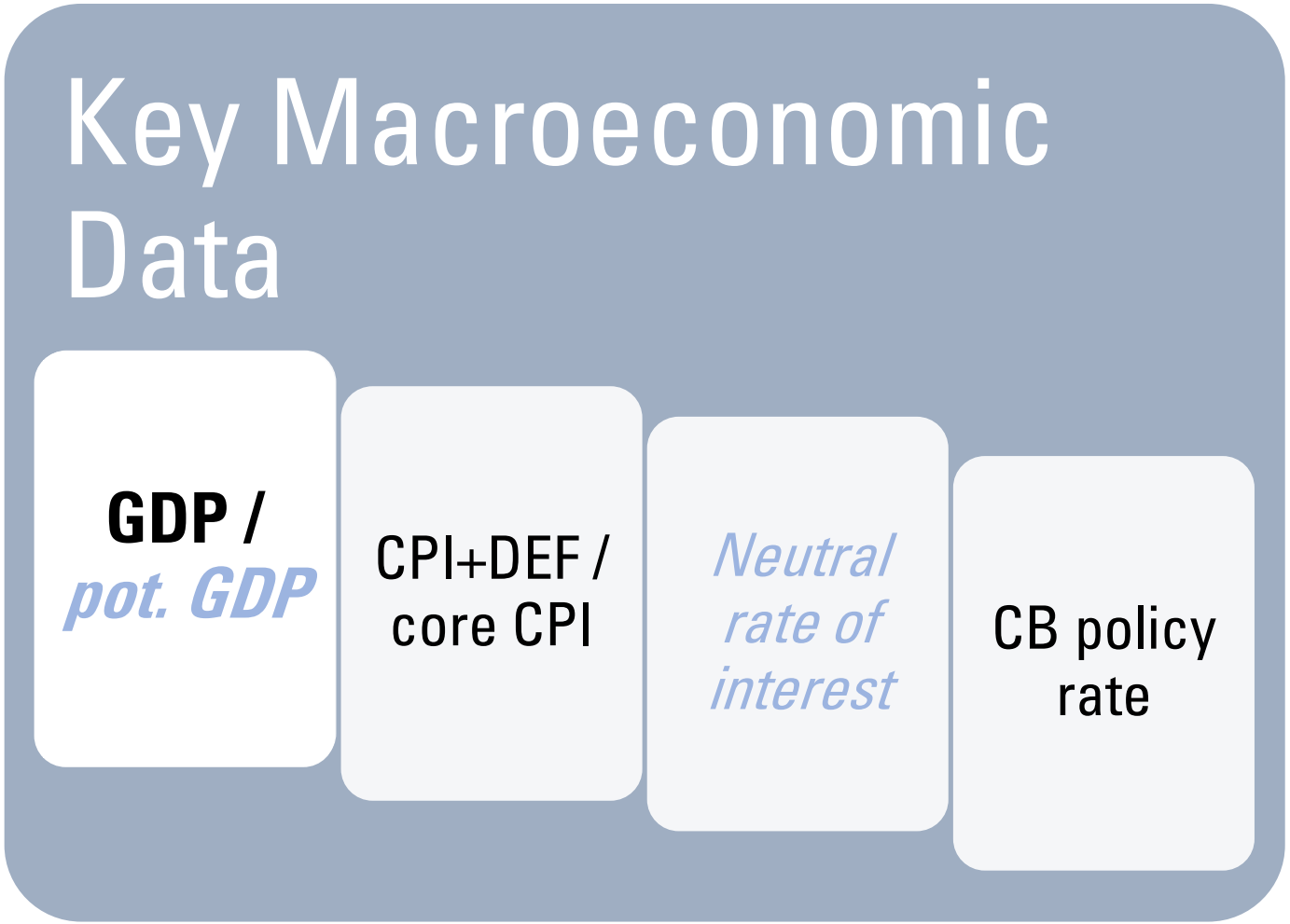
Let's start first by thinking about regimes

Vs. data regimes...



Source: Goldman Sachs

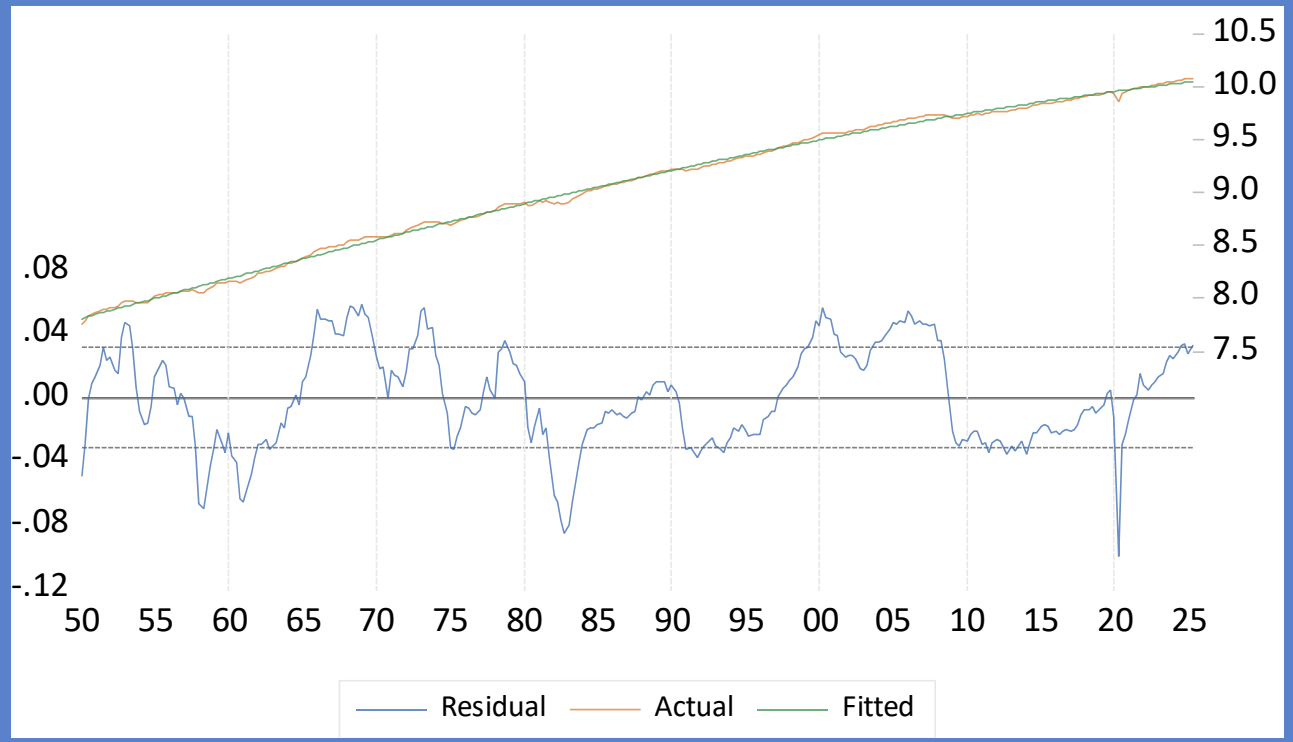
Key Macroeconomic Data you should be familiar
Real GDP and Output Gaps



Among all the various forms of data, we have four sets of data that are fundamental to understanding how economies work (macroeconomic **transition mechanism**), how they evolve (central bank **reaction functions**), and how they get into trouble.

Real GDP and Output Gaps
Observed vs unobserved elements

GDP /
pot. GDP

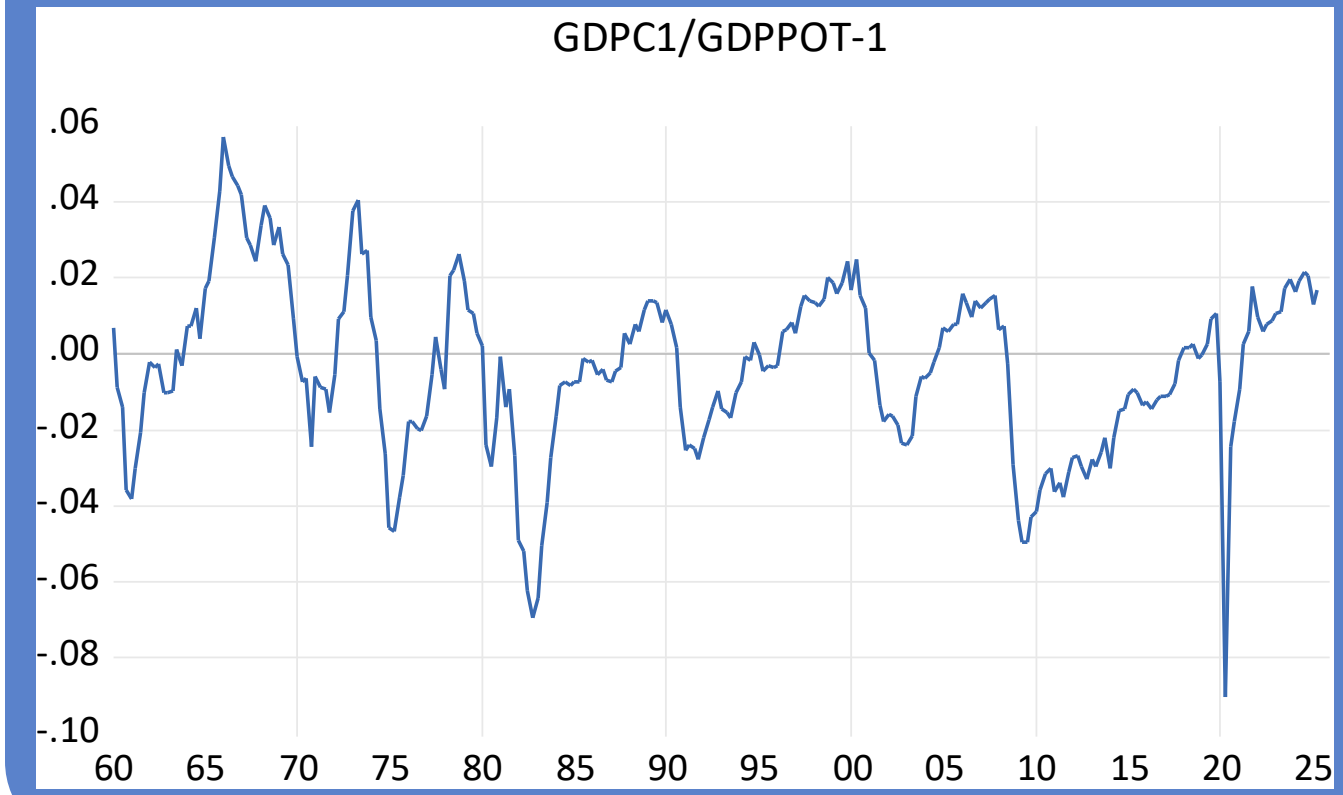


- Real GDP: actual output, inflation-adjusted
- Potential GDP: sustainable output at full capacity (unobservable)
- Output Gap = Real GDP / Potential GDP (unobservable)

- **Key signal for economic slack or overheating**

Real GDP and Output Gaps
Observed vs unobserved elements

GDP / *pot. GDP-1*



- Real GDP: actual output, inflation-adjusted
- Potential GDP: sustainable output at full capacity (unobservable)
- Output Gap = Real GDP / Potential GDP (unobservable)

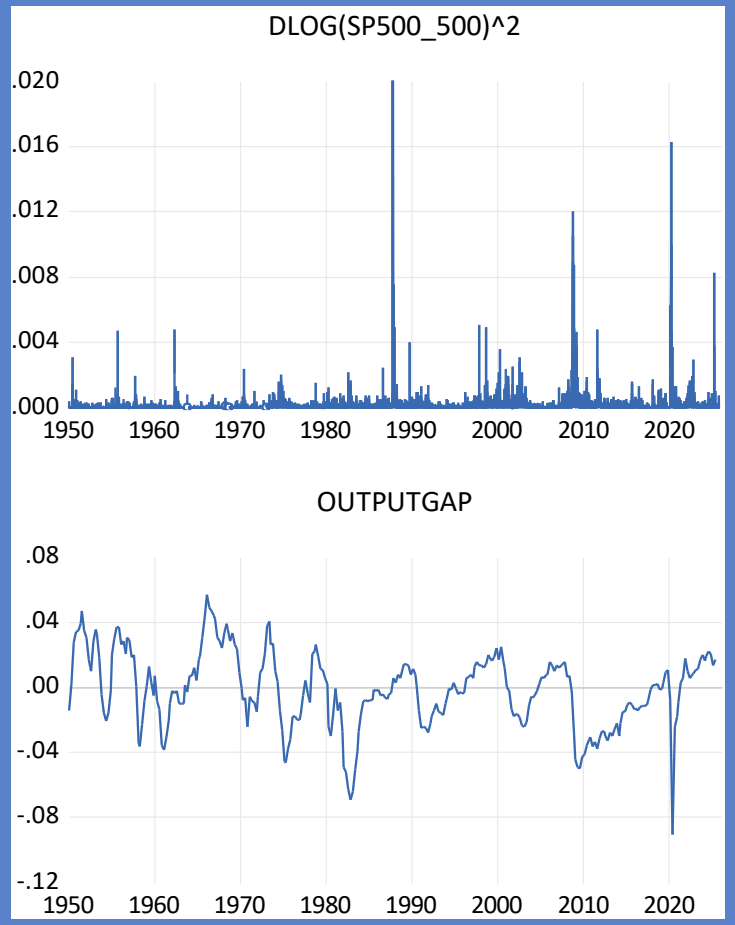
- **Key signal for economic slack or overheating**

