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The Determinants of Inflation

May 2023

Q Group Spring Seminar

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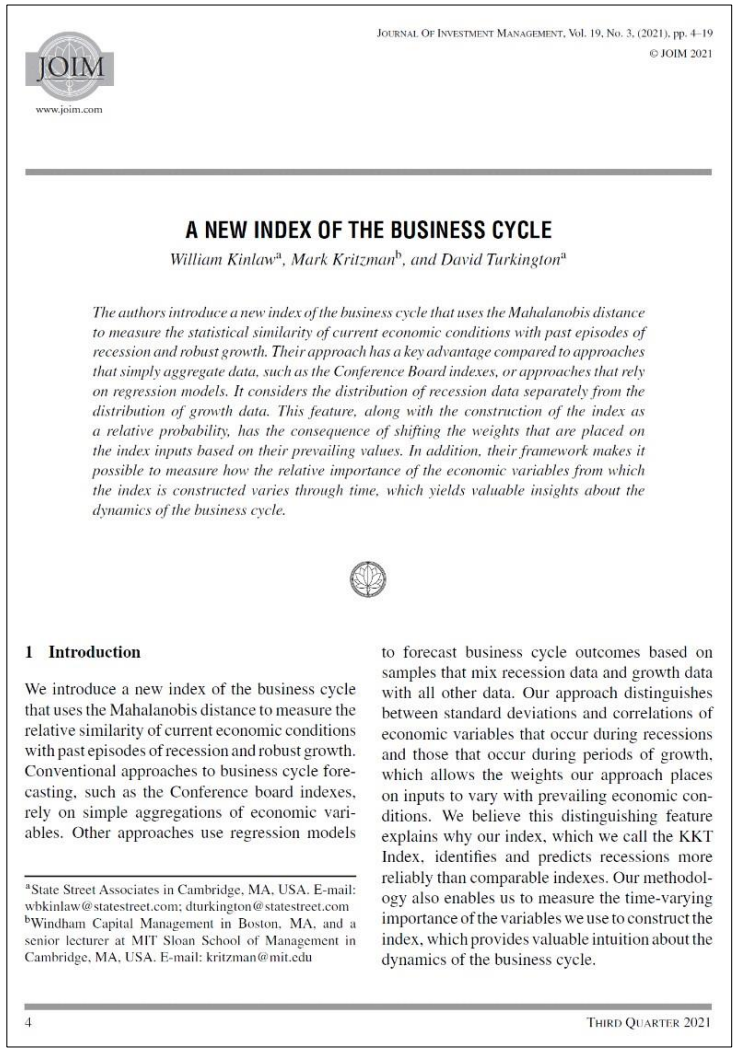
Agenda

1. **A new index of the business cycle**
2. **The determinants of inflation**
   - Inflation narratives
   - Inflation regimes
   - Inflation determinants

A New Index of the Business Cycle

- In our 2021 paper, we introduce a new index of the business cycle that uses the Mahalanobis distance to measure the relative similarity of current economic conditions to past episodes of recession and robust growth.

- Our approach distinguishes between standard deviations and correlations of economic variables that occur during recessions and those that occur during periods of growth, which allows the weights our approach places on inputs to vary with prevailing economic conditions.



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A NEW INDEX OF THE BUSINESS CYCLE

William Kinlaw[a], *Mark Kritzman*[b], *and David Turkington*[a]

The authors introduce a new index of the business cycle that uses the Mahalanobis distance to measure the statistical similarity of current economic conditions with past episodes of recession and robust growth. Their approach has a key advantage compared to approaches that simply aggregate data, such as the Conference Board indexes, or approaches that rely on regression models. It considers the distribution of recession data separately from the distribution of growth data. This feature, along with the construction of the index as a relative probability, has the consequence of shifting the weights that are placed on the index inputs based on their prevailing values. In addition, their framework makes it possible to measure how the relative importance of the economic variables from which the index is constructed varies through time, which yields valuable insights about the dynamics of the business cycle.

1 Introduction

We introduce a new index of the business cycle that uses the Mahalanobis distance to measure the relative similarity of current economic conditions with past episodes of recession and robust growth. Conventional approaches to business cycle forecasting, such as the Conference board indexes, rely on simple aggregations of economic variables. Other approaches use regression models to forecast business cycle outcomes based on samples that mix recession data and growth data with all other data. Our approach distinguishes between standard deviations and correlations of economic variables that occur during recessions and those that occur during periods of growth, which allows the weights our approach places on inputs to vary with prevailing economic conditions. We believe this distinguishing feature explains why our index, which we call the KKT Index, identifies and predicts recessions more reliably than comparable indexes. Our methodology also enables us to measure the time-varying importance of the variables we use to construct the index, which provides valuable intuition about the dynamics of the business cycle.

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Common measures

Conference Board

Publishes monthly business cycle indicators, including composite indexes for leading, coincident and lagging economic activity.

Began in 1961 in cooperation with the NBER and the President's Council of Economic Advisors.

Coincident index averages payrolls, personal income, industrial production, and manufacturing/trade sales.

NBER

Business Cycle Dating Committee of approximately 8 members applies judgment to define the peaks and troughs of economic activity in the US.

Recession is "a period of falling economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales."

Desirable features for our index

- Multivariate
- Summarized in one number, easy to interpret
- Adapts to changing conditions

Mahalanobis distance

Mahalanobis (1927, 1936) used multivariate distance to compare skull samples.

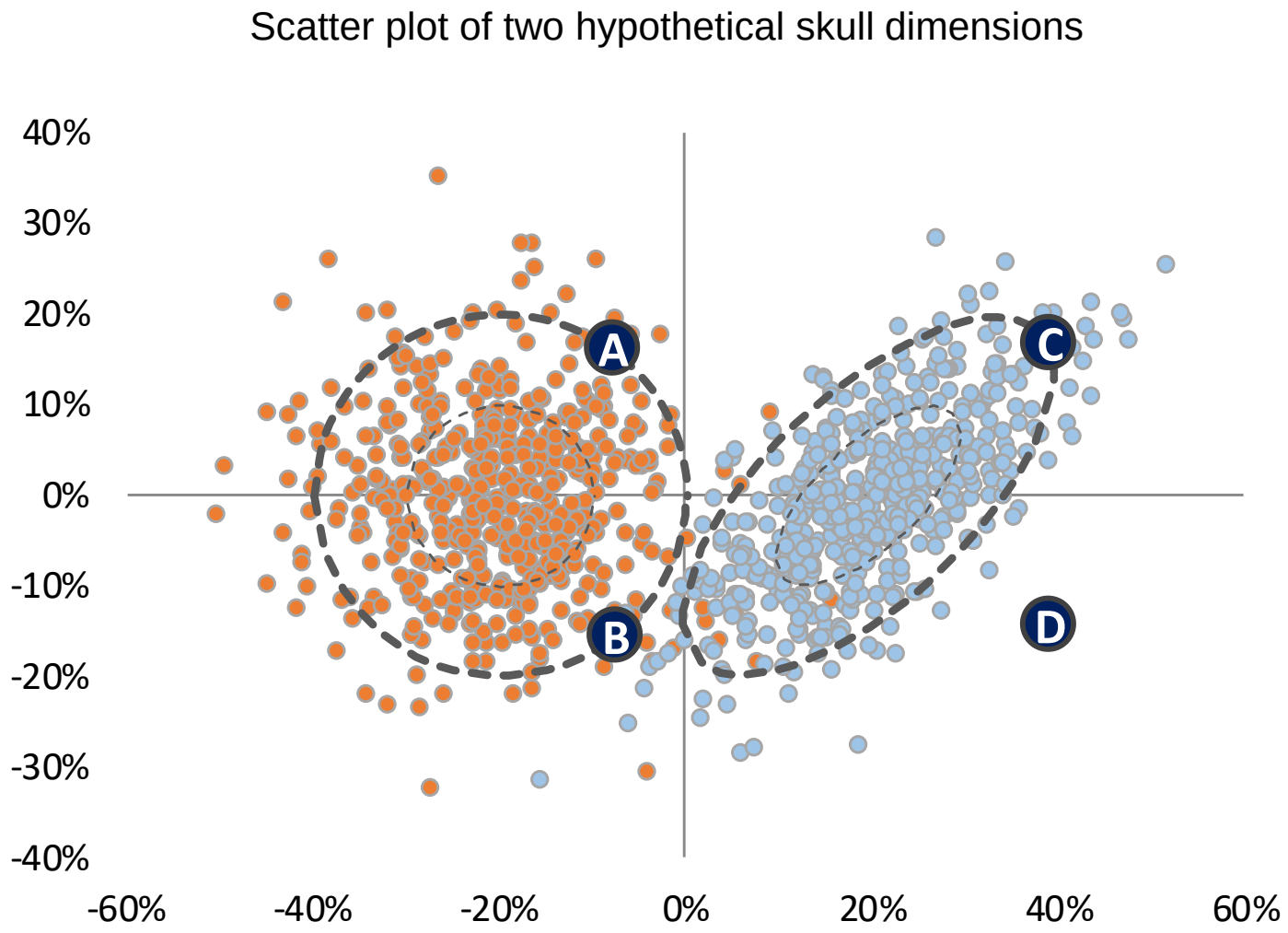
$$d = (x - \mu)\Omega^{-1}(x - \mu)'$$

x is a vector of values for an observation

μ is a vector of mean values within a group

Ω is the covariance matrix of values within a group

Mahalanobis distance



For illustrative purposes only; no live data. Source: State Street Global Markets.

