A statistical approach to identifying ECB monetary policy

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Introduction

- There is not ‘a’ monetary policy shock.
- Monetary policy is multi-dimensional: different policy instruments affect the yield curve and risky assets in distinct ways.
  - Policy rate, forward guidance, asset purchases.
- How can we extract the multiple dimensions of monetary policy from high-frequency financial market reactions?
- The literature uses economic identifying assumptions to rotate principal components (Gürkaynak et al., 2005; Altavilla et al., 2019; Swanson, 2021, among others).
- Can we identify these dimensions without strong assumptions? Can we uncover additional channels without imposing even stricter restrictions?

Contribution

- We propose an agnostic approach to identifying multidimensional monetary policy shocks.
- Our approach relies on statistical properties of the data, without imposing strong economic assumptions.
- We apply *Varimax rotation* to principal components (Kaiser, 1958).
- Rohe and Zeng (2023) show Varimax identifies "structural" dimensions if there is:
  - sparsity in the loadings, meaning each dimension concentrates on a subset of assets.
  - kurtosis in the dimensions, meaning the distribution of shocks exhibits fat tails.
- Varimax identifies dimensions similar to those found in the literature
  - *target*, *path*, and *quantitative easing*, as in Altavilla et al. (2019); Swanson (2021)
- It is easy to extend the set of assets without requiring stricter restrictions.
- We uncover a risk-shift dimension of monetary policy, which can be further decomposed into *sovereign risk*, *policy uncertainty*, and *corporate risk*.

Decomposing high-frequency monetary policy surprises

- $\underset{T\times n}{X}$ is a matrix with the changes in n asset prices around T monetary policy meetings
- Use principal components (PCs) to decompose

$$\underset{T\times n}{X} = \underset{T\times k}{F}\underset{k\times n}{\Lambda} + \underset{T\times n}{\eta}\ , \text{ with } k \ll n$$

- We now have F 'shocks,' but only in reduced form, similar to the VAR literature.
  - Note that for any orthonormal (rotation) matrix $\underset{k\times k}{U}$, $FUU'\Lambda = \tilde{F}\tilde{\Lambda} = F\Lambda$.
  - There is an infinite number of U matrices consistent with the observed data.
- We need additional structure to identify the dimensions of monetary policy surprises.

Conventional approach to identification

- Impose economic restrictions on FU (structural shocks) and on $U'\Lambda$ (loadings, i.e., response of assets to shocks) to find a unique rotation matrix U.
  - Euro area: Brand et al. (2010); Altavilla et al. (2019); Wright (2019); Mira Godinho (2021); Motto and Özen (2022); Fanelli and Marsi (2022); Tuteja (2023); Leombroni et al. (2021)
  - US: Gürkaynak et al. (2005); Swanson (2021)

- Most common restrictions:
  - Zero restrictions (e.g., forward guidance or QE does not affect the shortest maturity rate)
  - Variance minimisation (e.g., QE shocks are small before QE officially starts)
  - Sign restrictions (e.g., risk-free rates and risky sovereign debt react oppositely to a flight-to-quality shock)

- Dimensions commonly found in the literature:
  - Gürkaynak et al. (2005); Brand et al. (2010): *jump*, *path*
  - Altavilla et al. (2019); Swanson (2021): *target/timing*, *forward guidance (FG)*, *QE*
  - Motto and Özen (2022): *timing*, *FG*, *conventional QE*, and *market-stabilisation QE*

Varimax approach

- Conventional approach requires strong assumptions.
  - It almost assumes the results: for instance, if only one factor influences short-term risk-free rates, that same factor dominates the short end of the yield curve.
- Can we have an approach that requires weaker economic assumptions?
- Varimax rotation (Kaiser, 1958):

$$U^{\text{Varimax}} = \arg\max_{U} \sum_{j=1}^{k} \sum_{m=1}^{n} \left(U\Lambda_{j,m}\right)^4$$

- **Objective:** maximise the variance of squared loadings.
- **Intuition:** Loadings should be sparse: each dimension should concentrate on a subset of assets.