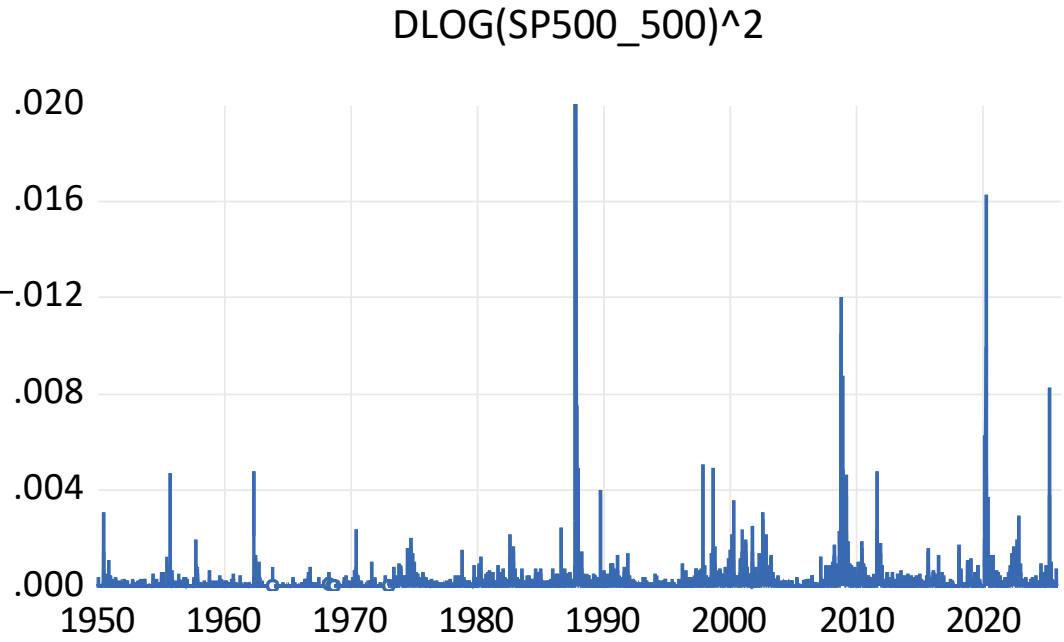
Real GDP and Output Gaps

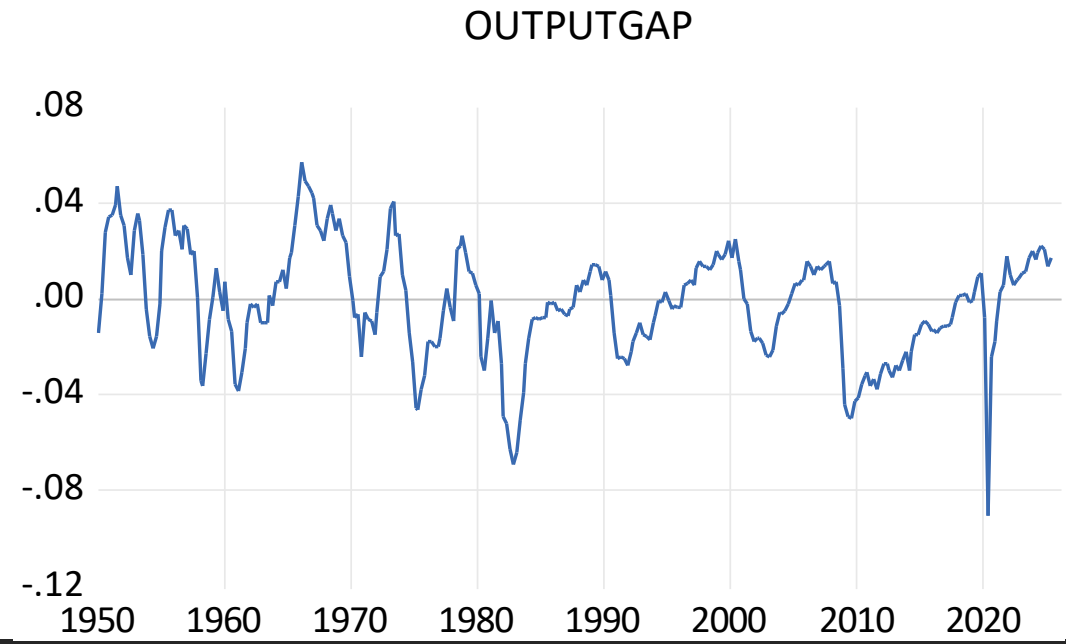
A first idea about regimes

GDP / *pot. GDP-1*

Vs. Sqrt(dlog(SPX))



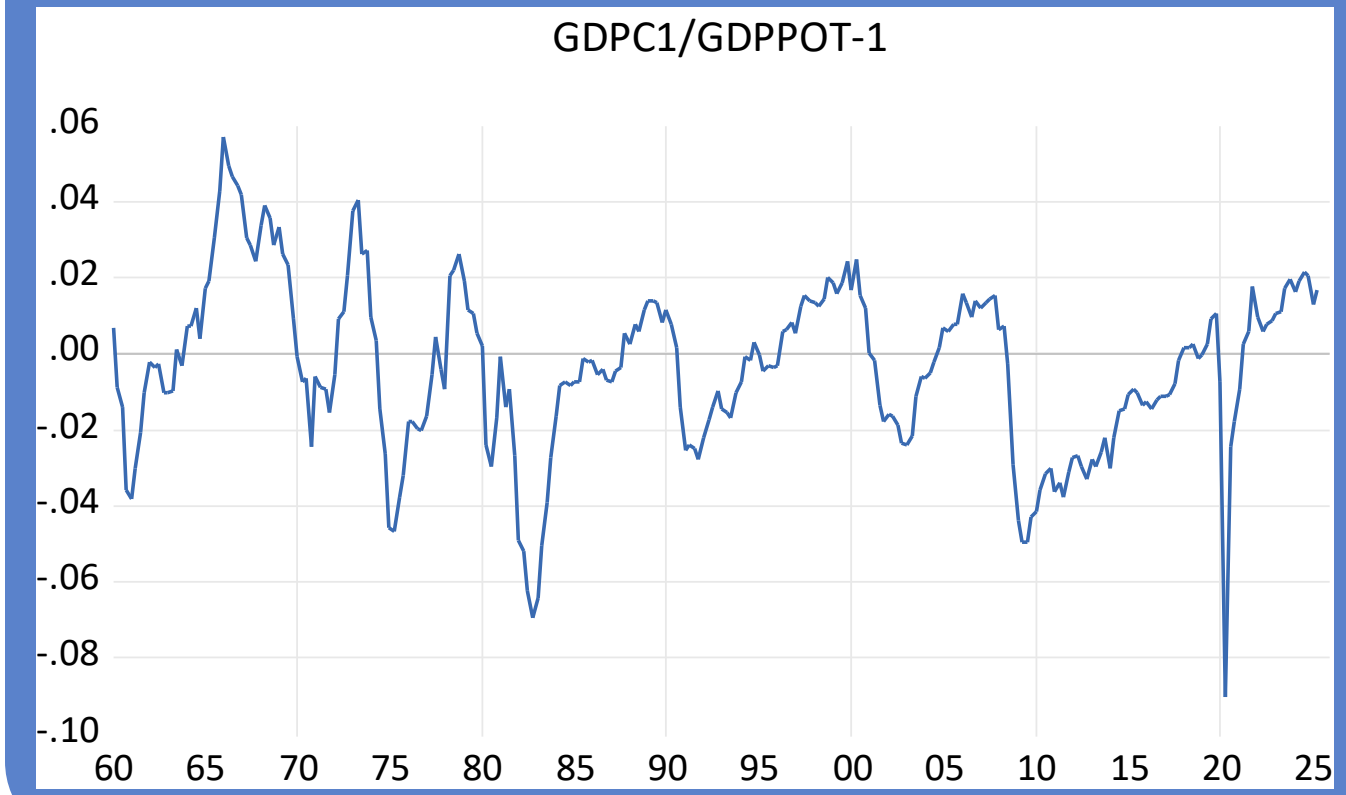




Real GDP and Output Gaps

Linking output gap to an economic model:

GDP / *pot. GDP-1*



Aggregate demand (referred to as IS curve)

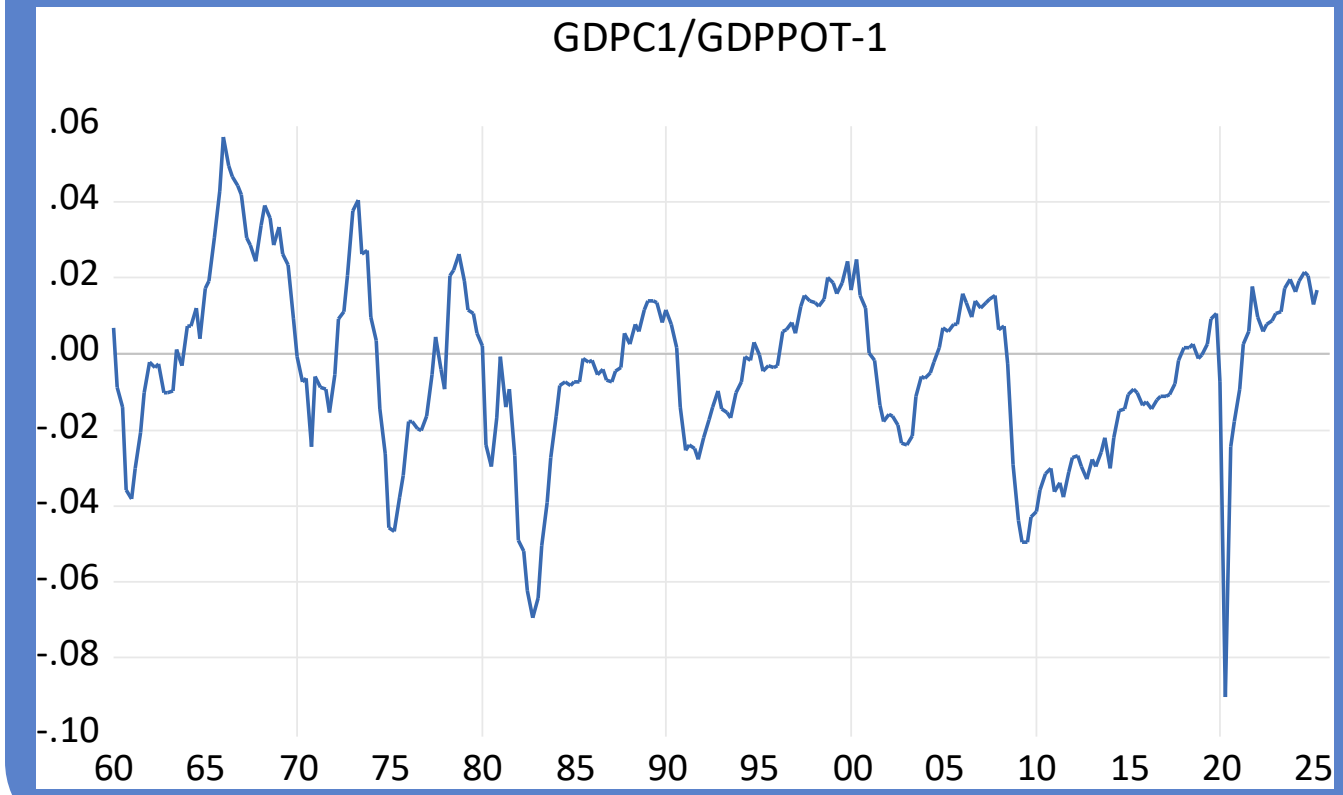
$$y_t = \mathrm{E}_t y_{t+1} - \alpha\left(r_t - r^0\right) + \xi_t$$

- Today's output (gap) as a function of the next period's expected output (gap), the real policy rate and the policy rate at "zero/neutral" growth.
- This is just one example of a New Keynesian model for a closed economy.

Real GDP and Output Gaps

Why estimate potential GDP and output gaps?

GDP / *pot. GDP-1*



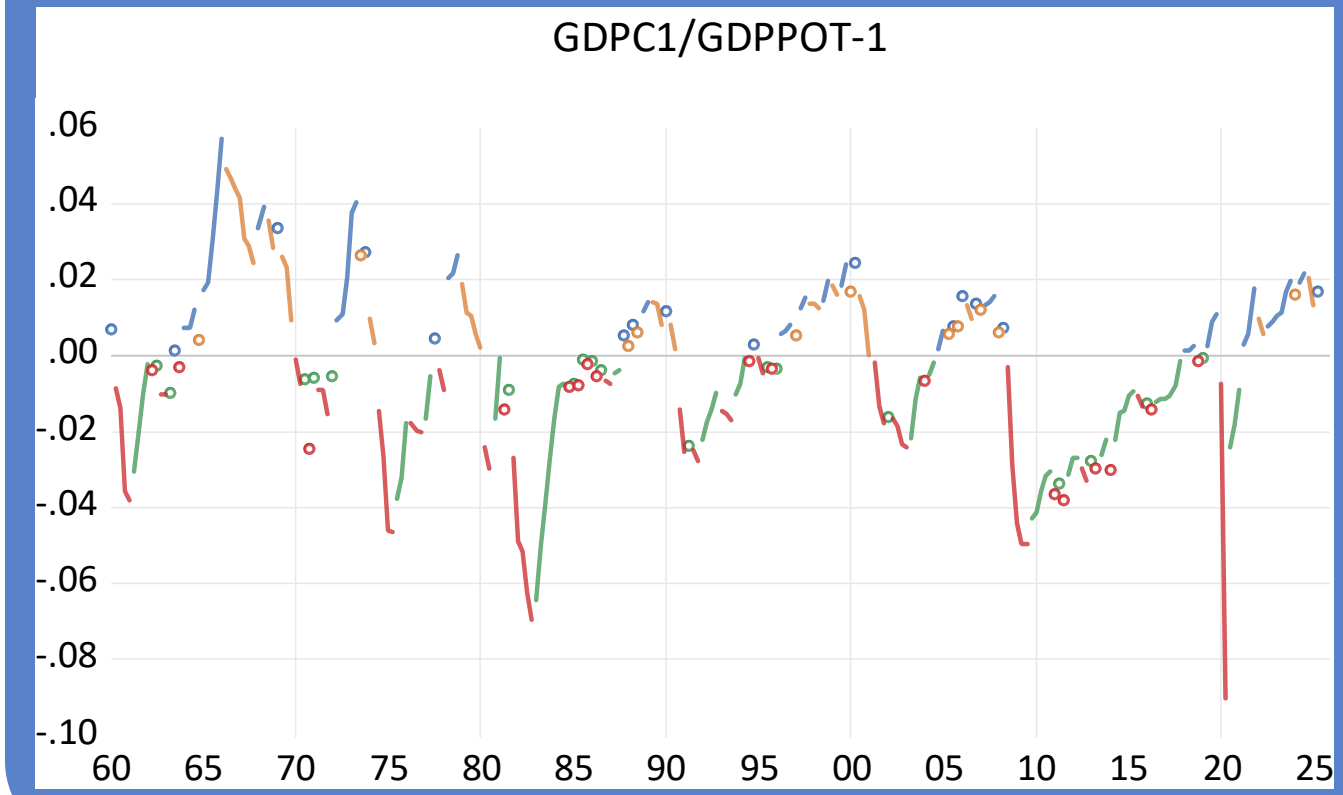
It is important because:

- Anchors economic capacity and trend growth
- Input for monetary policy (e.g., Taylor rule)
- Distinguishes cyclical vs. structural changes
- Used to detect output gaps → inflation signals

Real GDP and Output Gaps

The easiest way to think about regimes

GDP / *pot. GDP-1*

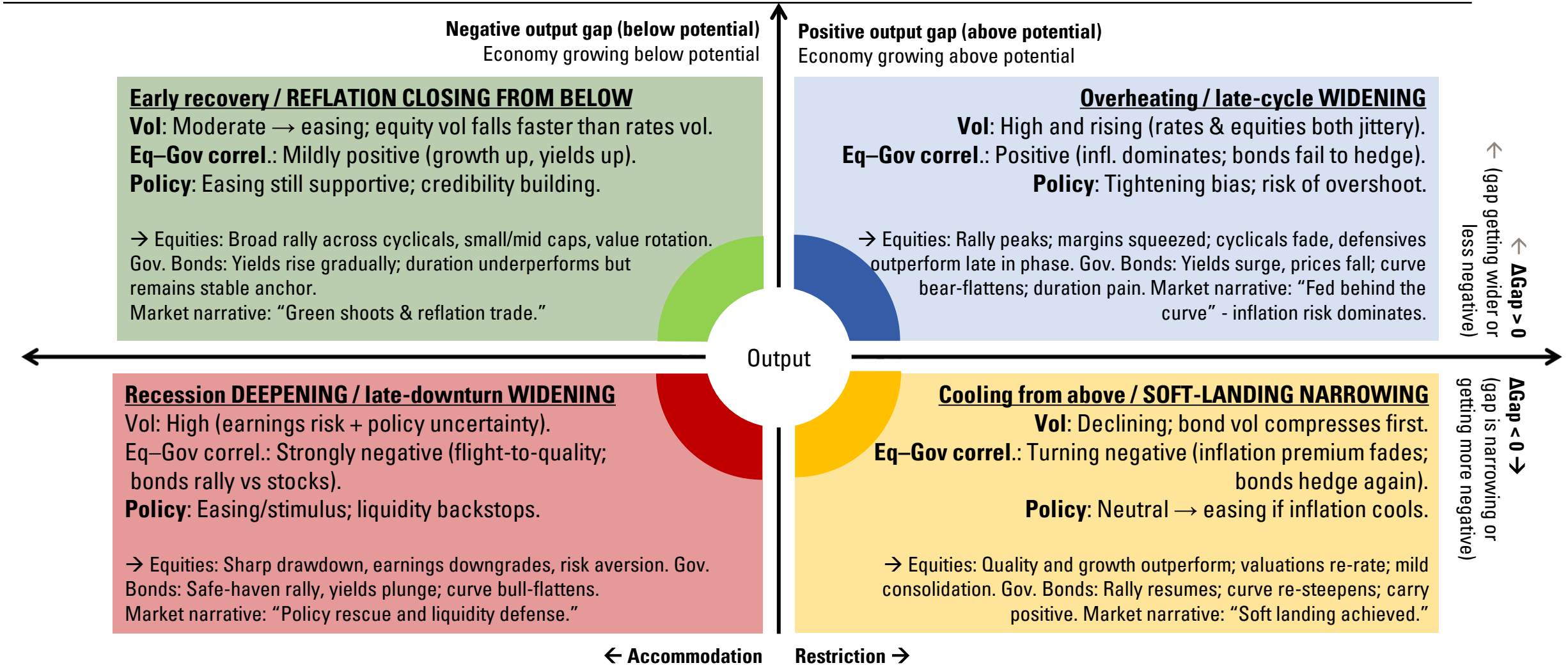


Use it as a regime indicator

- Positive and increasing
- Positive and falling
- Negative and falling
- Negative and increasing

Real GDP and Output Gaps

Output Gap – Volatility & Equity–Bond Correlation



Real GDP and Output Gaps

The price % return of the S&P 500 across regimes

Descr. stats for S&P500 price index % returns

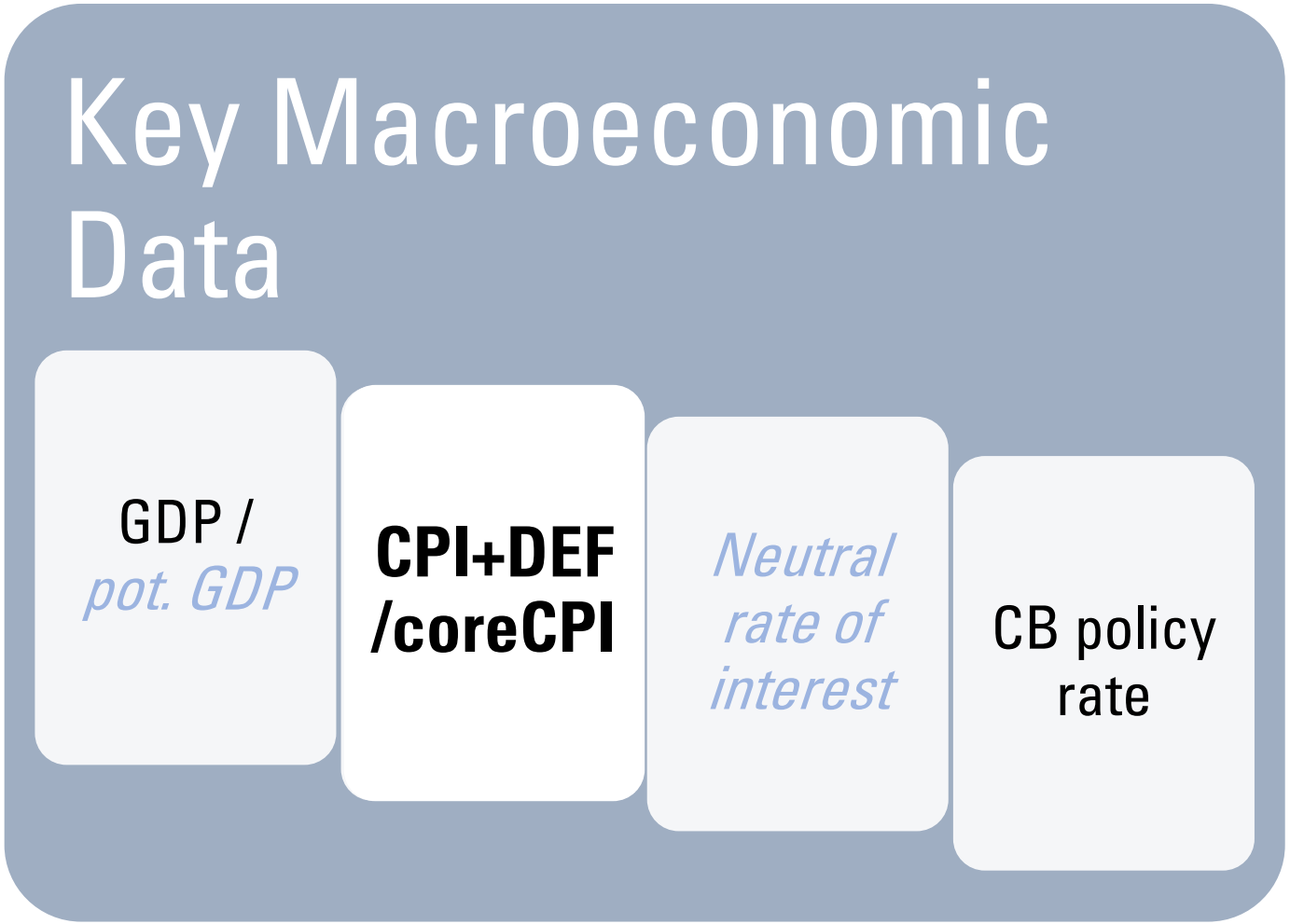
Date: 11/09/25 Time: 11:49
Sample: 1960Q1 2030Q4

	Top Left	Top Right	Bottom Right	Bottom Left
Mean	4.562149	2.535321	2.058545	-0.776533
Median	4.690138	3.787750	2.136736	0.169761
Maximum	21.58693	14.54265	20.86705	16.03691
Minimum	-20.00105	-23.22344	-10.30392	-26.11628
Std. Dev.	8.152504	6.725720	6.489388	8.949527
Skewness	-0.505210	-1.302009	0.342767	-0.672471
Kurtosis	3.608611	5.861833	3.493934	3.189185
Jarque-Bera	4.290016	40.54645	1.457602	5.533975
Probability	0.117067	0.000000	0.482487	0.062851
Sum	337.5991	164.7958	100.8687	-55.91040
Sum Sq. Dev.	4851.823	2895.060	2021.383	5686.676
Observations	74	65	49	72

Applying the following criteria for regime discrimination

- OP: Negative and improving
- OG: Positive and improving
- OP: Positive and falling
- OP: Negative and falling

Key Macroeconomic Data you should be familiar
Inflation & inflation expectations and its siblings

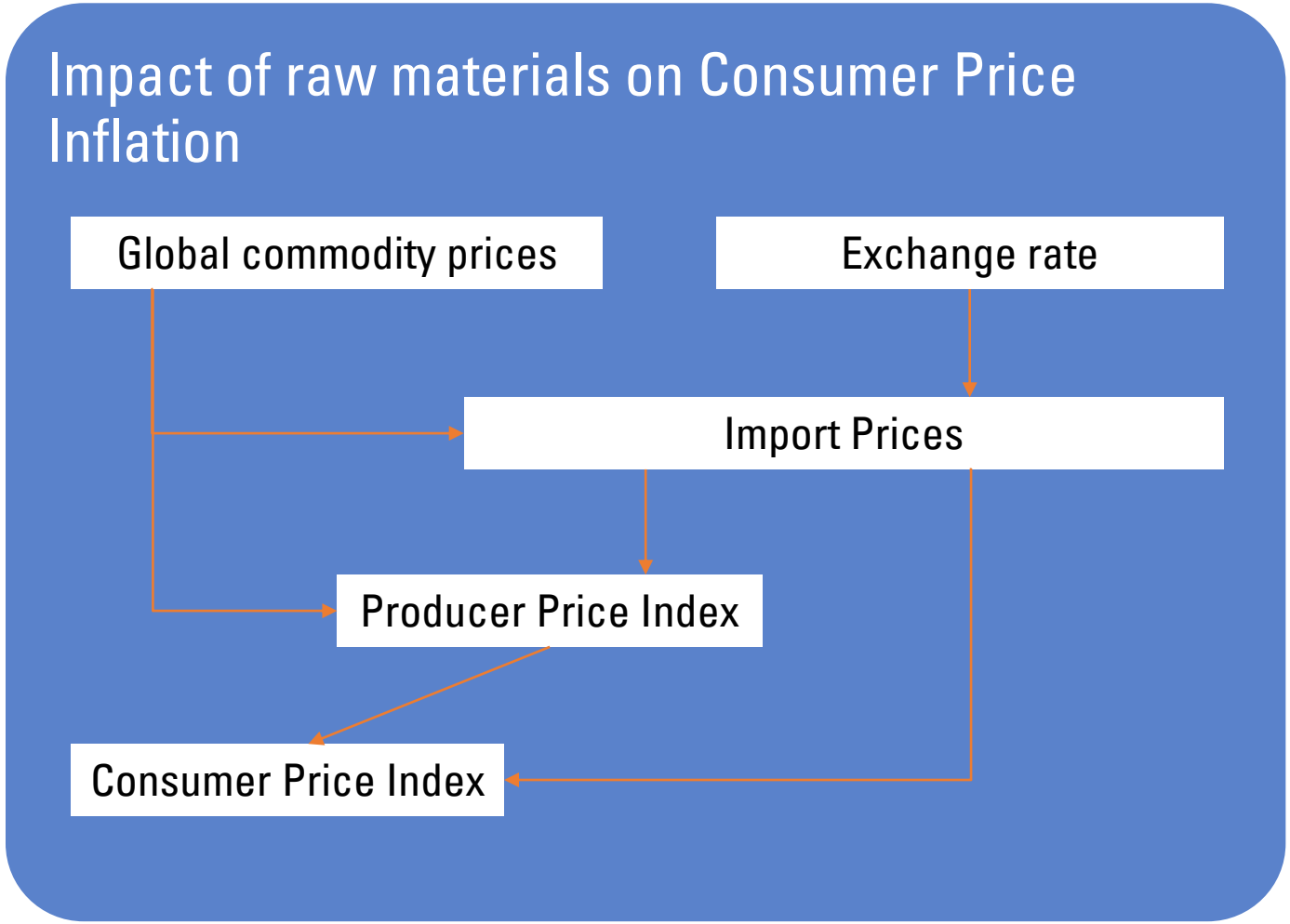


What is Inflation?

- Sustained increase in the general price level
- Reduces purchasing power of money
- Affects consumers, businesses, and markets

Inflation and its components

Inflation & inflation expectations and its siblings



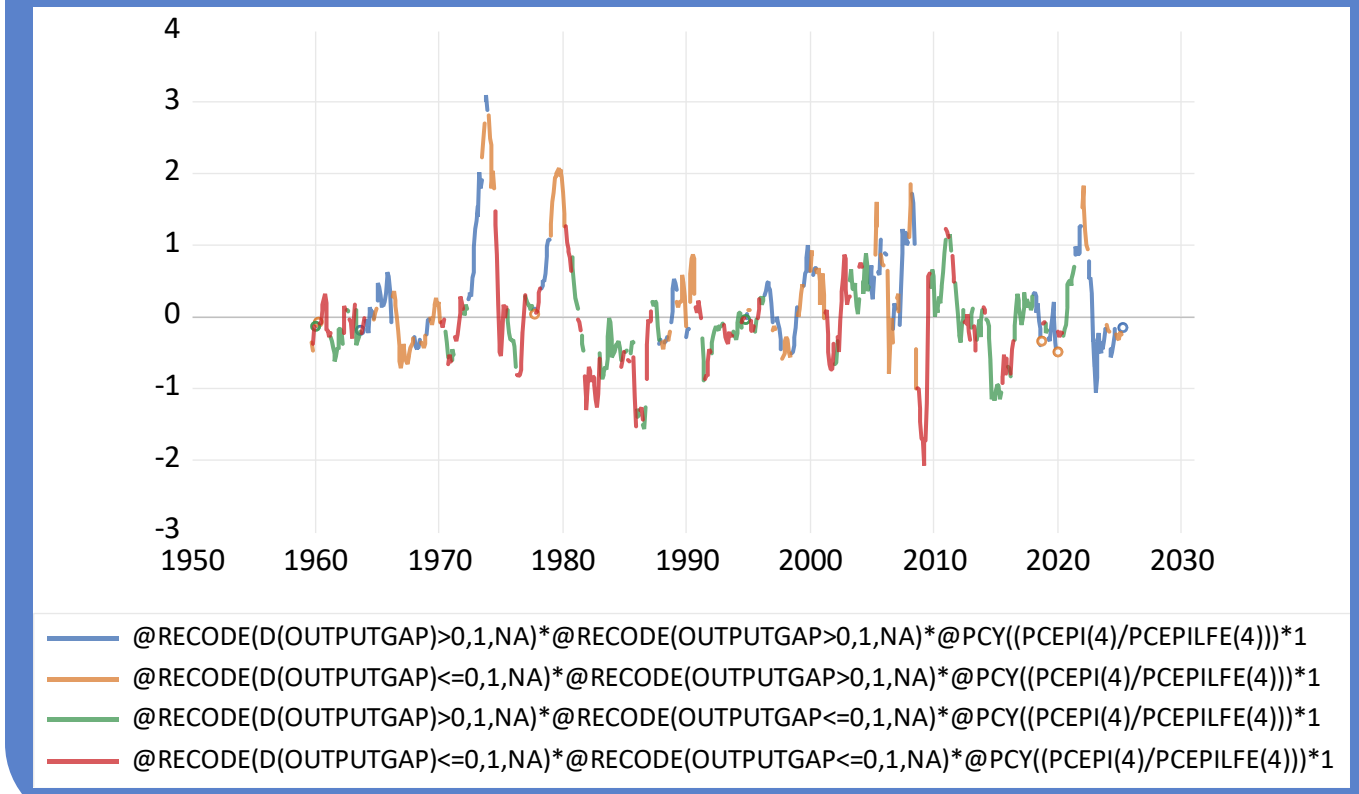
What drives Inflation?