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Mahalanobis distance

Why it is not arbitrary

- Defines the normal distribution
- Consistent with information theory
- Defines relevance with equivalence to linear regression
  - Czasonis, Kritzman and Turkington (2020a, 2020b, 2021)

Constructing the index

- **Data inputs (from St. Louis Fed, measured monthly, starting in January 1916)**
  - Industrial production (one-year percentage change)
  - Nonfarm payrolls (one-year percentage change)
  - Stock market (one-year return)
  - Yield curve (10-year rate minus Federal Funds rate, one-year average)

- **Since 1956 (when point-in-time data are available)**
  - Identify historical recessions and periods of robust growth
  - Measure the Mahalanobis distance from both, and transform into a “probability”

Constructing the index

Compute the Mahalanobis distance from recession and growth subsamples.

$$d_{rec}(x) = (x - \mu_{rec})\Omega_{rec}^{-1}(x - \mu_{rec})'$$

$$d_{gr}(x) = \left(x - \mu_{gr}\right)\Omega_{gr}^{-1}\left(x - \mu_{gr}\right)'$$

Convert to a likelihood (normal distribution).

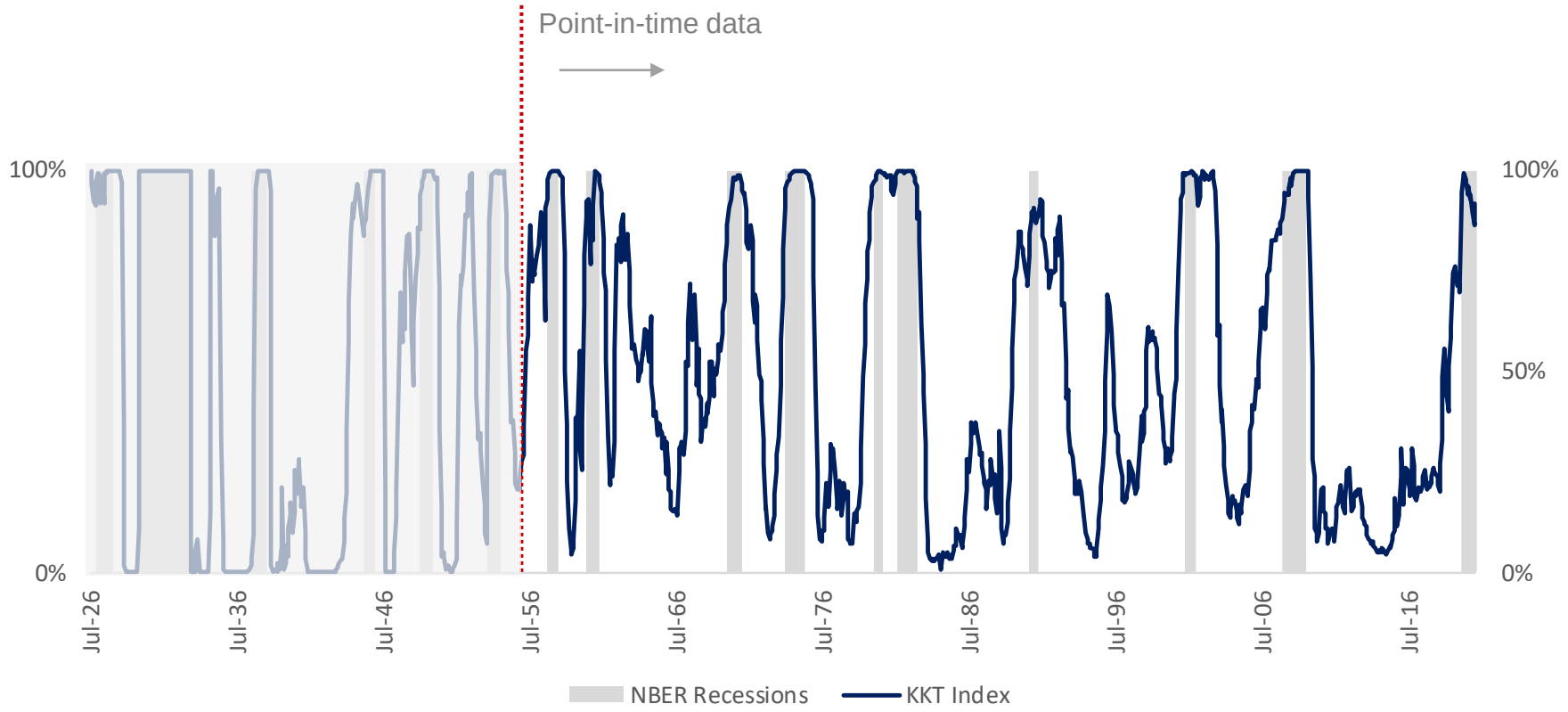
$$\xi_{rec}(d_{rec}) = \det(2\pi\Omega_{rec})^{-1/2}\, e^{-d_{rec}/2}$$

$$\xi_{gr}(d_{gr}) = \det\left(2\pi\Omega_{gr}\right)^{-1/2}\, e^{-d_{gr}/2}$$

Normalize to a value between zero and one.

$$p_{rec}(\xi_{rec}, \xi_{gr}) = \frac{\xi_{rec}}{\xi_{rec} + \xi_{gr}}$$

The index historically



Time period spans July 1926 to February 2021. Source: Kinlaw et. al (2021)

The index recently

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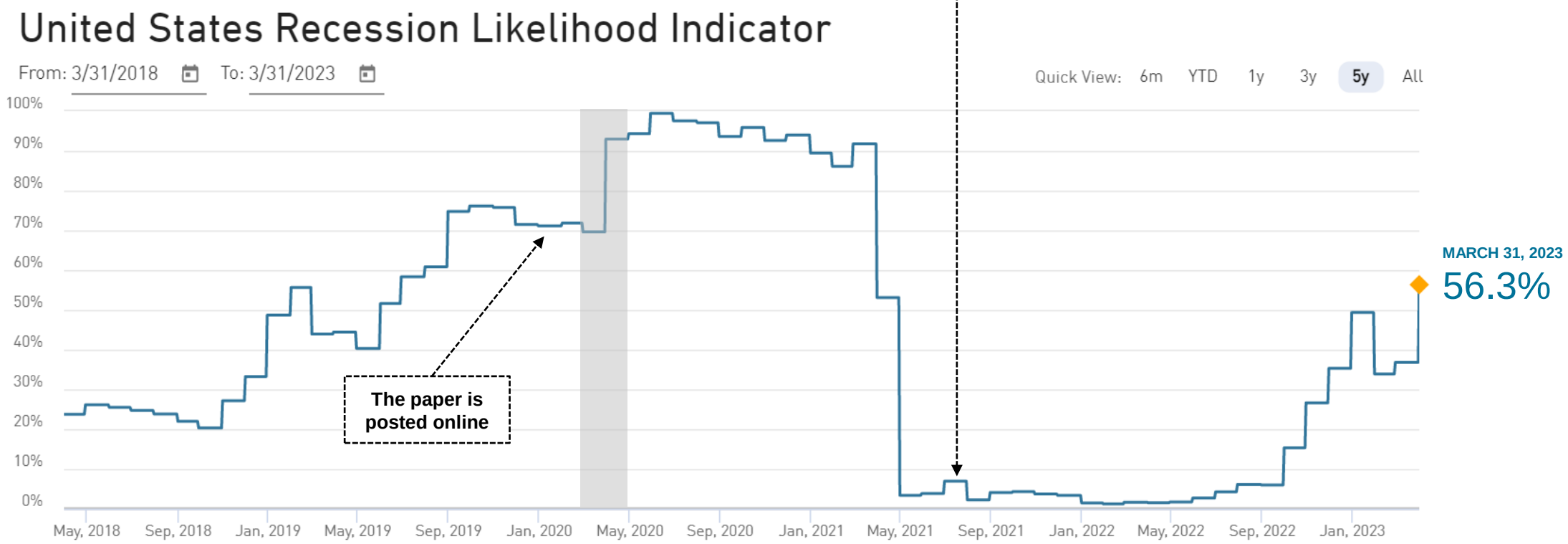
U.S. Coronavirus Recession Lasted Two Months, Ended in April 2020, Official Arbiter Says



Source: globalmarkets.statestreet.com. Shaded area indicates the "covid recession" of March and April 2020 which was called by NBER on July 19, 2021.