Varimax approach

- Varimax has been used in exploratory data analysis in many fields analysis to simplify the interpretation of principal components (PCs).
- However, since any rotation matrix appears equally consistent with the data, results were not interpreted structurally.
- Rohe and Zeng (2023) show that Varimax identifies structural dimensions if there is:
  1. sparsity in the loadings, i.e., each dimension concentrates on a subset of assets;
  2. excess kurtosis in the dimensions, i.e., there are fat tails in the distribution of shocks (compared to Gaussian).
- Is that the case in monetary policy?
  1. There is broad consensus that, e.g., some instruments affect short-term rates (policy rate), while others affect longer maturities (QE), as reflected in the use of zero restrictions.
  2. Yes, undoubtedly. Jarociński (2024) finds the same for the US.

Varimax approach

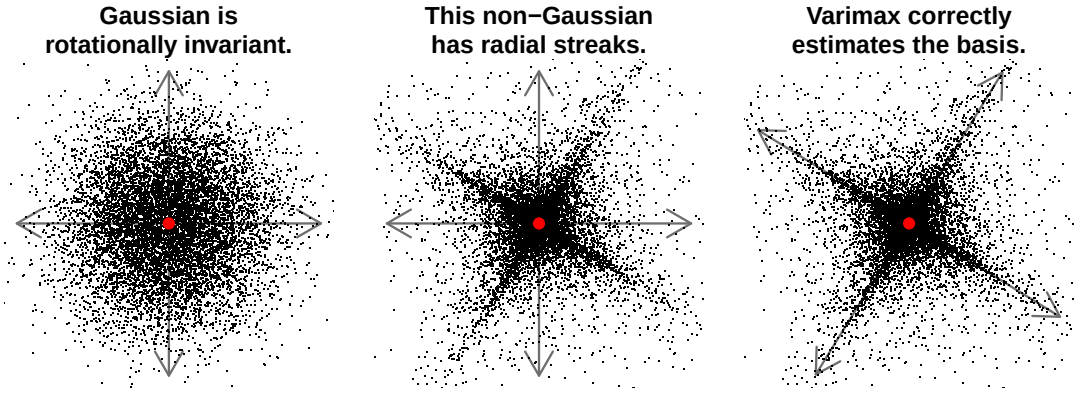


Figure: Figure 1 from Rohe and Zeng (2023).

- Maxwell (1860) shows that the Gaussian distribution is the only distribution of independent variables that is rotationally invariant. Similar argument in Jarociński (2024).

Varimax approach

- Empirical monetary policy surprises are strongly fat-tailed.
- Principal components preserve this property.

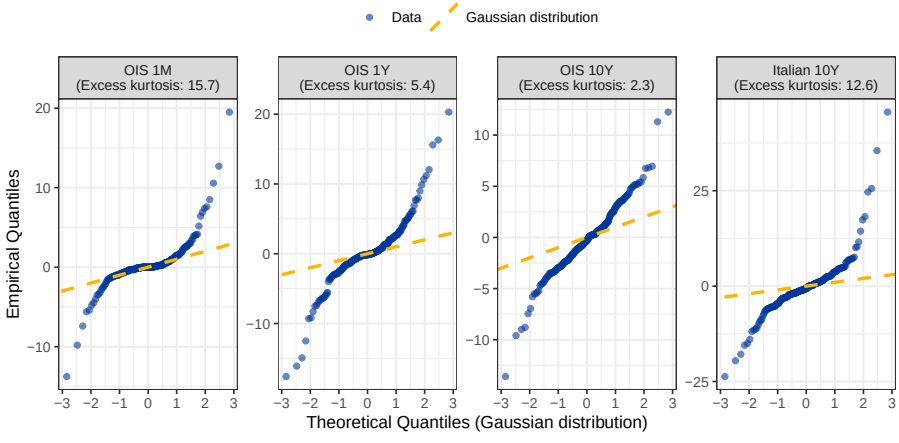


Figure: Q-Q plot of high-frequency surprises in yields, with a comparison to a Gaussian distribution.