- Demand-pull: output gap, excess demand (fiscal stim.)
- Cost-push: wages, import prices, supply shocks
- Inflation expectations: adaptive or rational models
- Global factors: commodities, supply chains, FX rates

Inflation and its components

Linking inflation to an economic model:

Inflation (headline/core) relative to output (gap)



How linked to theory?

Aggregate supply (referred to as Phillips curve)

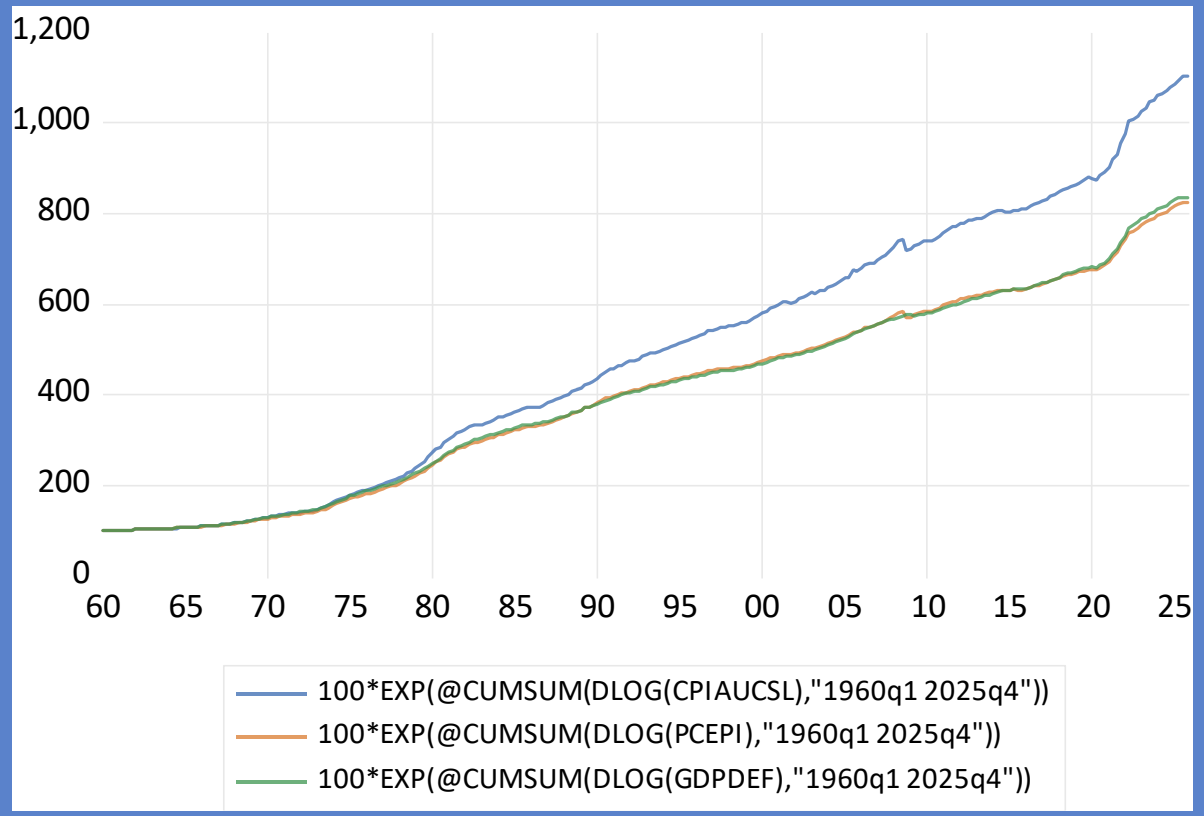
$$\pi_t = \beta \, \mathrm{E}_t \pi_{t+1} + \lambda\left(y_t - y_t^{pot}\right) + \varepsilon_t$$

- Today's inflation as a function of the next period's expected inflation and the output gap (beta represents time discount factor close to one).

Inflation and its components

Understanding how inflation can be measured

CPI vs. PCE Price Index vs. GDP deflator

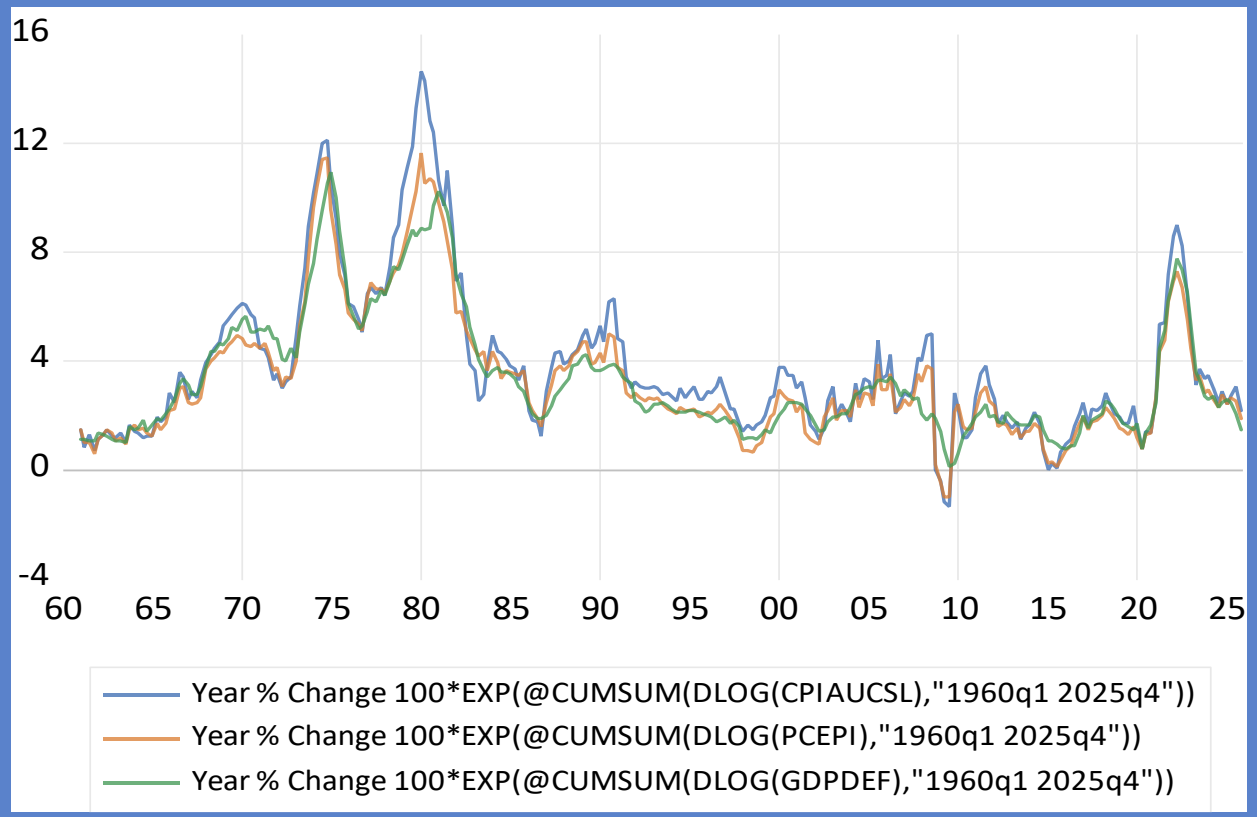


- CPI: Measures price change of a typical fixed (to some reference date) **consumer** basket (including imports)
- PCE-PI: broader than CPI (including enterprises / gov.)
- GDP Deflator: Price index for all home-**produced** goods / services that change with consumption and investment composition (C+I+G+NX)

Inflation and its components

Understanding what different measures capture

CPI vs. PCE Price Index vs. GDP deflator

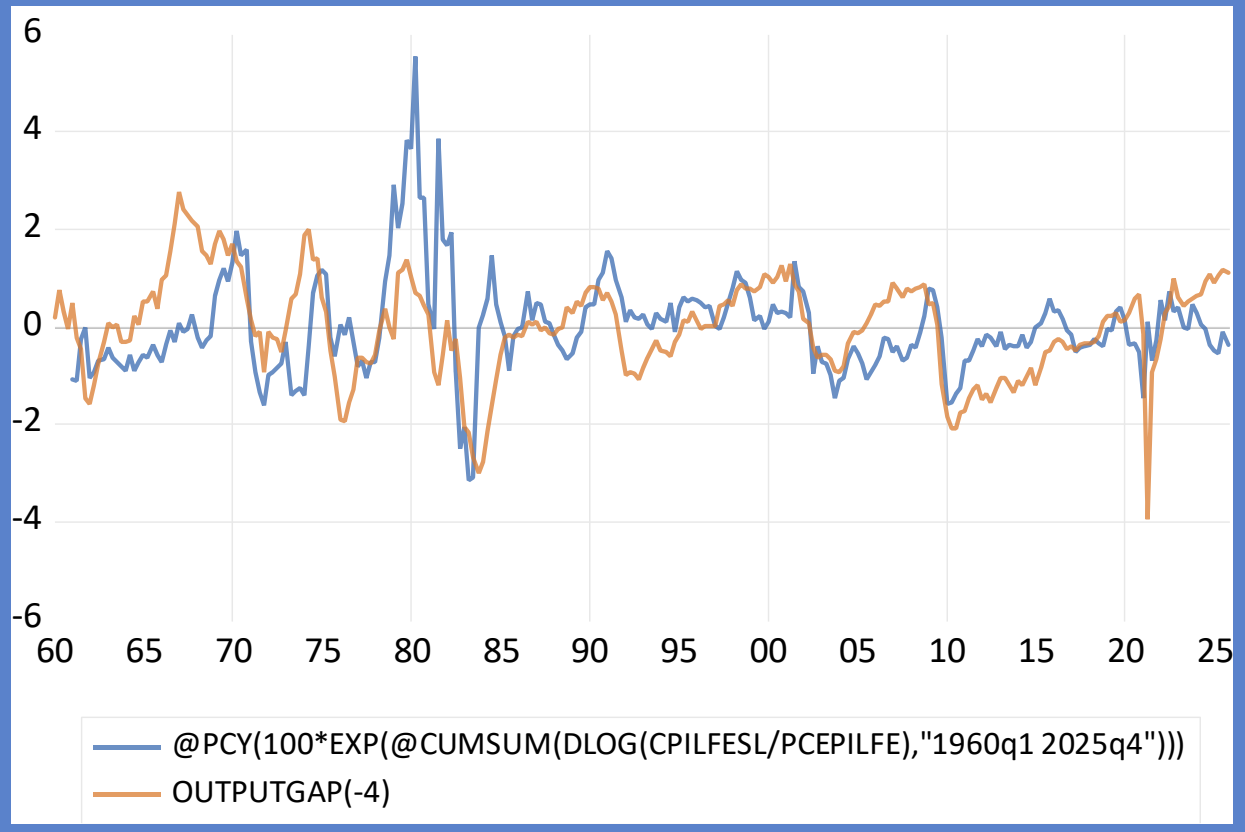


- CPI: How much more does it cost for a typical consumer to maintain the ***same*** **standard of living? – fixed basket**
- PCE-PI: broad-**floating basket**
- GDP Deflator: How much have the prices of all ***home-produced*** **goods and services** risen on average? – **changing basket**

Inflation and its components

Understanding what different measures capture

CPI vs. PCE Price Index to output gap

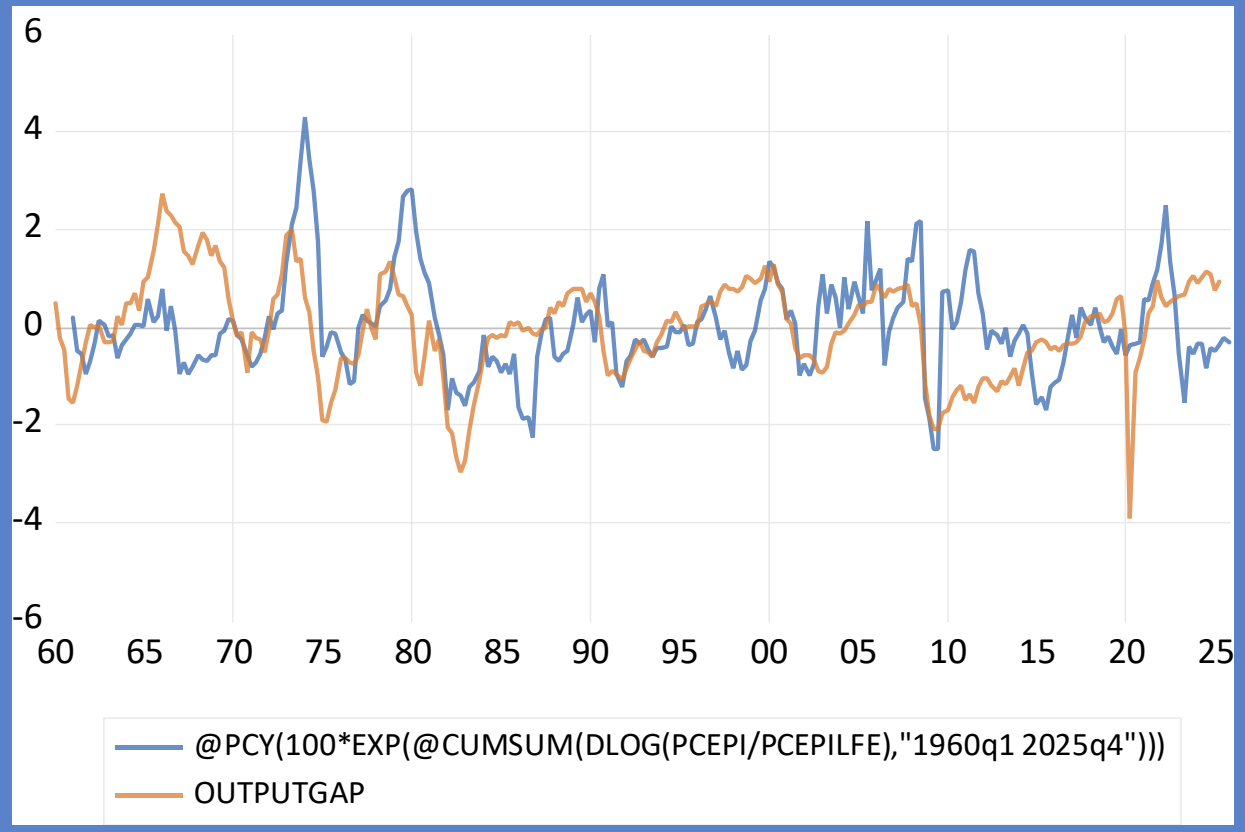


- CPI: **Will not account** for substitution effects (except if basket is updated, i.e., chained).
- PCE-PI: **Will account** for substitution (chained-index)
- GDP Deflator: **Will account** for substation – e.g., if beef price beef doubles, you buy chicken – your cost of living has not changed hence.