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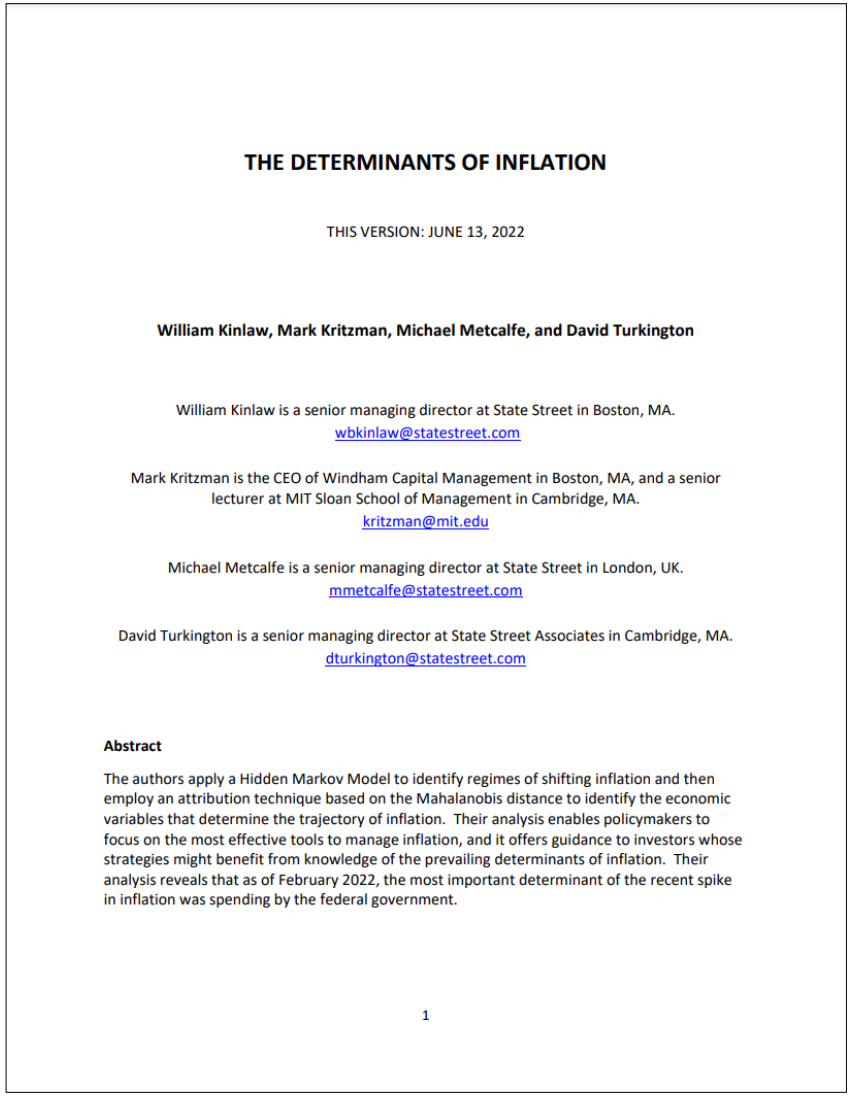
The Determinants of Inflation

- We apply a Hidden Markov Model to identify regimes of shifting inflation and then employ an attribution technique based on the Mahalanobis distance to identify the economic variables that determine the trajectory of inflation.
- Our analysis reveals that the most important determinant of the recent spike in inflation was spending by the federal government.
- *Forthcoming in the Journal of Investment Management.*



THE DETERMINANTS OF INFLATION

THIS VERSION: JUNE 13, 2022

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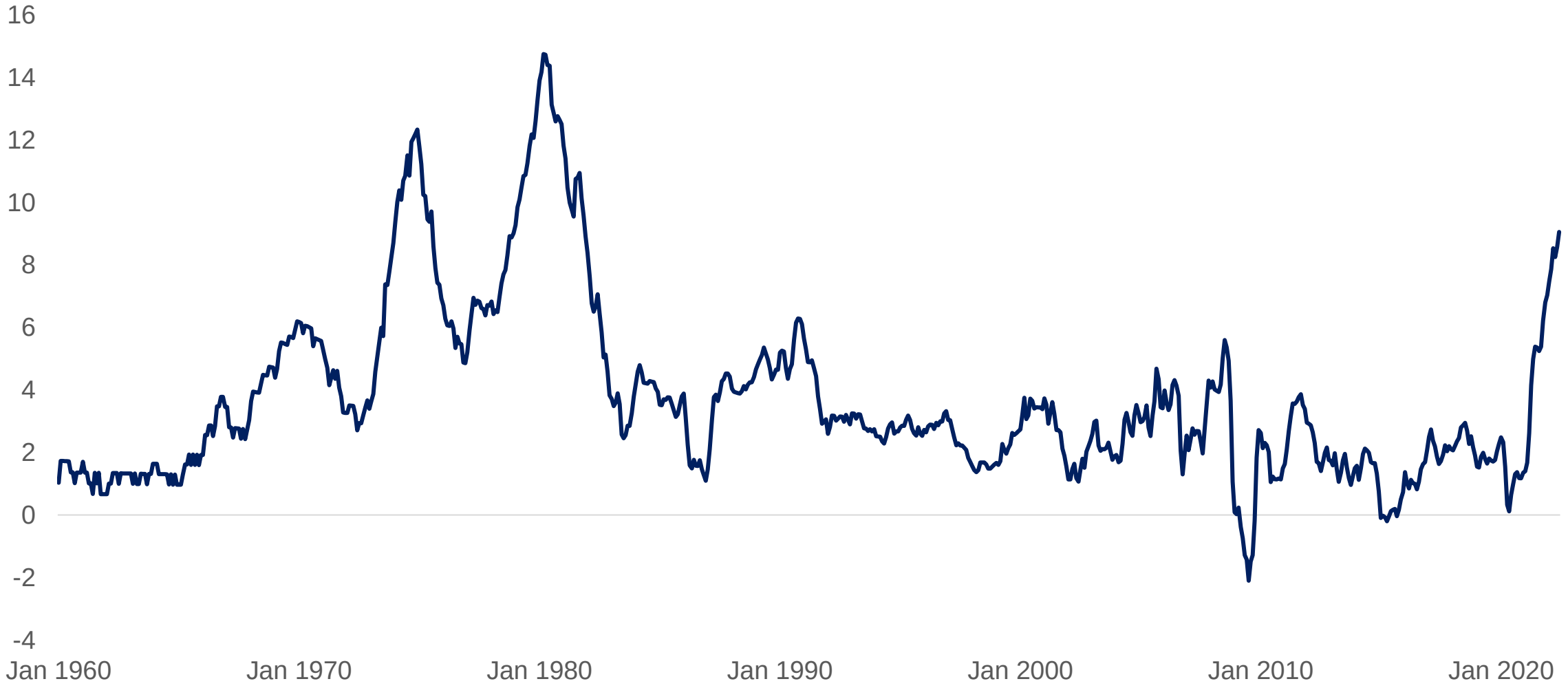
Abstract

The authors apply a Hidden Markov Model to identify regimes of shifting inflation and then employ an attribution technique based on the Mahalanobis distance to identify the economic variables that determine the trajectory of inflation. Their analysis enables policymakers to focus on the most effective tools to manage inflation, and it offers guidance to investors whose strategies might benefit from knowledge of the prevailing determinants of inflation. Their analysis reveals that as of February 2022, the most important determinant of the recent spike in inflation was spending by the federal government.

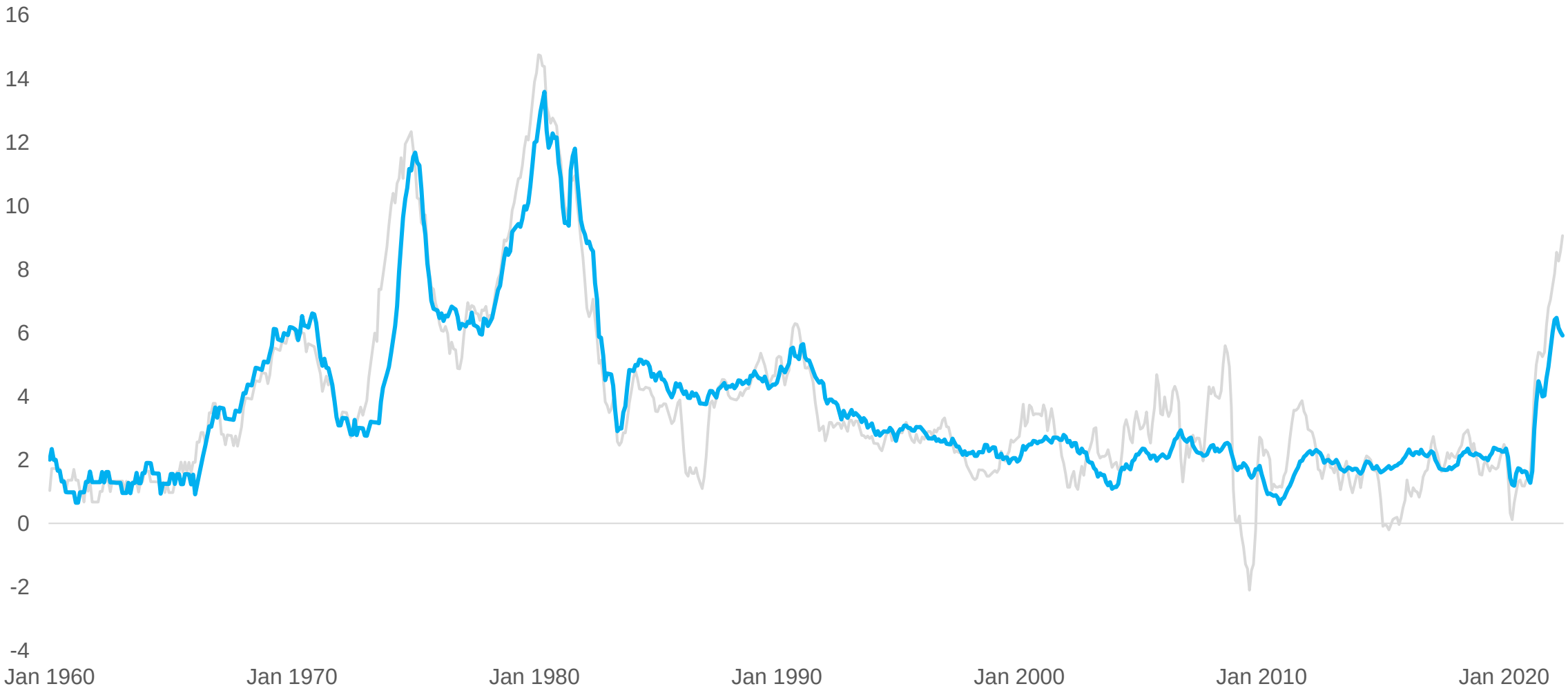
1

U.S. CPI annual inflation rate (%)



Source: Federal Reserve Bank of Saint Louis. Data covers the period January 1960 through June 2022 and reflects the one-year trailing inflation rate derived from CPI-U, NSA.