Varimax approach

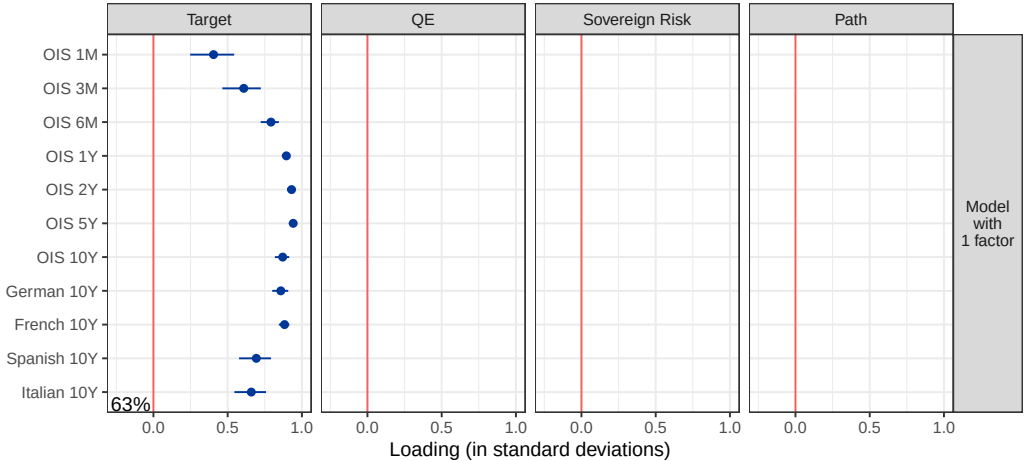
- **Intuition**: if two assets are outliers on the same day, it is more likely they are driven by the same 'shock' than by two orthogonal 'shocks'.

- Intuition is similar to Jarociński (2024) for the US, despite a different approach.
  - In his case, a maximum likelihood approach with Student-t shocks.
  - In our case, rotated principal components, more in line with the traditional approach.
  - In both cases, kurtosis in the shocks is crucial for identification.

- **Examples**: The ECB surprised markets in March 2023 with a 50 bp increase in the policy rate, despite expectations closer to 25 bp.
  - 19 bp surprise in the 1-month risk-free rate $\rightarrow$ 7 standard deviation (sd) surprise.
  - If surprises were Gaussian, this would happen less than once in 100 billion meetings.
  - On that day, the 6-month rate had a 4.3 sd surprise; the 10-year rate had a 0.4 sd surprise.

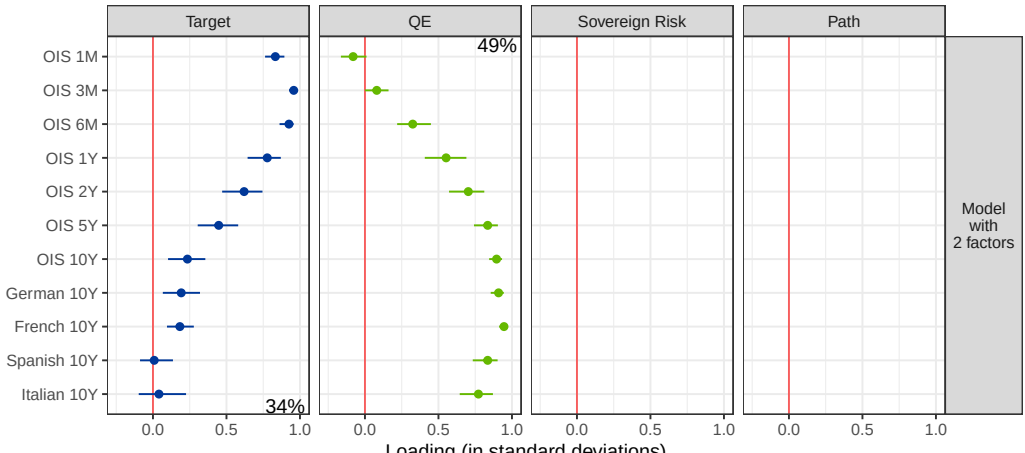
- On the 5 events where the 1-month rate had a surprise larger than 3 sd:
  - The 6-month rate had a surprise larger than 2 sd every time.
  - The 10-year rate never had a surprise larger than 2 sd.

Results on risk-free rates and sovereign yields



Percentage indicates share of variance explained by each factor.
90% confidence intervals based on 5000 bootstrapped samples.