Inflation and its components

Understanding how inflation enters the system

PCE headline vs. core to output gap

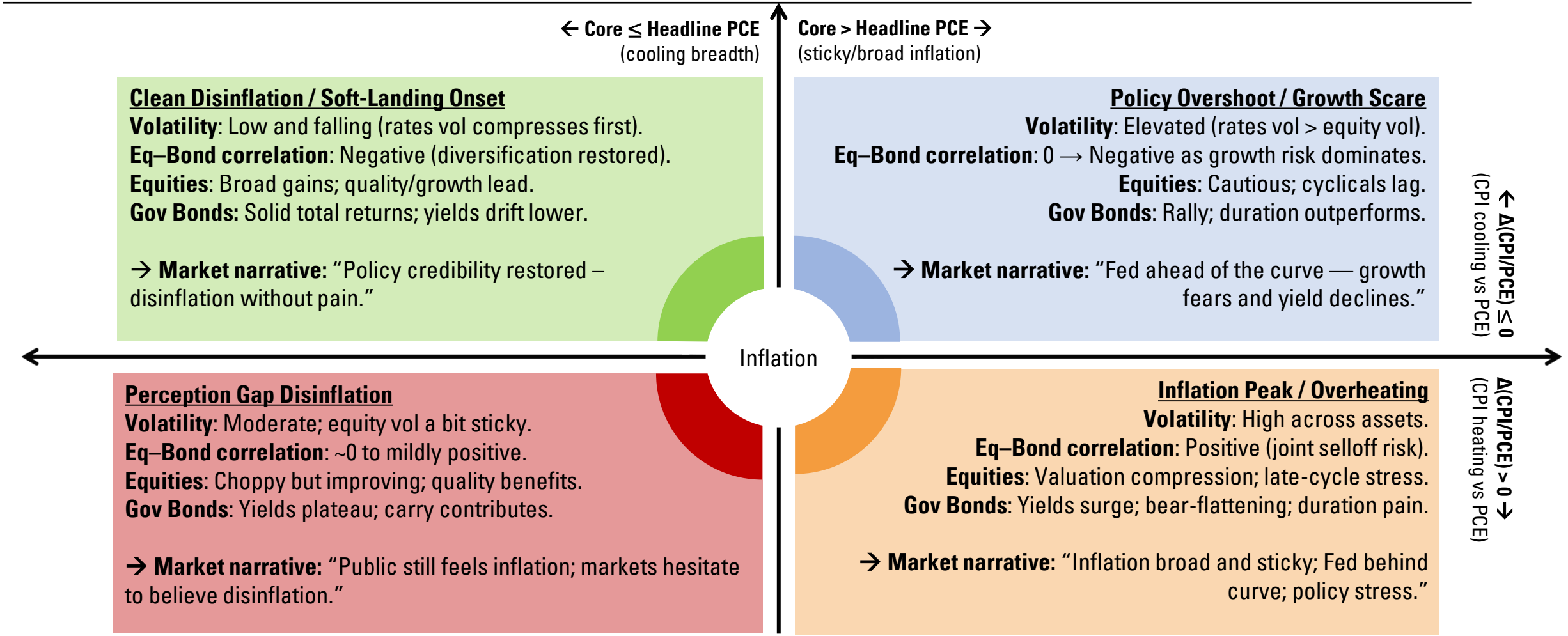


Difference between **Core** and so-called **Headline** Inflation

- Core: Excludes food and energy (volatile, that is cyclical components)
- Core: preferred for policy decisions due to stability
- Often "core" is labeled: CPI or PCE excluding food and energy

Inflation and its components

CPI vs PCE Matrix — Vol. & Correlation Dynamics



Inflation and its components

CPI vs PCE Matrix — Vol. & Correlation Dynamics

Descr. stats for S&P500 price index % returns

Date: 11/09/25 Time: 14:51
Sample: 1950M01 2030M12

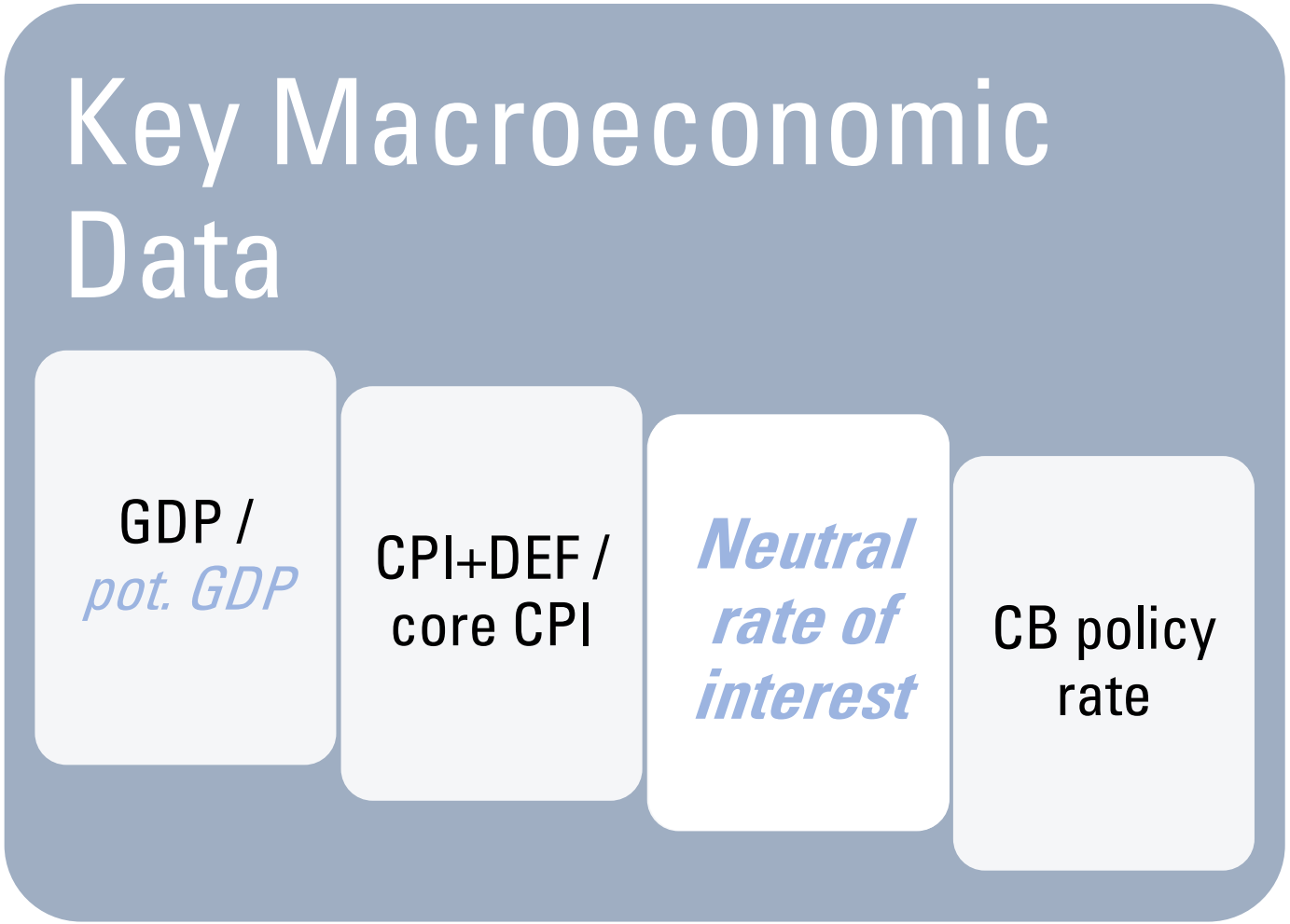
	Top Left	Top Right	Bottom Right	Bottom Left
Mean	0.074123	0.101448	0.076652	0.045184
Median	0.099874	0.143442	0.113477	0.095585
Maximum	0.975529	1.433051	1.812518	1.485856
Minimum	-1.450577	-2.945137	-1.176590	-1.524932
Std. Dev.	0.459131	0.575719	0.480573	0.506254
Skewness	-0.734428	-1.261850	-0.211192	-0.309518
Kurtosis	4.378020	7.585275	3.603828	3.365828
Jarque-Bera	12.33844	246.5444	4.841903	6.376774
Probability	0.002093	0.000000	0.088837	0.041238
Sum	5.410982	21.91283	16.40342	13.37458
Sum Sq. Dev.	15.17766	71.26216	49.19237	75.60642
Observations	73	216	214	296

Some results

- Top Left – Clean Disinflation
- Top Right – Policy Overshoot
- Bottom Right– Inflation Peak
- Bottom Left – Perception Gap

Key Macroeconomic Data you should be familiar

The Neutral Rate of Interest (r*)

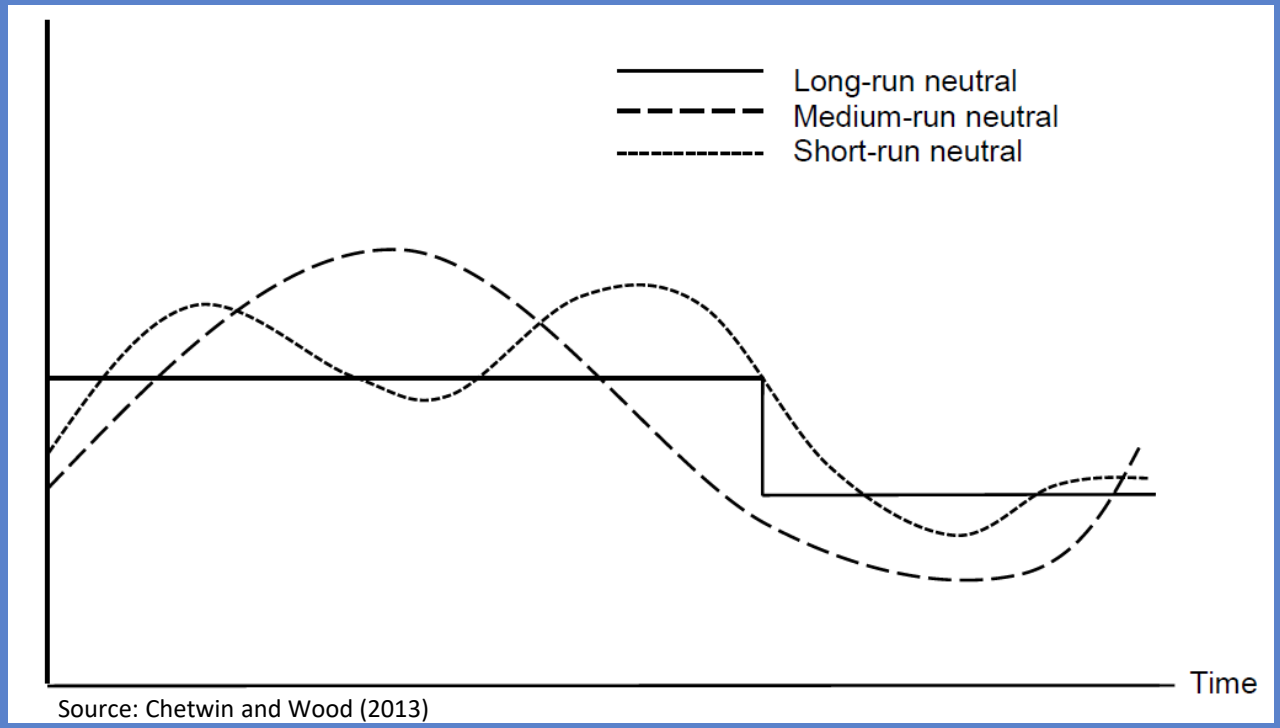


Neutral Rate of Interest (r*)

- Also known as: natural rate, equilibrium rate, R-star
- Not a policy target, but a benchmark for monetary stance
- Nominal rate = r* + expected inflation