U.S. CPI annual inflation rate (%, excluding food and energy)



Source: Federal Reserve Bank of Saint Louis. Data covers the period January 1960 through June 2022 and reflects the one-year trailing inflation rate, excluding food & energy, derived from CPI-U, NSA (blue). The analogous headline CPI is shown in grey.

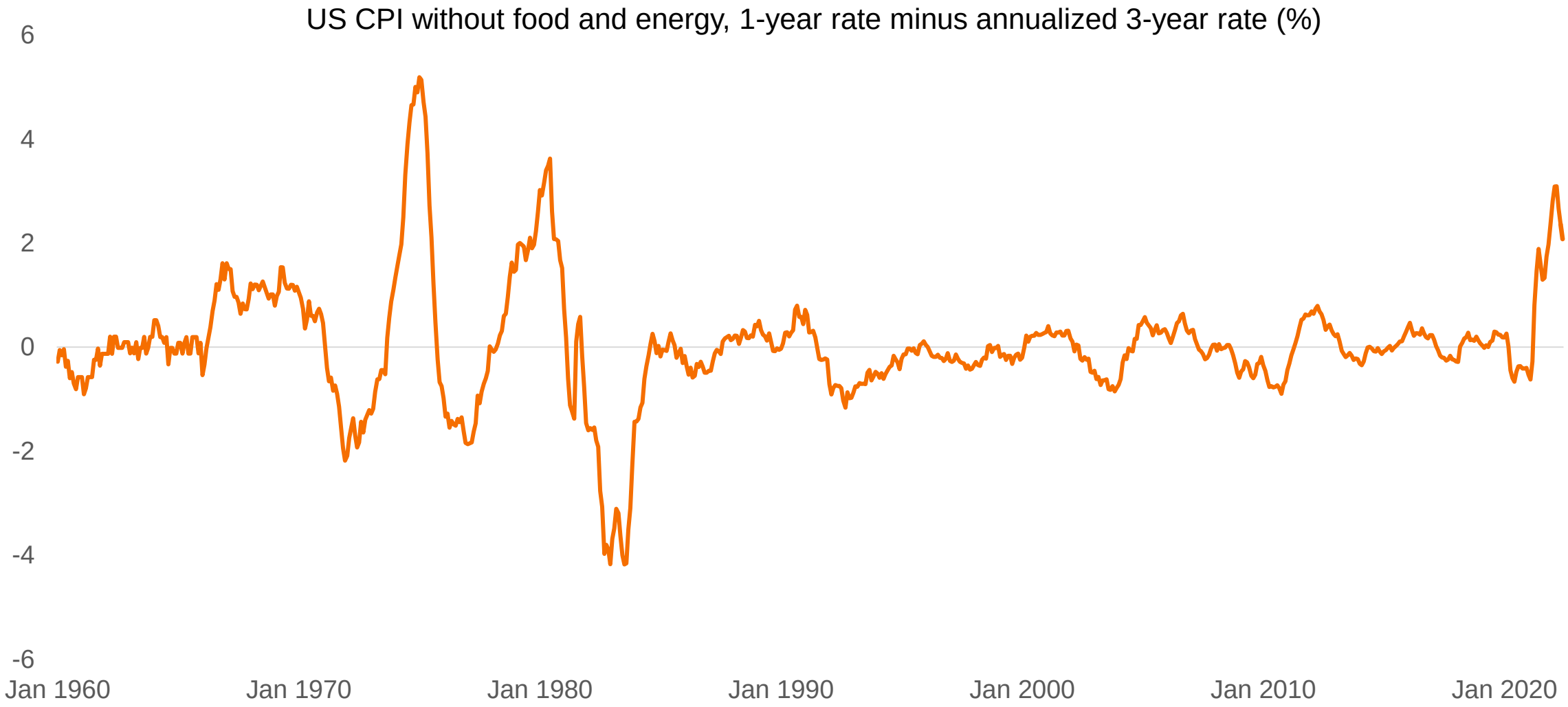
Potential inflation narratives

- Supply shortages force prices up
- Companies raise prices to cover input costs (fuel, labor, other)
- Government spending overheats the economy
- Low interest rates cause consumers to binge on borrowing and spending
- When the government “prints money” it debases the currency
- Tight labor markets ignite a wage-price spiral
- Inflation expectations create a self-fulfilling prophesy

Inflation data: Our analysis

1. Identify statistically distinct inflation regimes
2. Observe economic variables that determine inflation outcomes
3. Characterize each regime in terms of the behavior of these economic variables
4. Create an index of the likelihood of each regime based on the variables
5. Measure the importance of each variable in determining these index values
6. See how the relative importance of variables changes over time

Shifts away from the trend



Source: Federal Reserve Bank of Saint Louis. Data covers the period January 1960 through June 2022 and reflects the one-year trailing inflation rate, ex food & energy, minus the three-year trailing rate.

Hidden Markov Model

- We assume that observed inflation shifts emanate from multiple distributions that switch according to a hidden regime characteristic that follows a Markov process.
- Each regime has a degree of persistence from one period to the next. But there is also a chance that the regime will shift abruptly.
- We implement the Baum-Welch algorithm to fit the HMM. This gives us a time series for each regime that tells us how likely it is that we would observe each period's inflation shift were we in that regime.
- The model accounts for the fact that some values for the inflation shift are more likely to have come from one regime an another, given their respective distributions.
- It also captures the fact that a particular regime is more likely if it is highly persistent and believed to have prevailed in the preceding months.