Results on risk-free rates and sovereign yields



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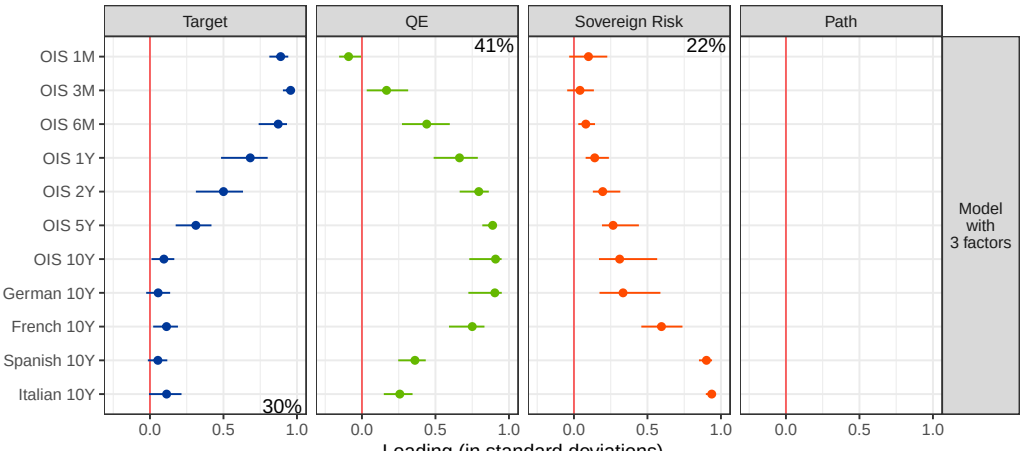

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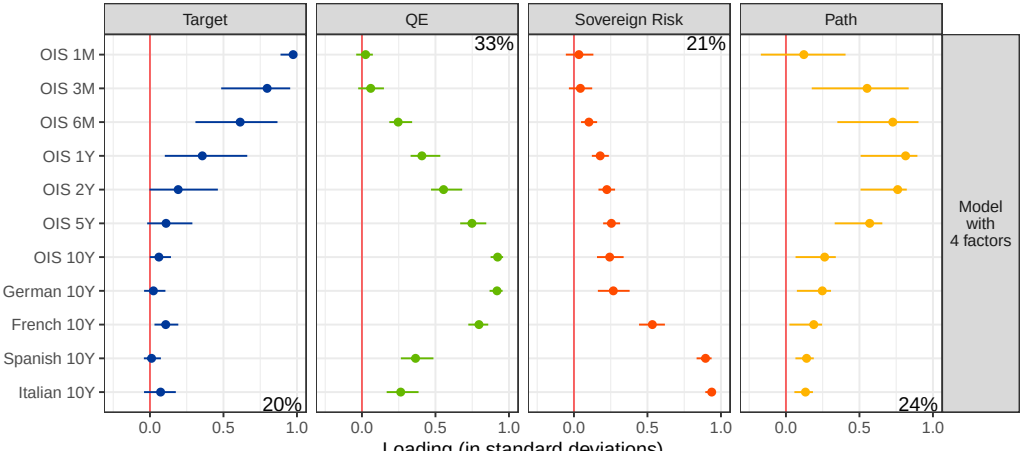

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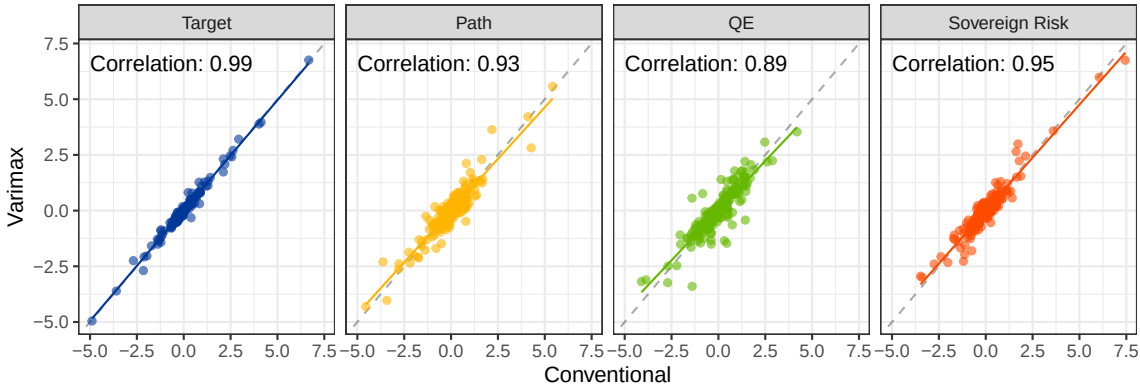
Comparing Varimax and conventional approaches

- We document in the paper a conventional approach that imposes:
  - Only *Target* affects the 1-month rate.
  - Only *Target* and *Path* affect the 6-month rate.
  - *QE* should affect sovereign yields as equally as possible.