The Neutral Rate of Interest (r*)
Definition

NROI definitions for different horizons*



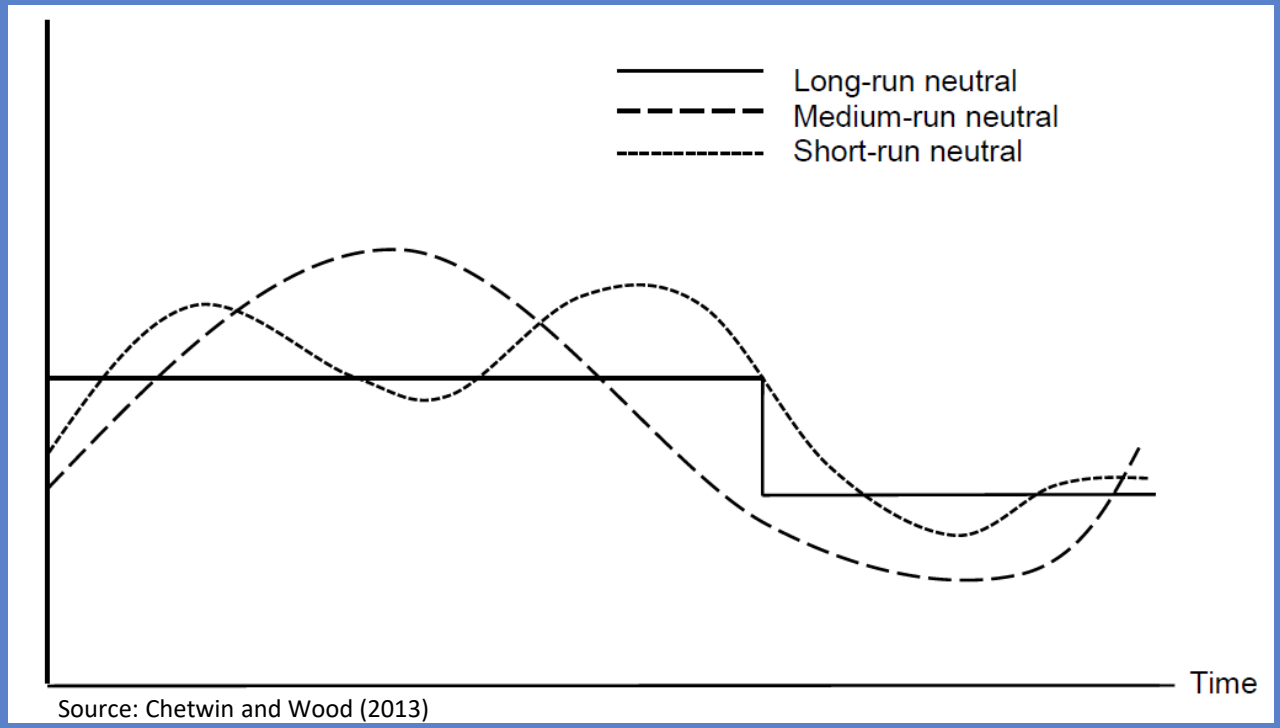
Source: Chetwin and Wood (2013)

*The influence of the time horizon on the definition is nicely described in Chetwin and Wood (2013), "Neutral interest rates in the post-crisis period", RBoNZ WP.

The natural/neutral/equilibrium rate is defined as the real short-term rate at which output is **at** its **potential** level (i.e. the output gap is at zero) and **inflation** is at/around target and **neither accelerating nor decelerating**). This represents the medium-term horizon definition.

The Neutral Rate of Interest (r*)
Theoretical concept for estimating the NROI*

NROI definitions for different horizons*



Source: Chetwin and Wood (2013)

*The influence of the time horizon on the definition is nicely described in Chetwin and Wood (2013), "Neutral interest rates in the post-crisis period", RBoNZ WP.

- Pure interest parity (as GDP-weighted foreign long-term yields).
- Yield level implied methods (steady-state slope or yield avg. around target).
- Neoclassical growth model.
- Structural (reduced-form) models.
- Implied Taylor-rule intercept.

*For a good summary see Mendes (2014), "The Neutral Rate of Interest in Canada", BoC WP or Basdevant et al (2004), "Estimating a time varying neutral real interest rate for New Zealand", RBoNZ WP.

The Neutral Rate of Interest (r*)

Neoclassical growth model (Ramsey-Cass-Koopmans)

Model implied equilibrium real interest rate (in steady state):*

$$r^* + \gamma = \rho + \sigma g + n,$$

where

- r*: Natural rate of interest (risk-free rate)
- γ: Credit spread
- ρ: Rate of time preference
- σ: Inverse relative risk aversion
- g: Potential output growth rate
- n: Population growth rate

*also known as modified golden rule of capital intensity, where the marginal product of capital equals the required rate of returns, taking into account the rate of time preference ρ and desire for consumption smoothing σ (see Ramsey model).

The Neutral Rate of Interest (r*)

Neoclassical growth model (Ramsey-Cass-Koopmans)

Practical approach (medium-run horizon): $r^* + \gamma = \rho + \sigma g + n,$

Steady state

- Estimate r, g, and n as the average of the real policy rate, potential output growth, and population growth, respectively, over a relatively long sample.

Risk-premium and time preference

- Calibrate σ between 1-2 (standard choice in the literature).
- By using these values, solve the equation for the natural rate of interest for $\rho - \gamma$.

Extract NROI

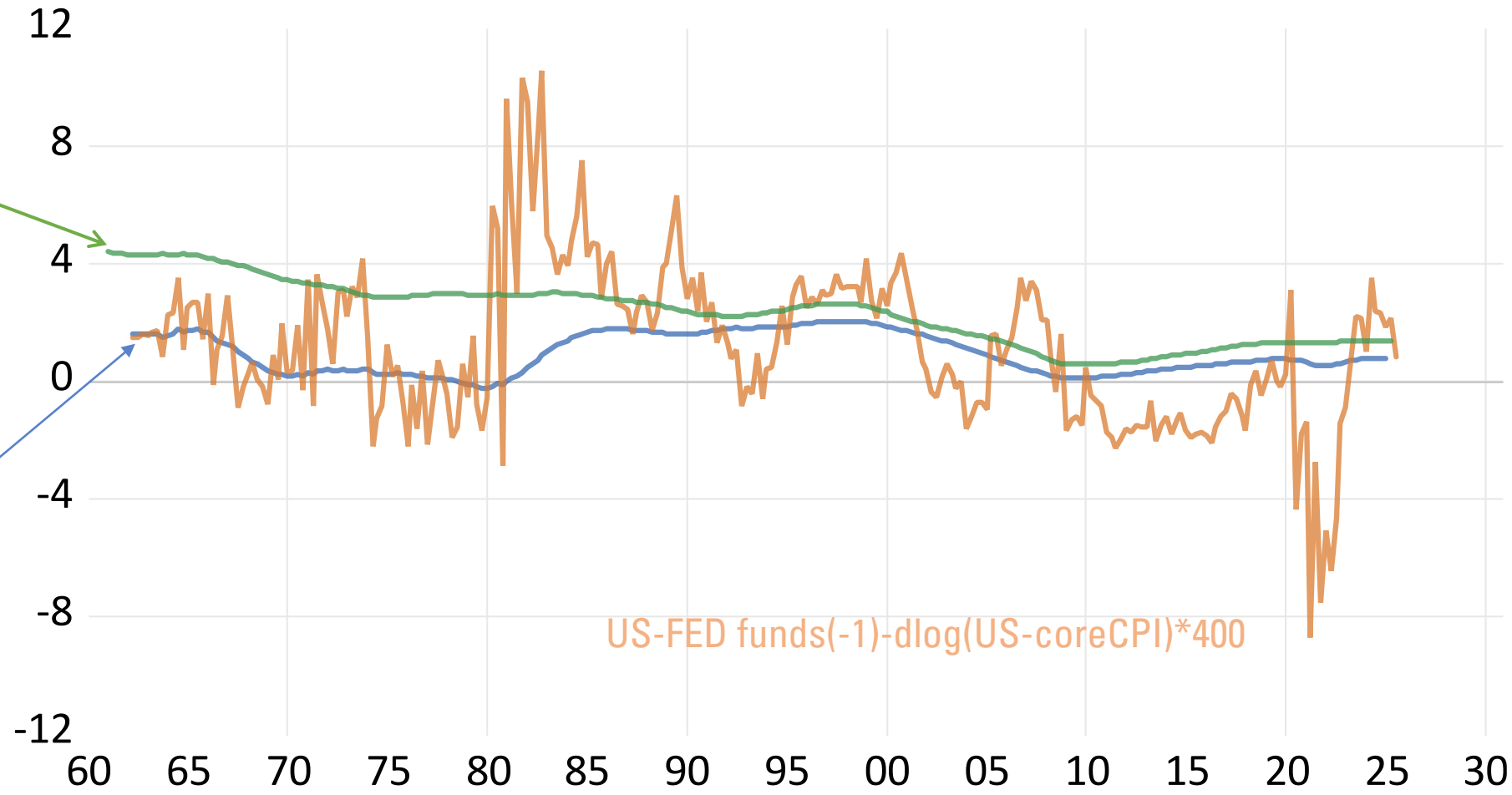
- Using data for potential output and population growth, calculate a time-varying estimate of the natural rate of interest from $r_t^* = \hat{\rho} - \hat{\gamma} + \sigma g_t + n_t$

The Neutral Rate of Interest (r*)

The US neutral rate – FED estimate vs QIO estimate

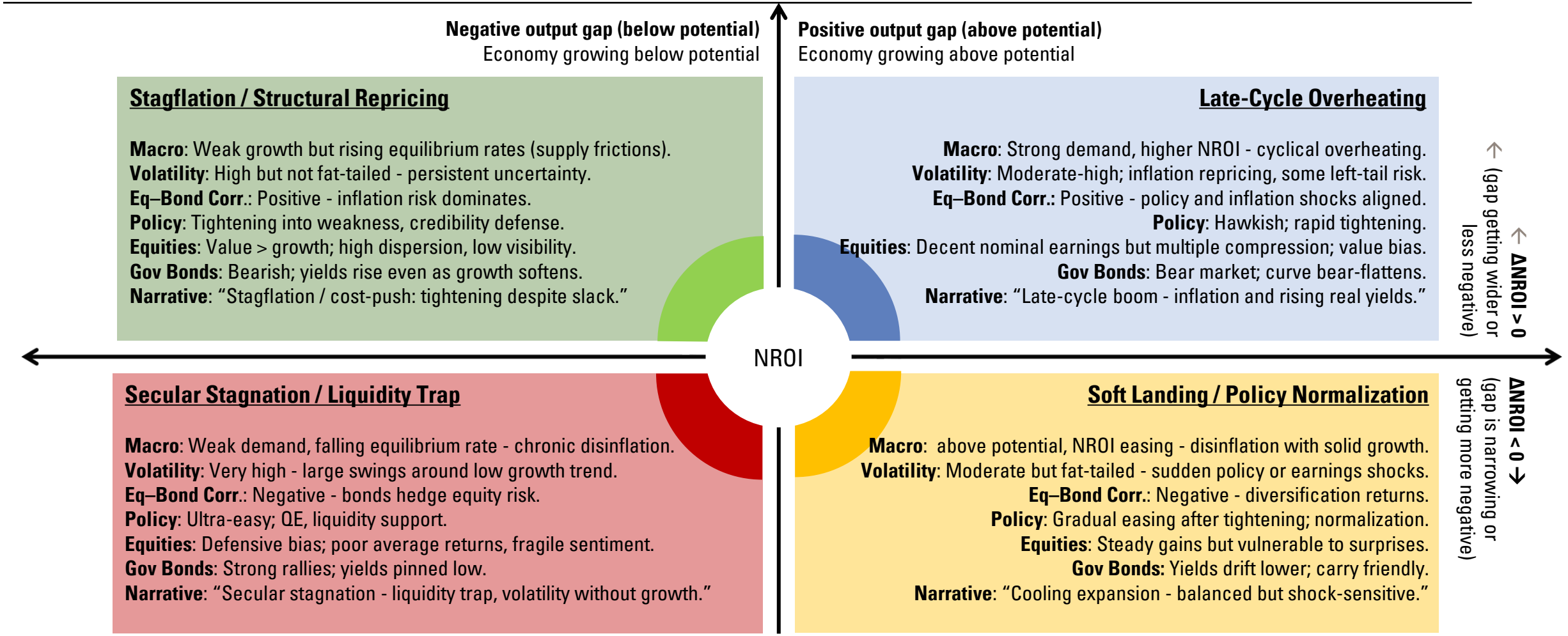
United States, Federal Reserve Bank of New York, Laubach-Williams Natural Rate of Interest Estimates, Two-Sided, Natural Rate of Interest, Estimate

Neoclassical growth model, QIO



NROI and Output Gaps

NROI vs Output – Volatility & Equity–Bond Correlation



NROI and Output Gaps

The price % return of the S&P 500 across regimes

Descr. stats for S&P500 price index % returns

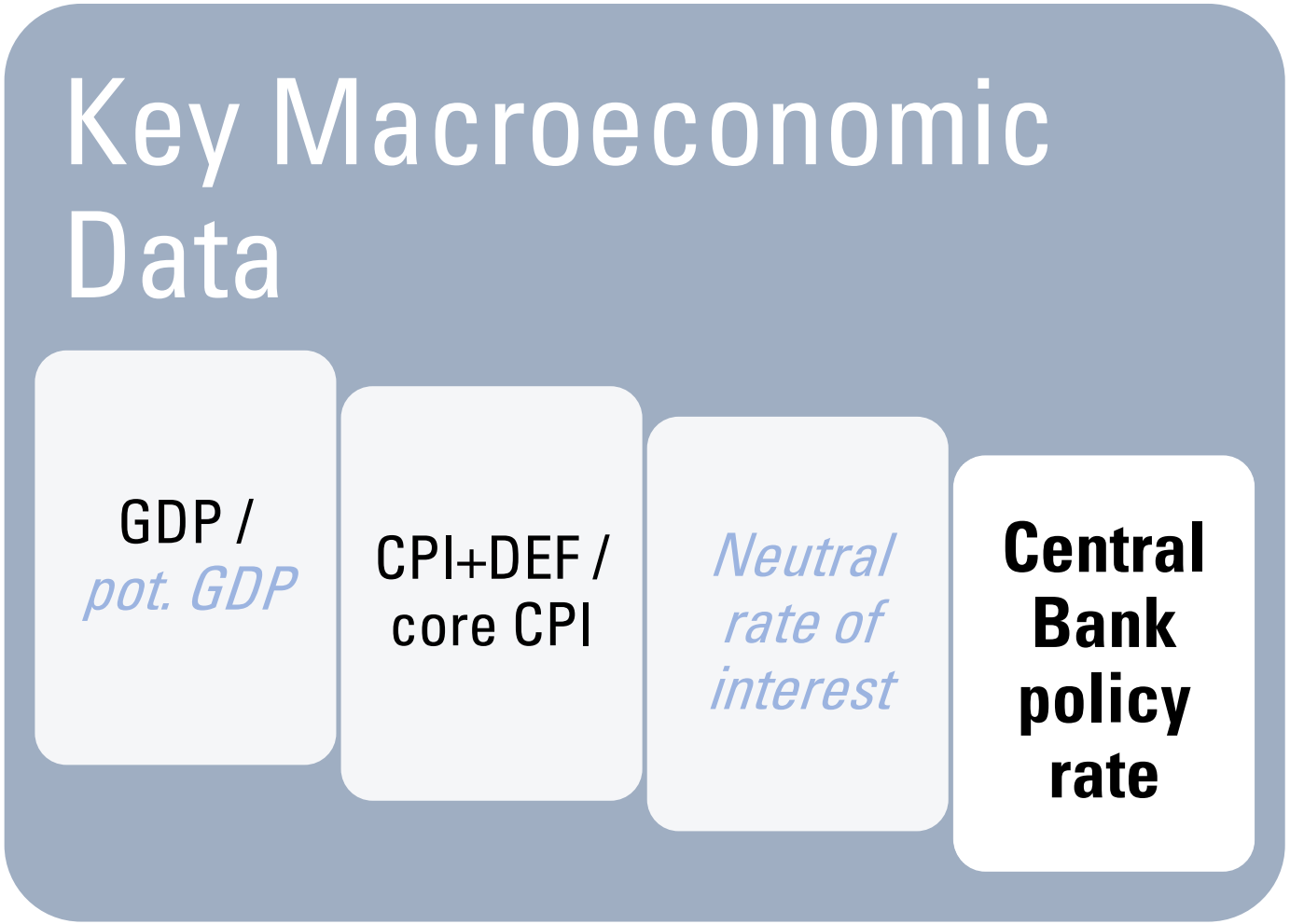
Date: 11/11/25 Time: 12:43
Sample: 1960Q1 2030Q4