HMM regimes

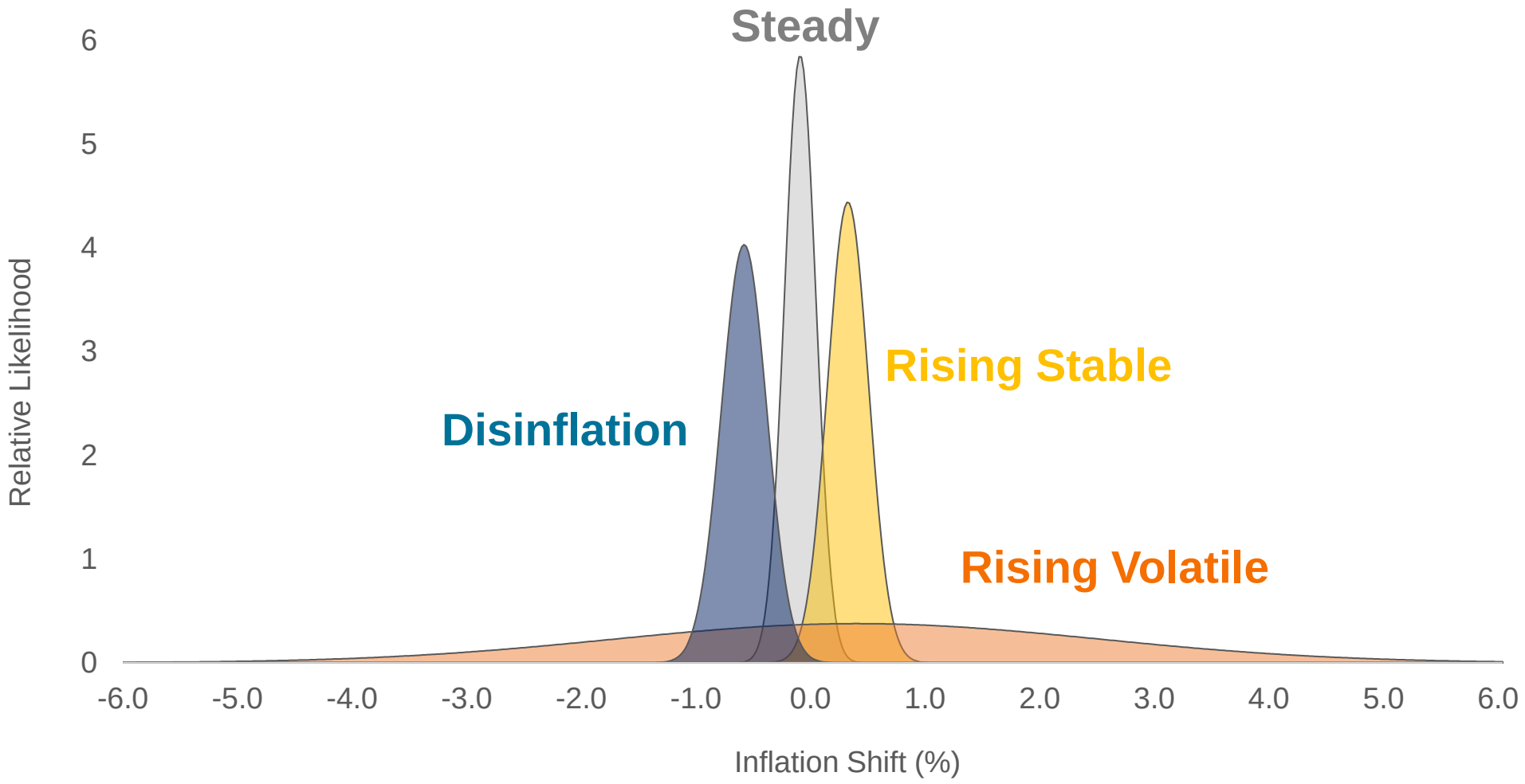
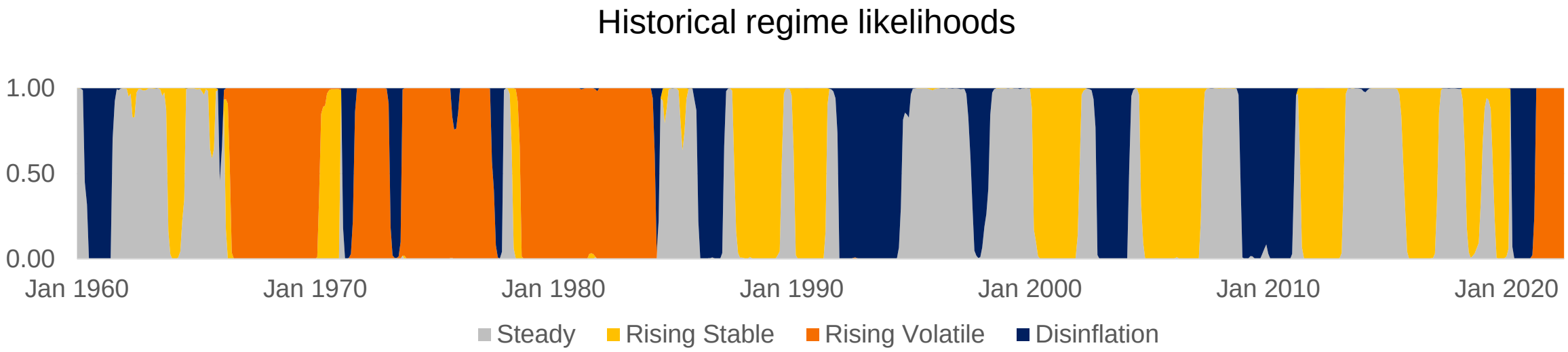


Chart shows normal distributions corresponding to four HMM regimes derived from the inflation shift metric. Data covers the periods January 1960 through June 2022.

Regime labels based on the most likely fit

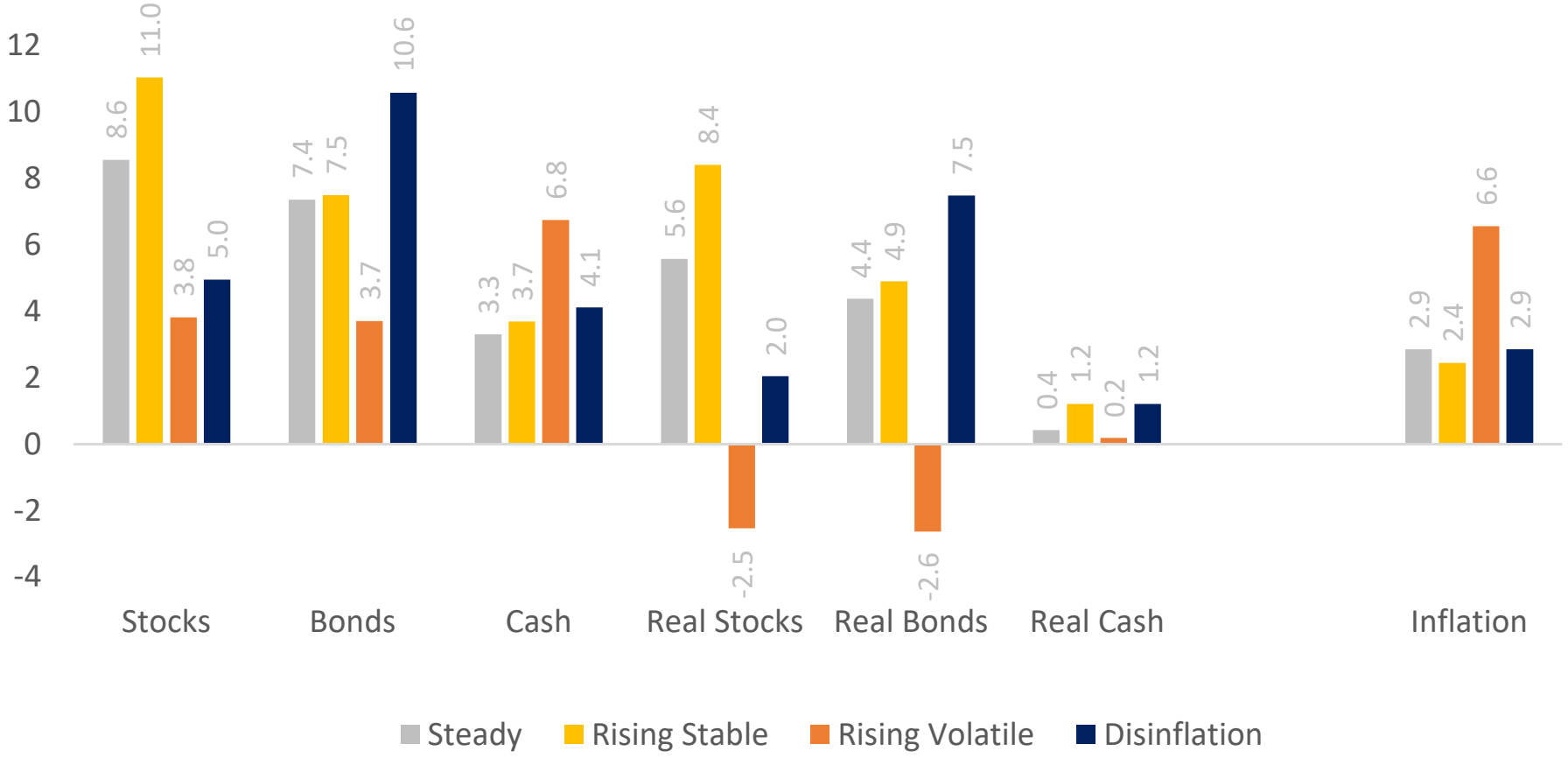


Monthly transition frequencies (%)

Transition Frequencies (%)	Steady	Rising Stable	Rising Volatile	Disinflation
From Steady to…	**91.0**	5.2	0.0	3.7
From Rising Stable to…	6.5	**92.4**	1.1	0.0
From Rising Volatile to…	0.0	0.5	**97.7**	1.7
From Disinflation to…	6.1	0.0	2.3	**91.6**

Source: Kinlaw et al. (2022)

Average asset returns during each inflation regime (%)



Data covers the periods January 1960 through February 2022. Source: Kinlaw et al. (2022).