Sample period: January 2002 − October 2023.

Comparing Varimax and conventional approaches

- Varimax statistically validates the results in Altavilla et al. (2019), ▸ Swanson (2021) ,
  ▸ Motto and Özen (2022)

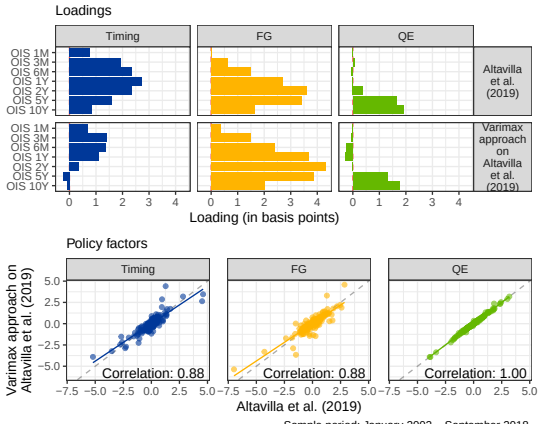


Figure: Comparison of Altavilla et al. (2019) and the Varimax approach applied to the same dataset.

Extending to risky assets - Stock market

- Many papers also study stock market reactions, focusing on two channels:
  1. **Information Effects**: Central banks release macro information that leads to positive co-movement of risk-free rates and risky assets
     - (Nakamura and Steinsson, 2018; Jarociński and Karadi, 2022; Miranda-Agrippino and Ricco, 2021; Kerssenfischer, 2022; Acosta, 2023; Andrade and Ferroni, 2021; Fanelli and Marsi, 2022)
  2. **Risk-Shift**: Monetary policy impacts risk-taking in a way that extends beyond the direct effects of monetary policy instruments
     - (Kroencke et al., 2021; Cieslak and Schrimpf, 2019; Cieslak and Pang, 2021)

Extending to risky assets - Stock market

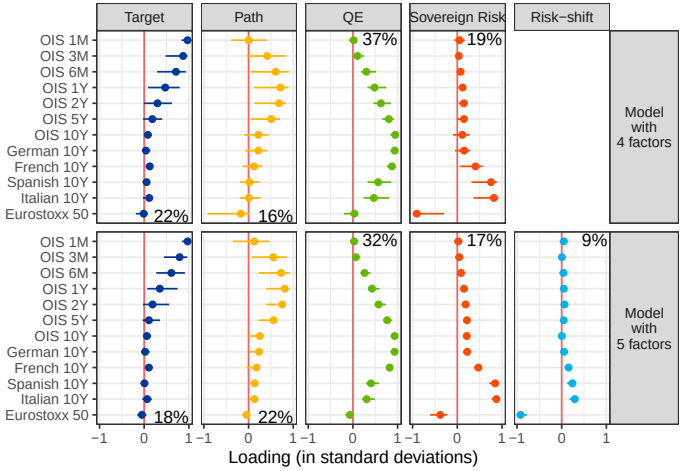


Figure: Varimax rotation applied to principal components for a first risk-extended set of assets.

Extending to risky assets - Stock market

- No evidence of an information effect emerges in any factor; either it is not a relevant mechanism in the euro area or it is not fat-tailed enough to be identified statistically.