	Top Left	Top Right	Buttom Right	Bottom Left
Mean	3.606070	2.955802	1.979132	-0.400748
Median	4.206099	3.893106	2.067686	0.920598
Maximum	21.58693	16.90881	20.86705	20.45755
Minimum	-14.51595	-16.44509	-23.22344	-26.11628
Std. Dev.	7.073743	6.671252	6.580195	10.91013
Skewness	-0.330948	-0.934064	-0.475127	-0.293546
Kurtosis	3.295378	4.280389	5.256407	2.617986
Jarque-Bera	1.860627	8.762556	18.23283	1.042550
Probability	0.394430	0.012509	0.000110	0.593763
Sum	306.5160	121.1879	144.4766	-20.43813
Sum Sq. Dev.	4203.179	1780.224	3117.526	5951.549
Observations	85	41	73	51

Applying the following criteria for regime discrimination

- OP: Negative & ΔNROI
- OG: Positive & ΔNROI
- OP: Positive & -ΔNROI
- OP: Negative & -ΔNROI

Key Macroeconomic Data you should be familiar
Central Bank Policy Rate



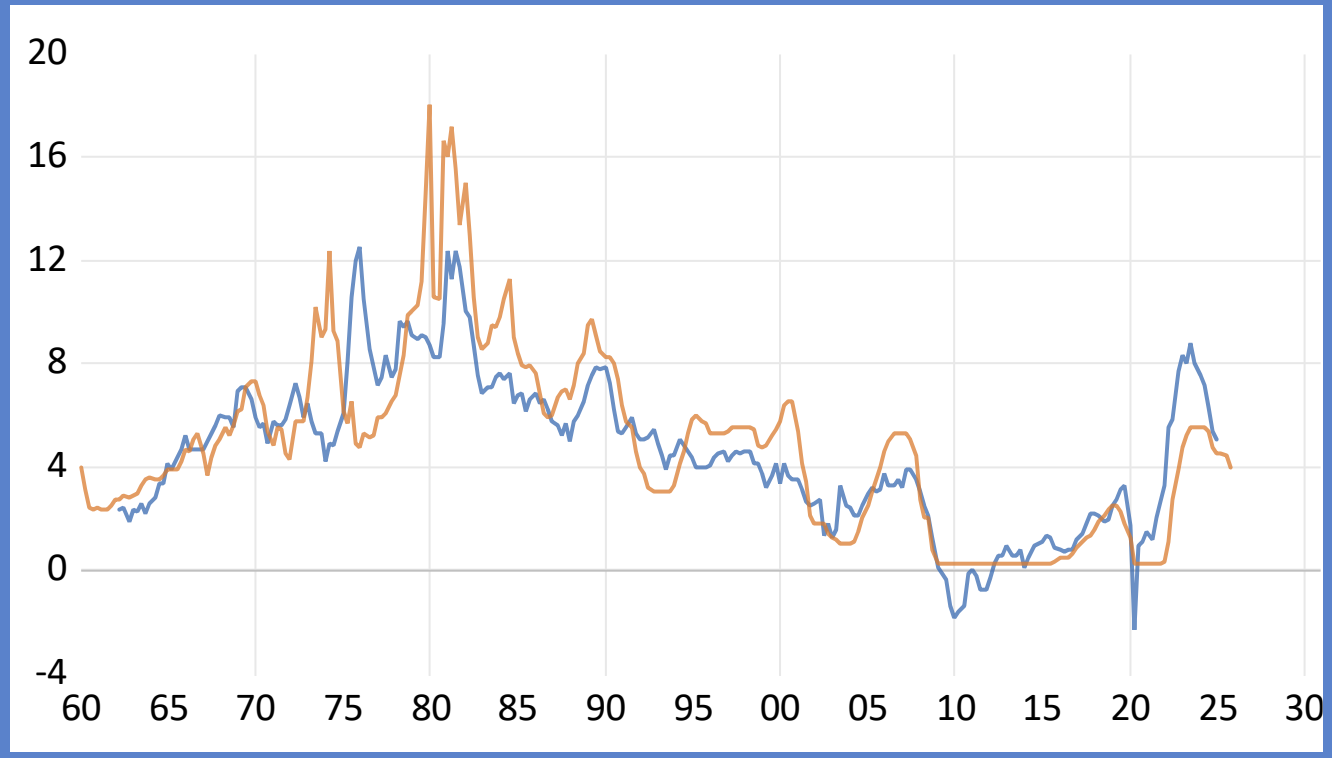
What Is the Policy Rate?

- The short-term interest rate set by the central bank
- Primary tool for steering inflation and economic activity
- Communicated via official statements and forward guidance

Examples: Fed Funds Rate (US), Main Refinancing Rate (ECB)

Central Bank Policy Rate
A Taylor-Rule targeting Central Bank

Taylor-Rule vs. realized policy rate



NROI+@MOVAV(DLOG(PCEPILFE(-4))*400,4)+0.5*OUTPUTGAP*100+0.5*(@MOVAV(DLOG(PCEPILFE(-4))*400,4)-2)

Central Bank Reaction function

- Guideline for setting the policy rate based on macro conditions
- Incorporates inflation deviation and output gap
- Anchors policy rate to neutral rate (r*)
- Used as a reference, not a strict rule

Central Bank Policy Rate
Estimating a CB Reaction Function via Objective

For the US Federal Reserve

- The mission of the Board is to foster the stability, integrity, and efficiency of the nation's monetary, financial, and payment systems so as to promote optimal macroeconomic performance.
- The Board has six primary strategic goals with interrelated and mutually reinforcing elements:

1) conduct monetary policy that promotes the achievement of the Federal Reserve's statutory objectives of **maximum employment** and **stable prices**
2) ....

Source: http://www.federalreserve.gov/publications/gpra/2011-mission-values-and-goals-of-the-board-of-governors.htm

For the SNB

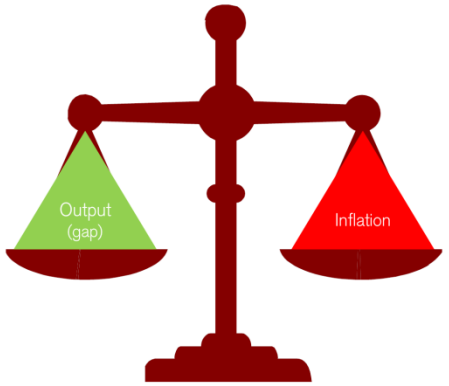
- Article 99 of the Federal Constitution entrusts the SNB, as an independent central bank, with the conduct of monetary policy in the interests of the country as a whole. The mandate is explained in detail in the National Bank Act (art. 5 para. 1 NBA), which requires the **SNB to ensure price stability and, in so doing, to take due account of economic developments.**

- The SNB is thus charged with resolving in the best general interests any conflicts arising between the objective of price stability and business cycle considerations, **giving priority to price stability.** The requirement to act in the interests of the country as a whole .....

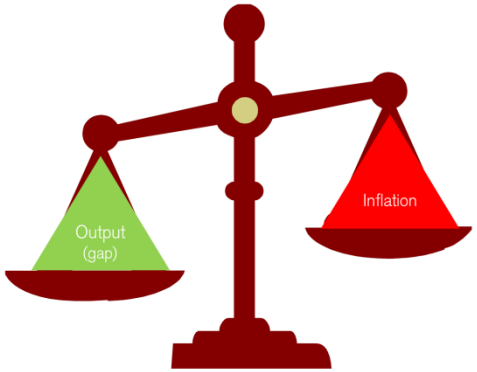
Source: ttp://www.snb.ch/en/iabout/monpol/id/monpol_strat

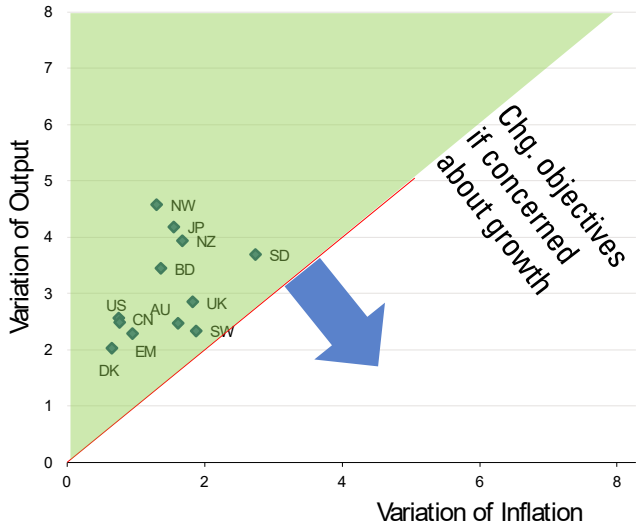
Central Bank Policy Rate
Estimating a CB Reaction Function via Objective

How it should be...maybe?



How it is often perceived!





We can conclude:

- If ex-post output variability is higher than inflation variability, the country's central bank was more concerned about stable inflation (inflation targeting central bank).

Central Bank Policy Rate
Estimating a CB Reaction Function via Objective

Linking objective to an economic model: one example of a New Keynesian model for closed economy.

Aggregated demand (referred to as IS curve)

$$y_t = \mathrm{E}_t y_{t+1} - \alpha\left(r_t - r^0\right) + \xi_t$$

=> Today's output (gap) as a function of the next period's expected output (gap), the real policy rate and the policy rate at zero growth.

Aggregated supply (referred to as Phillips curve)

$$\pi_t = \beta\, \mathrm{E}_t \pi_{t+1} + \lambda\left(y_t - y_t^{pot}\right) + \varepsilon_t$$

=> Today's inflation as a function of the next period's expected inflation and the output gap (beta represents time discount factor close to one).

Policy rates influence inflation via its impact on output.

We need a 3rd equation that describes the policy rate setting r_t, => but how?

Central Bank Policy Rate
Estimating a CB Reaction Function via Objective

The Taylor rule with a dynamic intercept: $r_{r,t}^{N}$

The Taylor rule – named after the US economist John B. Taylor – describes the policy rate setting mechanism for the US economy via the deviation of inflation from target (Phillips curve) and output from trend output (IS curve).

$$\pi_t = \beta\, \mathrm{E}_t\pi_{t+1} + \lambda\left(y_t - y_t^{pot}\right) + \varepsilon_t \qquad y_t = \mathrm{E}_t y_{t+1} - \alpha\left(r_t - r^0\right) + \xi_t$$

$$r_t = \pi_{t+1}^{e} + r_{r,t}^{N} + \eta\left(\pi_{t+1}^{e} - \pi_t^{\text{target}}\right) + \rho\left(y_t - y_t^{\text{pot}}\right)$$

Together with the IS and Phillips curve, we can state that:

- An aggregated demand shock (to output) will move output and inflation in the same direction => no trade off, we can offset with a change in policy rate.
- An aggregated supply shock (to inflation) will move output and inflation in the different direction => **trade off!**

Central Bank Policy Rate
Putting the pieces together

The Taylor rule with a dynamic intercept **as explicit rule:** $r_{r,t}^{N}$

2nd: Expected inflation vs. inflation target (Inflation over- vs. undershooting)

$$r_t = \pi_{t+1}^{e} + r_{r,t}^{N} + \eta\left(\pi_{t+1}^{e} - \pi_t^{\text{target}}\right) + \rho\left(y_t - y_t^{\text{pot}}\right)$$

1st: Realized policy rate vs. neutral policy rate (policy accommodation vs restriction)

3rd: Realized output vs. potential output (Output Slack vs Overheating)

Central Bank Policy Rate
Putting the pieces together

How factually central banks operate **using an implicit rule:**

The central bank aims for the minimization of a quadratic loss function that incorporates all its targets. Due to **exogenous, idiosyncratic shocks** the evolution of output gap, inflation and the neutral interest rate is uncertain, which leads to **uncertainty about future losses** (even for one particular path of nominal interest rates). So, it is rational for the central bank to minimize the expectation about future losses, conditional on the current state of the economy, i.e. today's inflation, output gap and neutral interest rate:

$$\max_{\{i_t\}_{t=0}^{+\infty}} -E_0\left[\sum_{t=0}^{+\infty} \beta^t \left\{\lambda_1(\pi_t - \pi_t^*)^2 + \lambda_2(\tilde{y}_t - \tilde{y}^*)^2 + \lambda_3 i_t^2 + \lambda_4(i_{t-1} - i_{t-2})^2\right\}\right]$$