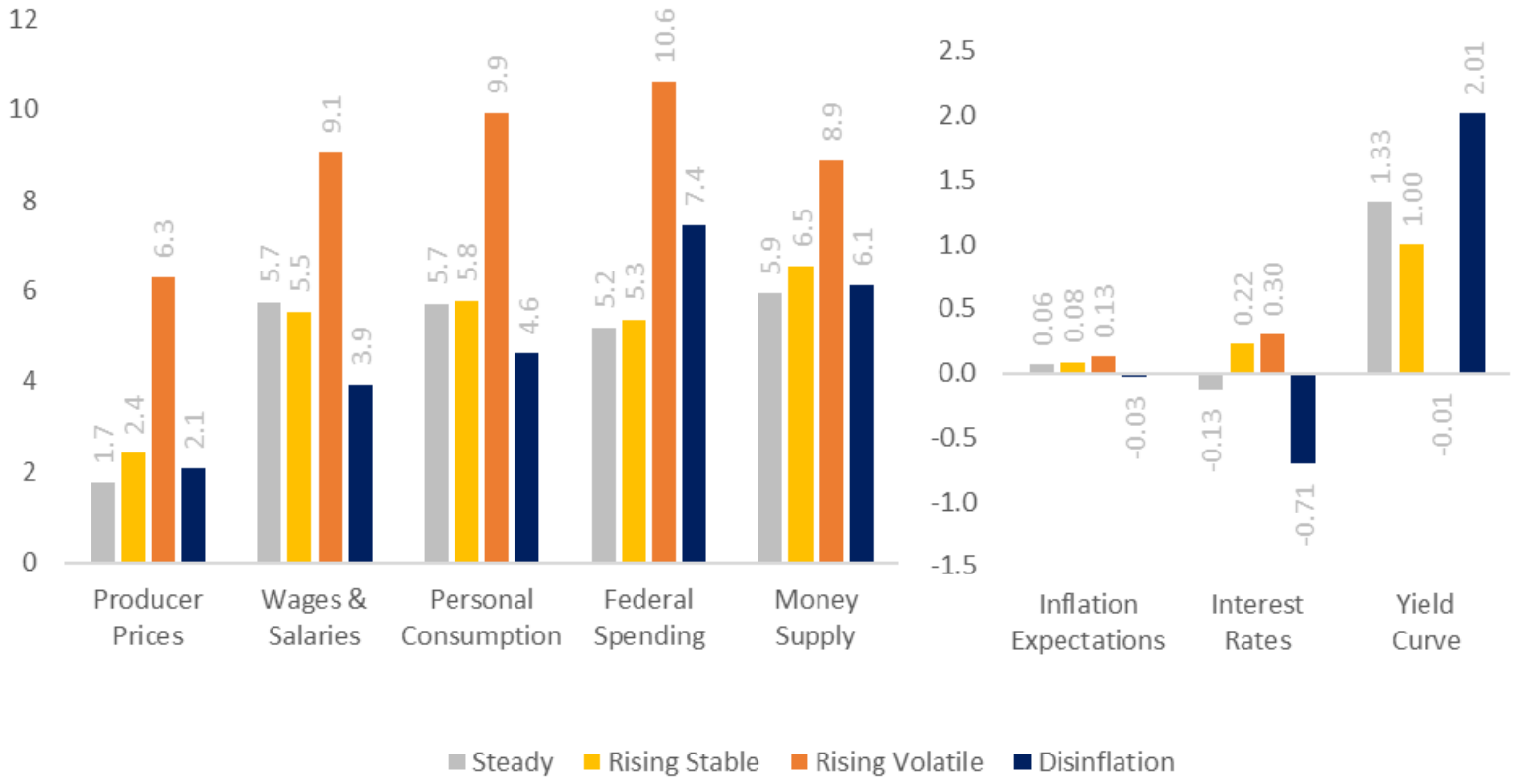
Potential drivers of inflation

Category	Variable	Data	Units	Frequency / Start Date
Cost Push	Producer Prices	Producer price index*	Year-over-year change	Monthly, 1913
Demand Pull	Wages & Salaries	Compensation of employees received (wage and salary disbursements)	Year-over-year change	Monthly, 1959
	Personal Consumption	Personal consumption expenditures	Year-over-year change	Monthly, 1959
Inflation Expectations	Inflation Expectations	Michigan Consumer Survey**	One-year change in one-year-ahead forecast	Monthly, 1978
Monetary Policy	Interest Rates	Federal funds rate	Year-over-year change	Monthly, 1954
	Yield Curve	10-year yield minus federal funds rate	One-year moving average	Monthly, 1954
	Money Supply	Money supply M2***	Five-year change	Monthly, 1960
Fiscal Policy	Federal Spending	Federal spending****	Five-year change	Quarterly, 1948

* We use the core PPI which excludes food and energy costs. Prior to 1974 the core PPI is not available, so we use the headline PPI. ** Prior to 1979 survey data is unavailable; for this period, we use the most recent one-year change in headline CPI minus the prior one-year change in headline CPI. *** The one-year change in M2 becomes available in January 1960; we begin with the one-year change and increase the window until January 1964, then we roll forward a five-year change. **** We repeat the most recent quarterly value for each month in our analysis.

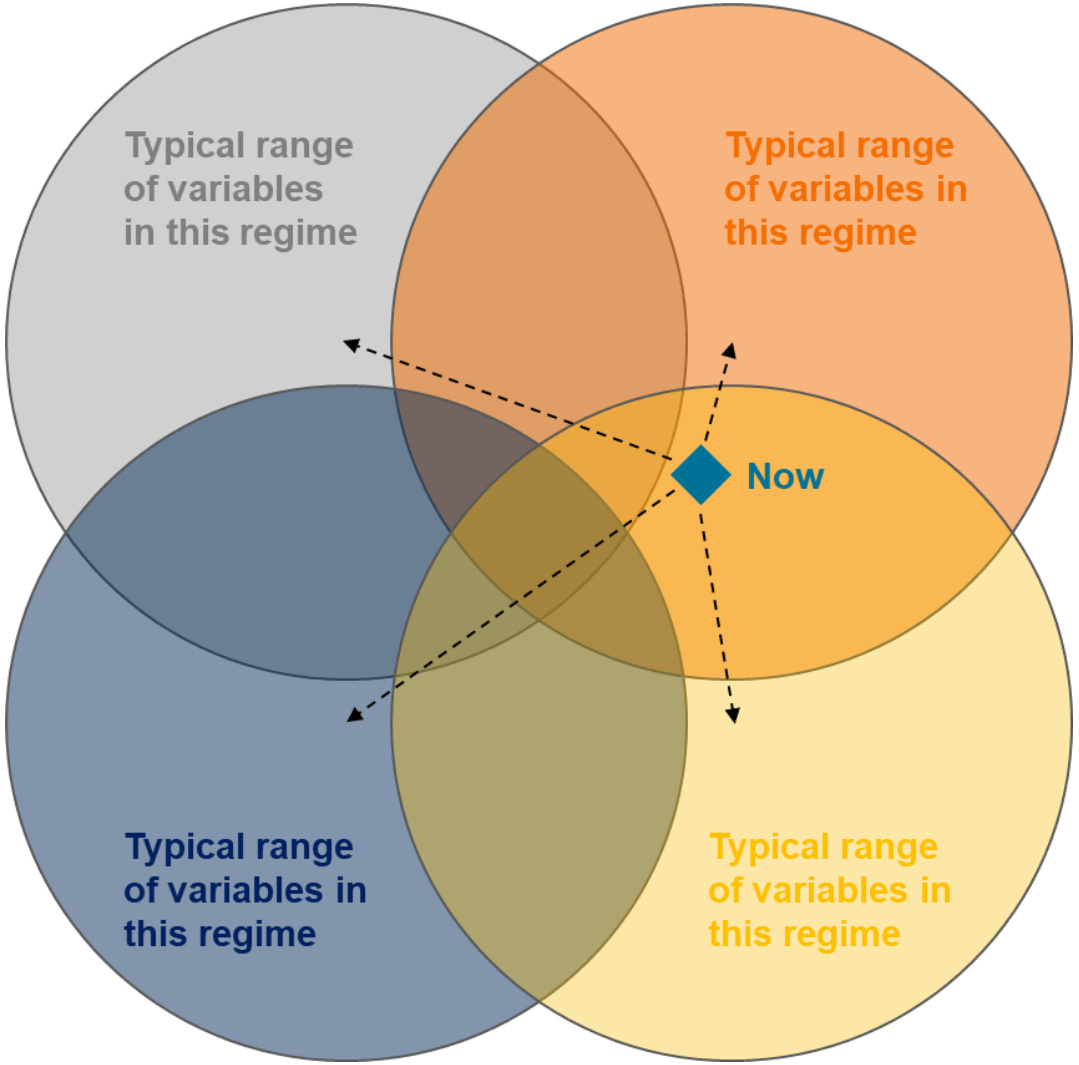
Source: U.S. Federal Reserve Bank of Saint Louis, State Street Global Markets

Average economic conditions during each inflation regime



Data covers the period January 1960 through February 2022. Source: Kinlaw et al. (2022).

Regime determination, conceptually (Mahalanobis distance)



Regime determination, mathematically

Mahalanobis distance

$$d_r = (x - \mu_r)\Omega_r^{-1}(x - \mu_r)'$$

Regime likelihood

$$\xi_r(d_r) = (\det(2\pi\Omega))^{-1/2} e^{-d_r/2}$$

Normalized probability (relative likelihood)

$$p_r = \frac{\xi_r}{\sum_{all\ regimes\ i} \xi_i}$$

Marginal sensitivity of the probability to changes in x (derivative)

$$\frac{\partial p_r}{\partial x} = p_r \left(\left(\sum_{\substack{regimes \\ i \neq r}} p_i \frac{\partial d_i}{\partial x} \right) - (1 - p_r) \frac{\partial d_r}{\partial x} \right)$$