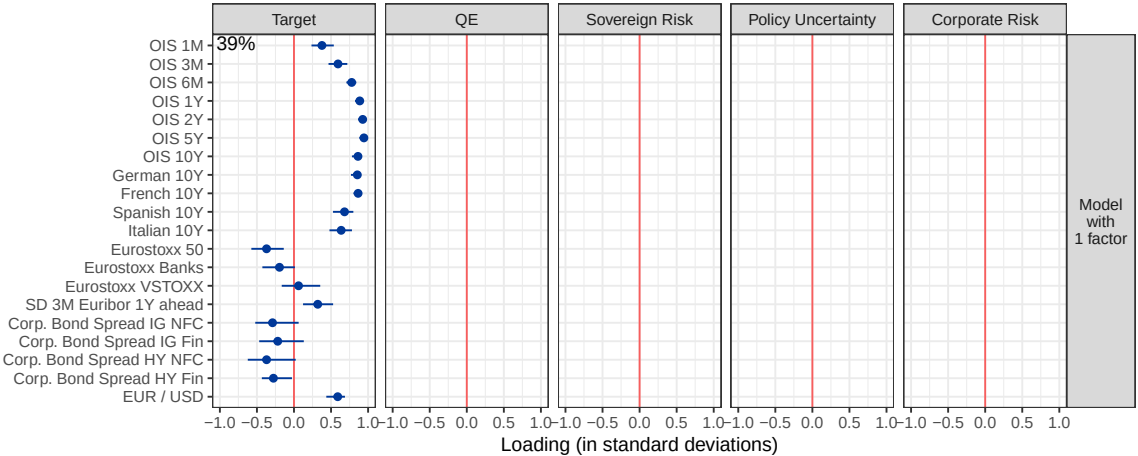
- Instead, risk dimensions emerge, which will be explored in more detail.

- Jarociński and Karadi (2022) find that 40% of meetings in the euro area exhibit positive co-movement between the 3-month risk-free rate and the stock market
  - We find that these two assets are driven by different factors
  - In the euro area, sovereign risk is a confounder, as flight-to-quality effects may lead to movements of risk-free rates and sovereign yields in the same direction (also discussed in Motto and Özen, 2022)

Extending to risky assets - Risk channels

- We extend the set of risky assets to uncover broader channels of risk
- Advantage of Varimax: no need to impose increasingly stronger assumptions.
- Include:
  - Eurostoxx Bank stock index
  - EUR/USD exchange rate
  - Eurostoxx VSTOXX (stock market implied volatility)
  - Option-implied standard deviation of 3-month EURIBOR 1-year ahead (interest rate uncertainty)
  - Corporate bond spreads (IG/HY $\times$ Financials / NFCs)
- All variables are more volatile on ECB Governing Council meeting days compared to other Thursdays.

Extending to risky assets - Risk channels



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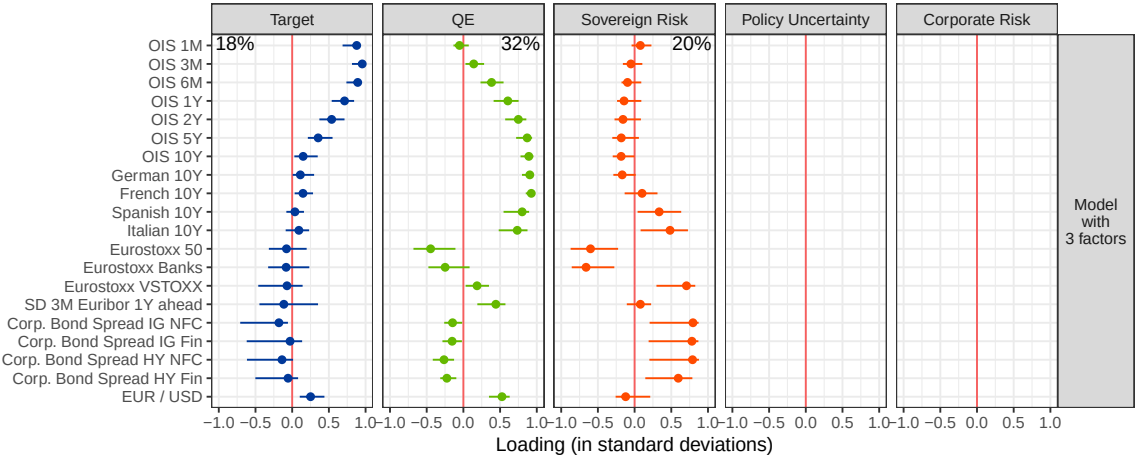
Extending to risky assets - Risk channels