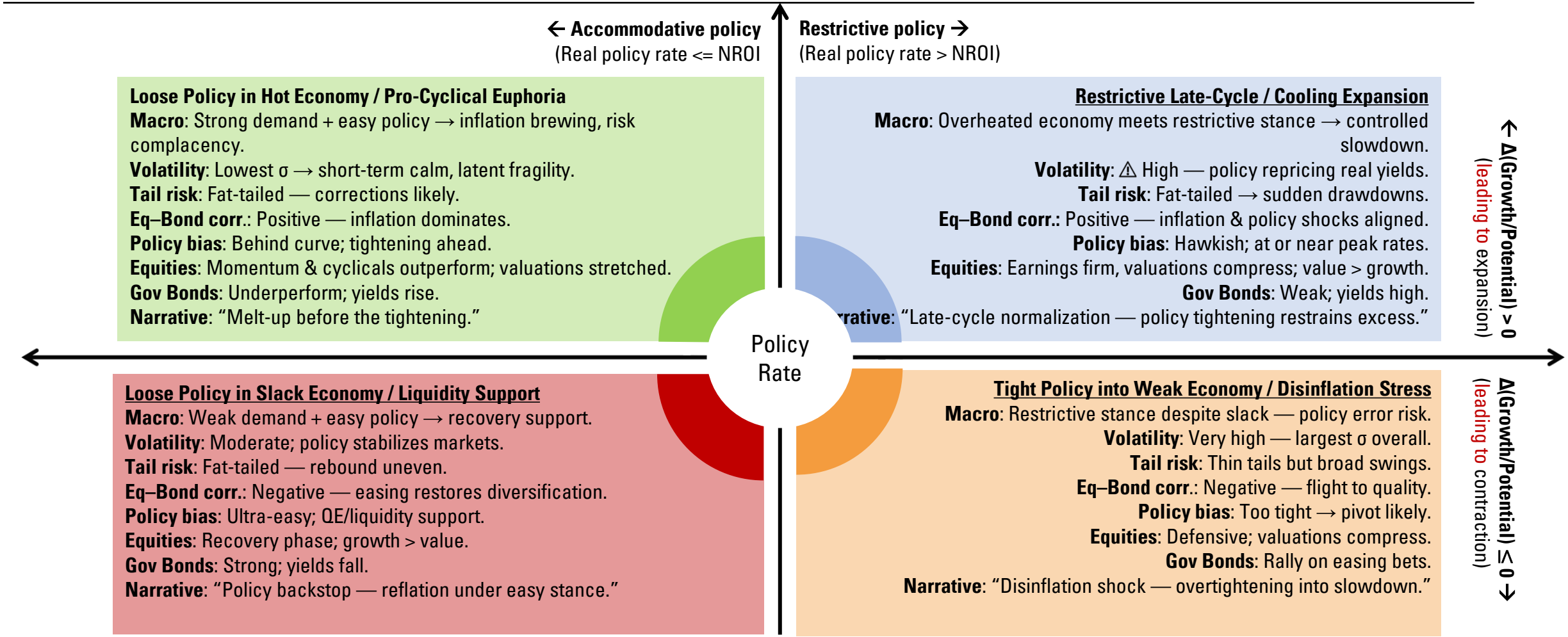
Inflation Variability
Keeping inflation around its target is usually the most prioritized objective for any central bank

Interest Rate Variability
Central banks appreciate rather low than high interest rates

Output Gap Variability
Stabilizing the economy is often the second most important objective. Stabilization is thereby translated as achieving (almost) potential GDP growth.

Interest Rate Smoothing
Central banks are usually adjusting interest rates only gradually

Central Bank Policy Rate
Formulating a market transition mechanism



Central Bank Policy Rate relative to NROI

The price % return of the S&P 500 across regimes

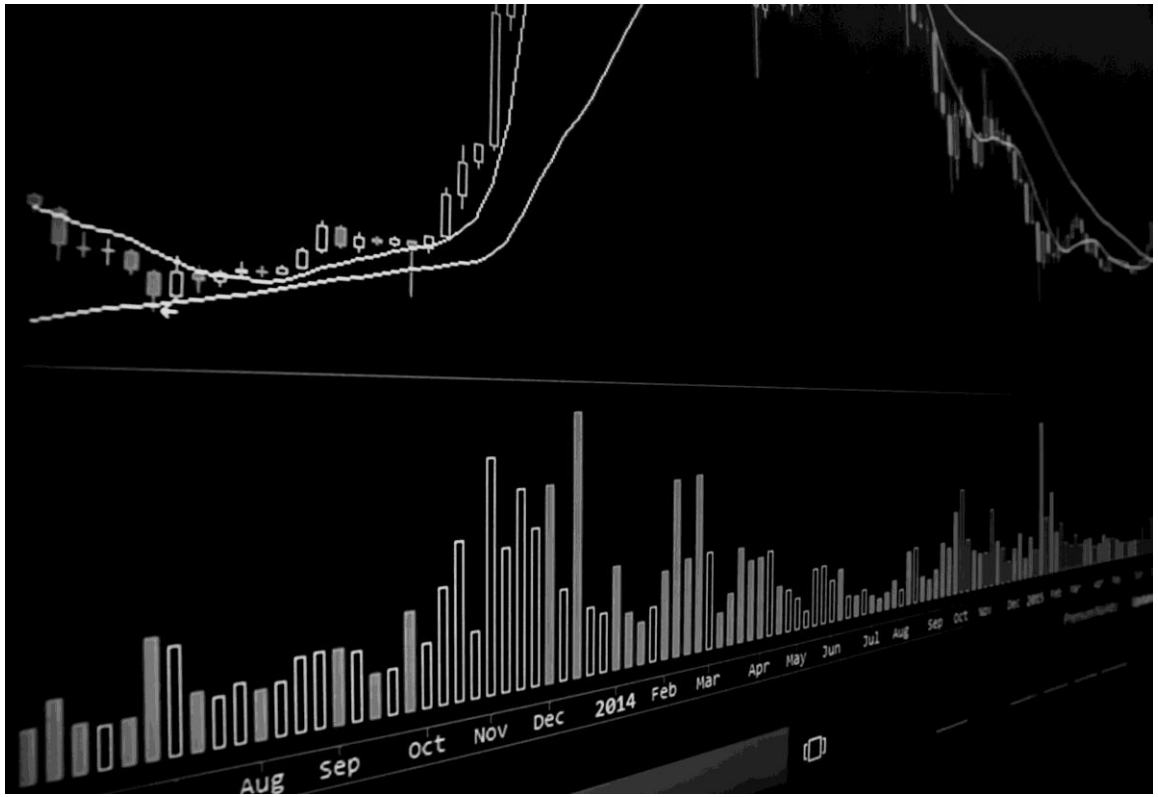
Descr. stats for S&P500 price index % returns

Date: 11/11/25 Time: 23:46
Sample: 1960Q1 2030Q4

	Top Left	Top Right	Bottom Right	Bottom Left
Mean	2.524923	2.105740	0.615742	3.272844
Median	3.670938	2.699926	0.686334	3.254207
Maximum	13.06620	20.86705	21.58693	19.95287
Minimum	-16.44509	-23.22344	-26.11628	-20.00105
Std. Dev.	5.987560	7.182221	10.52628	7.029562
Skewness	-0.910091	-0.442010	-0.327719	-0.572109
Kurtosis	4.234310	4.815950	2.667435	4.231446
Jarque-Bera	10.68079	10.19791	1.418024	8.359340
Probability	0.004794	0.006103	0.492130	0.015304
Sum	133.8209	126.3444	38.79176	232.3719
Sum Sq. Dev.	1864.245	3043.473	6869.765	3459.032
Observations	53	60	63	71

Applying the following criteria for CB policy **today leading to:**

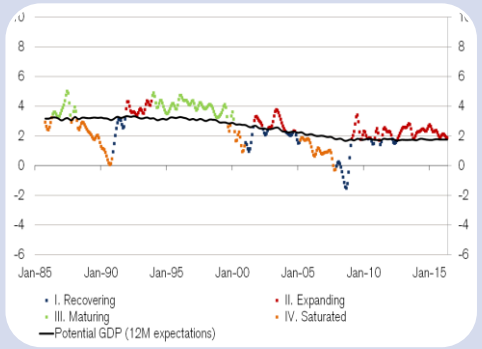
- Accommodative policy → stronger economy
- Restrictive policy → stronger economy
- Restrictive policy → weaker economy
- Accommodative policy → weaker economy

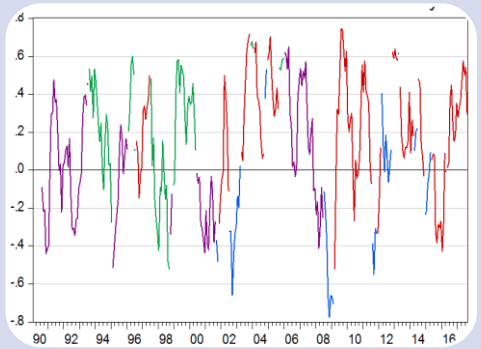


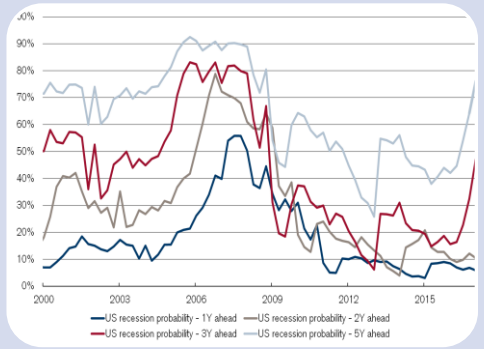
How to apply all the theory in practice

The conceptual links

How to apply all the theory in practice
Some key conceptual links







Regime Analysis: Calculate historical premiums for each asset relative to NROI estimate and identified regimes

Return Analysis: Extract average realized Sharpe-ratio as allocation risk indicator across identified regimes

Recession Risk: Check if our forecasts are justifiable with the estimated recession probabilities

How to applied all the theory in practice
Some key conceptual links

Macroeconomic projections

- GDP / pot. GDP
- CPI+DEF / core CPI
- Neutral rate of interest
- CB policy rate

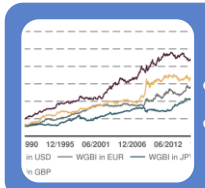
Sovereign interest rates

- BM rate fair values
- BM sovereign yield curve

Foreign exchange

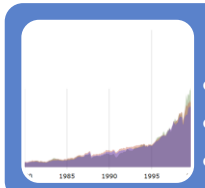
- FX pairs to USD
- Nominal effective exchange rates

Macroeconomic assumptions form in our framework the key basis for estimating returns, volatilities, correlations and scenario projections. Therefore, all macroeconomic estimation are shocked to form strong and weak trajectories for our estimations.



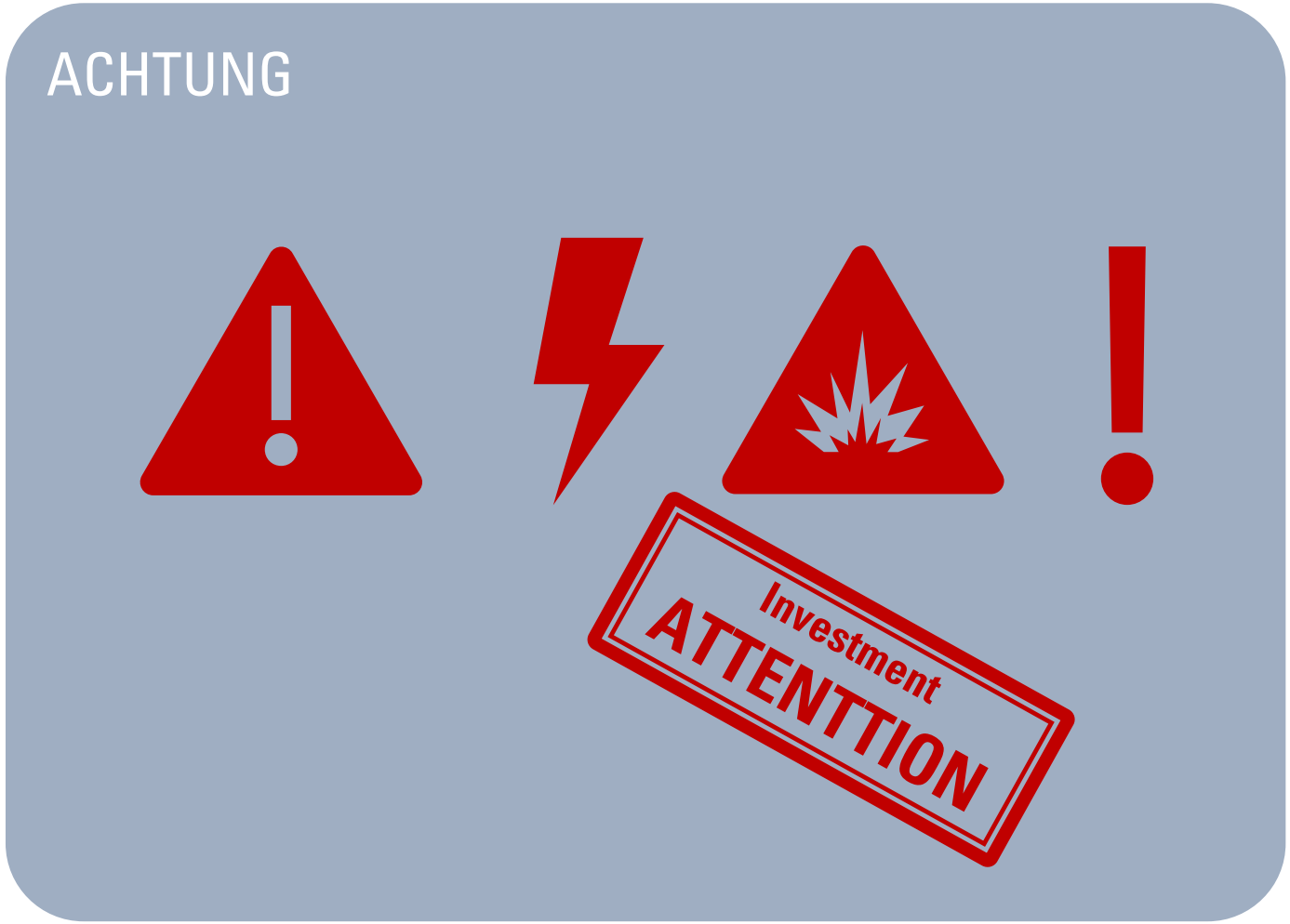
Sovereign indices
- Coupon index
- Total return (incl. coupon)

Credit indices / spreads
- Investment grade
- High yield



Equity indices
- Trend earnings
- Sectors total return forecasts
- Countries / Regions total return forecasts

How to applied all the theory in practice
Some key conceptual links



When is this going to fail?

- ....

Thank you for your time!

- ....