Marginal sensitivity of the Mahalanobis distance

$$\frac{\partial d_r}{\partial x} = \Omega_r^{-1}(x - \mu_r)'$$

Aggregated sensitivity across four regimes

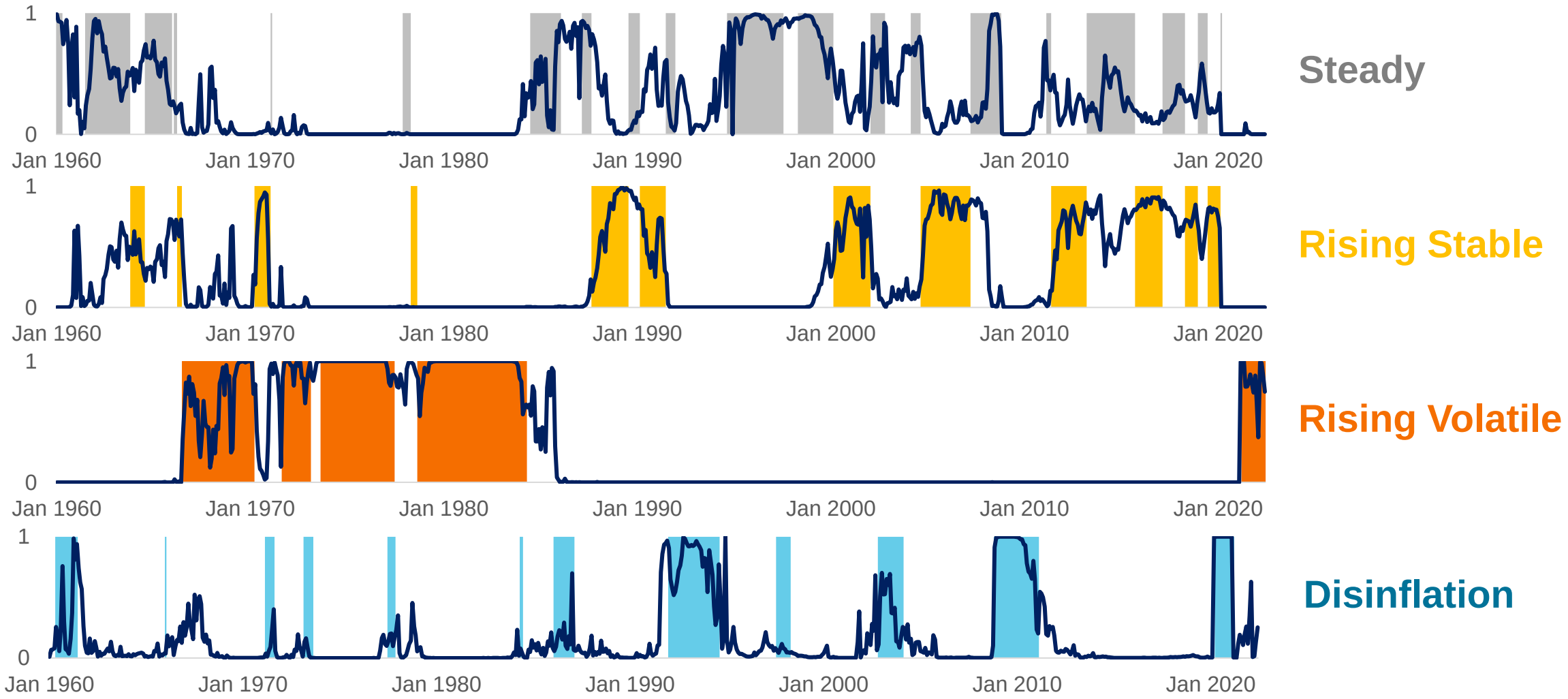
$$sensitivity = \frac{1}{4}\left(\left| \frac{\partial p_A}{\partial x} \right| + \left| \frac{\partial p_B}{\partial x} \right| + \left| \frac{\partial p_C}{\partial x} \right| + \left| \frac{\partial p_D}{\partial x} \right| \right)$$

Normalized variable importance

$$variable\ importance = \frac{sensitivity \circ \sigma}{|sensitivity \circ \sigma|}$$

Source: State Street Global Markets, Kinlaw et al. (2022)

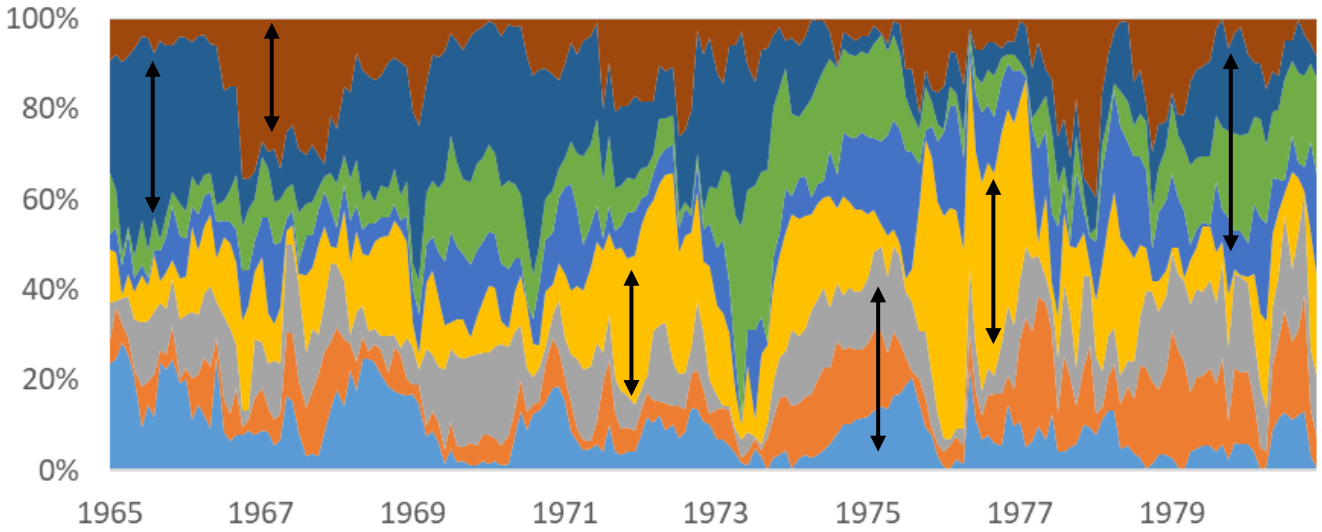
Economic variables' ability to determine the inflation regime



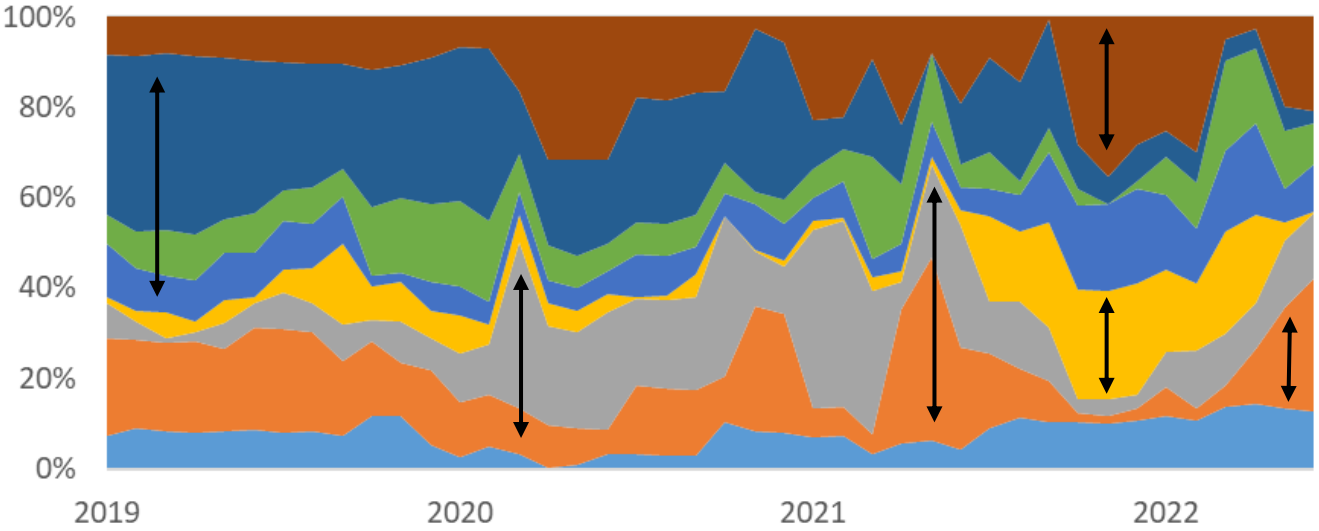
Source: State Street Global Markets. Data covers the period Jan 1960 through June 2022.