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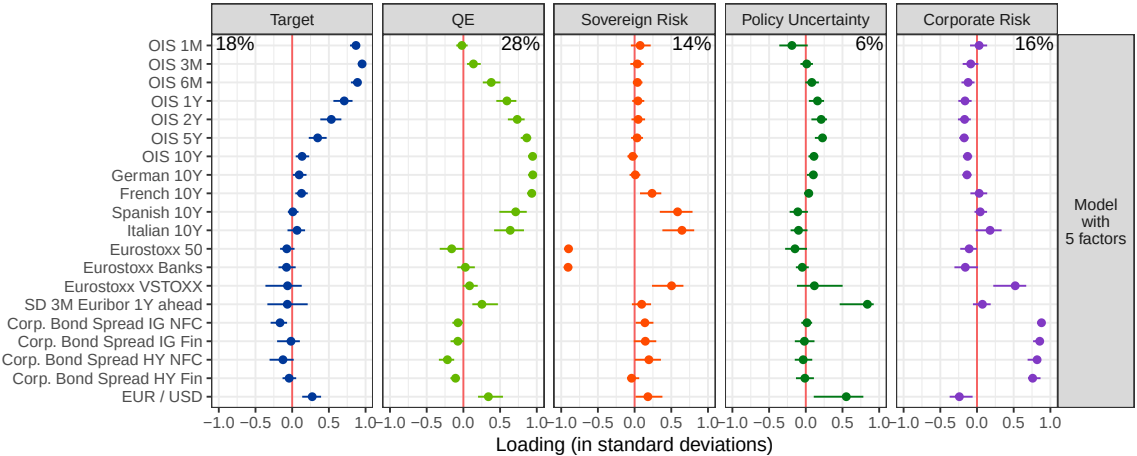
Extending to risky assets - Risk channels



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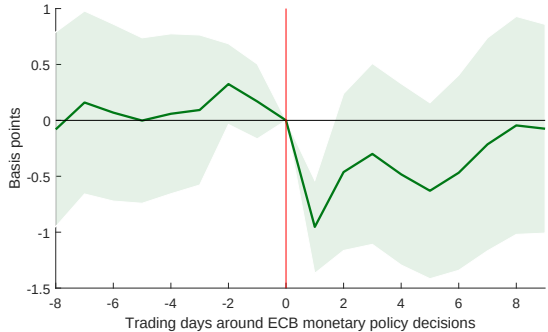
Monetary policy uncertainty



- ECB meetings usually resolve some interest rate uncertainty..
  - Large decreases in March 2023 (Silicon Valley Bank crisis), December 2011 (rate cut and 3-year LTRO announcements).
- .. but not always.
  - June 2023, February 2022, June 2008 (rate hikes); October 2021 (inflation uncertainty)
- Bauer et al. (2022) shows a similar pattern for the US

Corporate risk

- Increase in corporate bond spreads and stock market implied volatility, slight decline in risk-free rates, and a weaker euro.

- Aligns with the *risk-shift* factor identified for the US by Kroencke et al. (2021), which loads little on risk-free yields but more strongly on VIX, CDS spreads, and exchange rates.

- Largest movements occurred around COVID (March and June 2020) and the Global Financial Crisis (July, October, December 2008; March and May 2009; May 2020).

Financial propagation

- We run Proxy-BVARs including the Eurostoxx 50, exchange rate, the 2-year inflation-linked swap, and a risk-free/sovereign yield, starting in 2014.

- We instrument the risk-free/sovereign yield with the monetary policy dimension most closely associated:
  - *Target* with the 3-month rate
  - *Path* with the 2-year rate
  - *QE* with the 10-year rate
  - *Sovereign risk* with the Italian-German 10-year spread
  - *Policy uncertainty* with uncertainty over the 3-month EURIBOR 1-year ahead
  - *Corporate risk* with the IG NFC corporate spread

- Impact of monetary policy shocks on financial variables is significant and persistent.