Inflation determinants: ‘The Great Inflation’ vs. ‘Covid Inflation’

The Great Inflation: 1965 - 1980



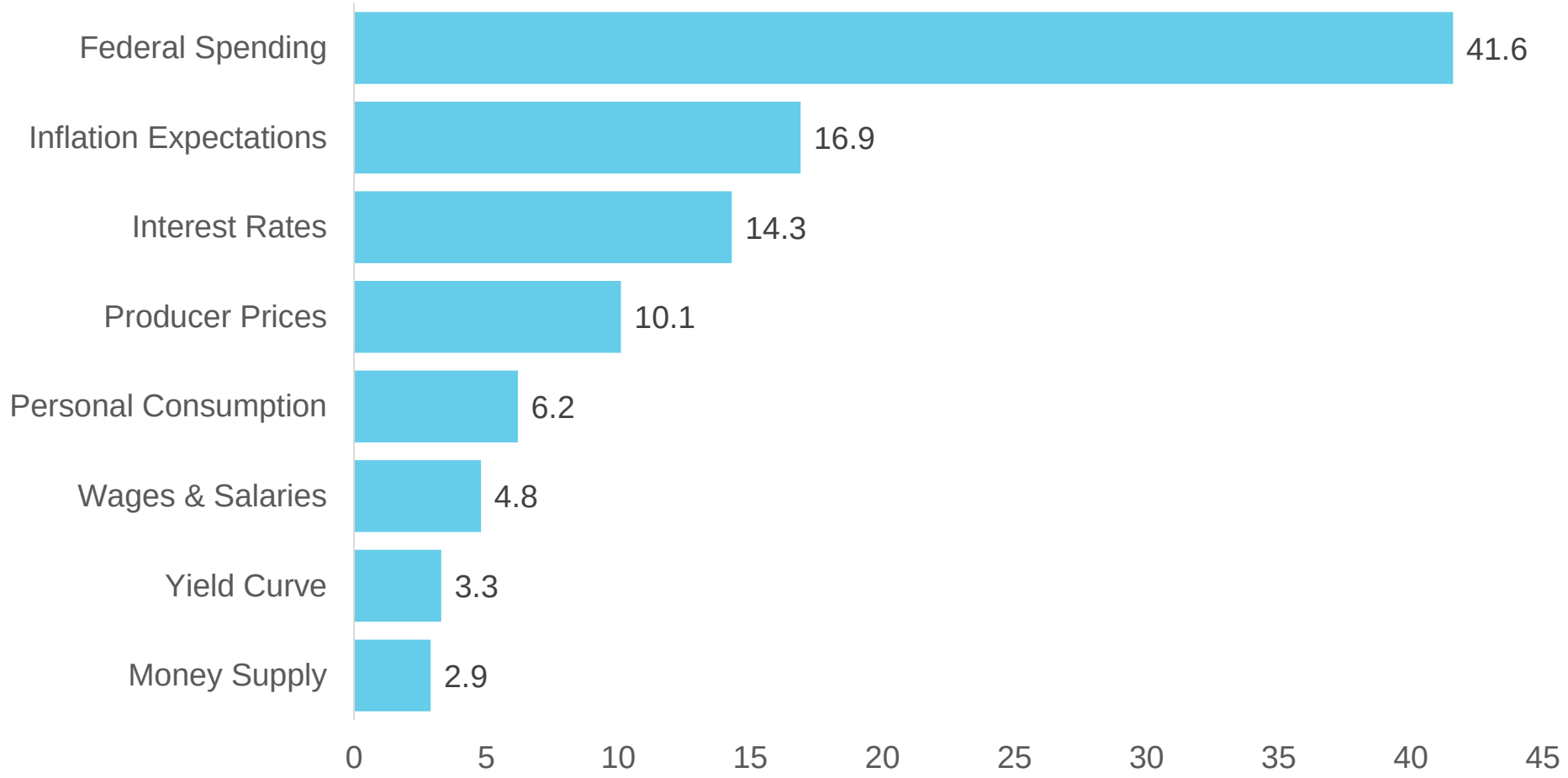
Covid-19 Pandemic: 2019 - June 2022



- Producer Prices
- Wages & Salaries
- Personal Consumption
- Inflation Expectations
- Interest Rates
- Yield Curve
- Money Supply
- Federal Spending

Source: State Street Global Markets, Kinlaw et al. (2022)

The determinants of inflation at “peak shift” in Feb 2022 (%)



Source: State Street Global Markets, Kinlaw et al. (2022)

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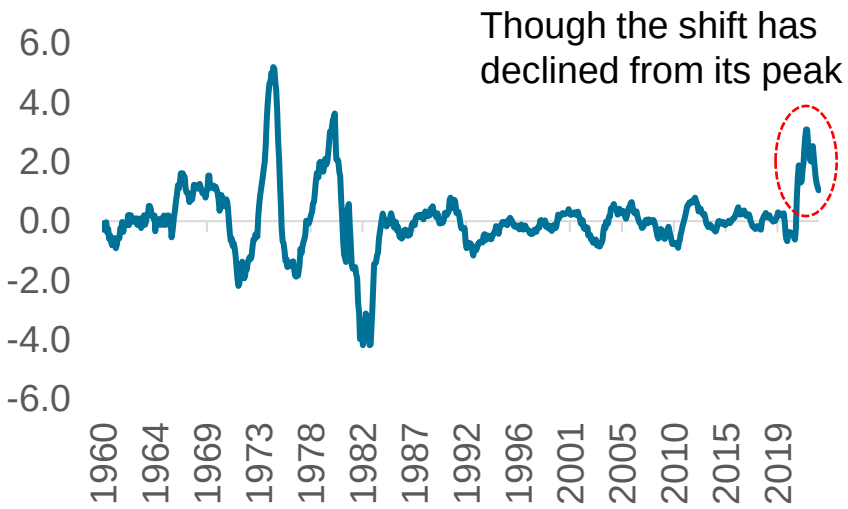
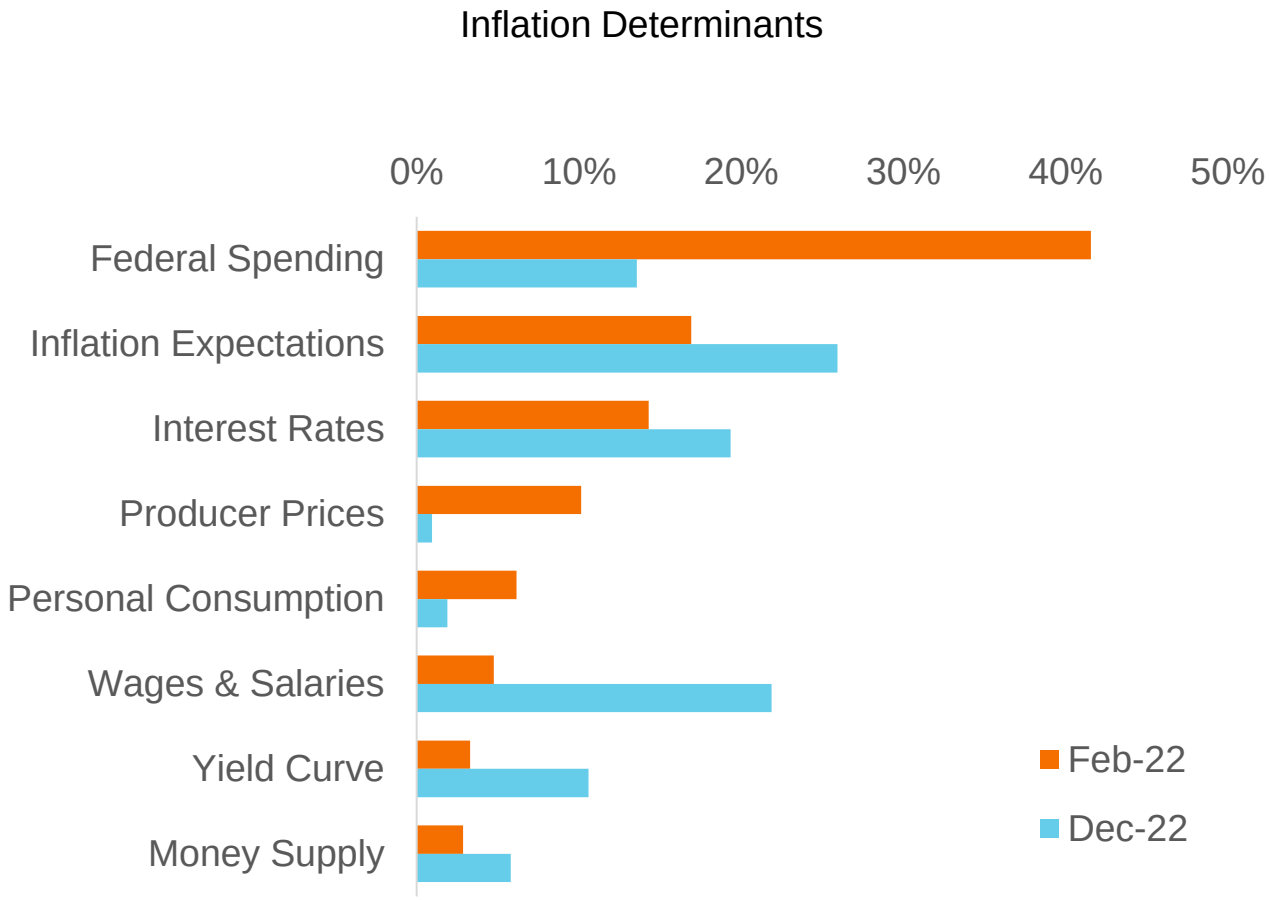
What has happened since the paper?

HMM Regime

We remain in "**Rising Volatile**" as of March 31, 2023





Source: State Street Global Markets

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Summary

- We used a Hidden Markov Model to identify four distinct inflation regimes since 1960.
- We then proposed several economic variables as potential determinants of inflation.
- We used the Mahalanobis distance to evaluate the relative likelihood of each regime, and we computed the relative importance of each variable in determining the regime.
- The variables that most influence inflation regimes change over time.
- We observed that spending by the federal government stands out as the most important determinant at the onset of the recent spike in inflation.

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