- Heterogeneity of financial variables reactions
  - Stocks react significantly to some, but not all shocks (e.g. target or policy uncertainty)
  - Exchange rate reaction is usually uncertain; depreciation following corporate risk
  - Market-based 2-year inflation compensation generally declines in reaction to all shocks

Financial propagation

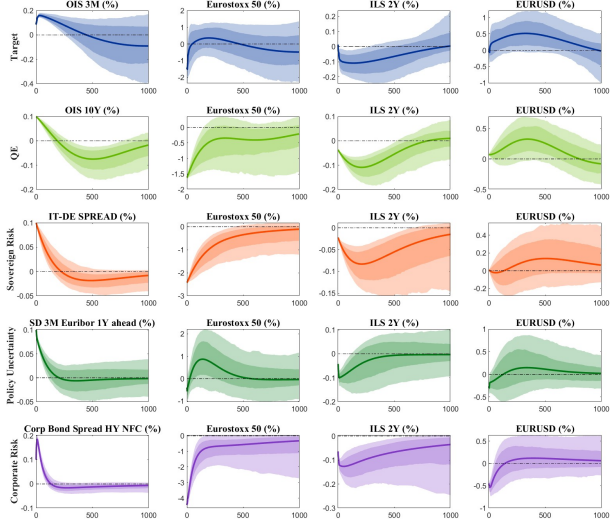


Figure: Daily financial Proxy VAR with Varimax risk-extended monetary policy factors as instruments.

Risk channel and risk appetite

- To further illustrate the importance of the risk channels identified, we build a risk appetite index for the euro area following the methodology of Bauer et al. (2023):
  - Includes the Eurostoxx 50, VSTOXX, HY Financial corporate bond spreads, EUR/USD, and the Italian sovereign spread.
- Tightening policy shocks across all dimensions (except *corporate risk*, which is positive but small/insignificant) lead to a significant and persistent decline in risk appetite.
  - Particularly *sovereign risk* and *policy uncertainty*.

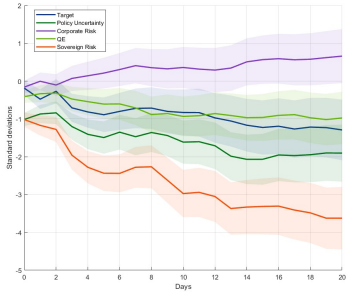


Figure: Dynamic response of risk appetite to a monetary policy tightening.

Conclusions

- There is no single ‘monetary policy shock’; policy is multi-dimensional.
- Literature relies on strong economic assumptions; scaling to broader channels is hard.
- We provide an agnostic approach to identification that delivers sensible results consistent with existing literature, aligning with policy instruments.
- We find no evidence of a central bank information effect in the euro area.
- We find evidence of a broad risk channel, which can be decomposed into sovereign risk, policy uncertainty, and corporate risk.
- Once risk channels are included, the distinction between forward guidance and QE is blurred.
- Persistent effects on financial variables follow the policy decision.

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Comparing Varimax and conventional approaches

Back

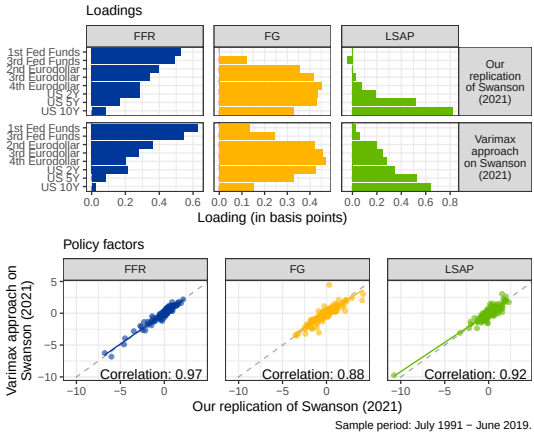

Figure: Comparison of the replicated Swanson (2021) factors for the US and the Varimax approach applied to the same dataset.

Comparing Varimax and conventional approaches

Back

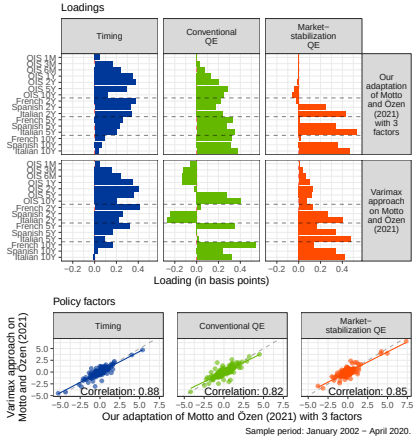

Figure: Comparison of an adapted version for three factors of the Motto and Özen (2022) press conference factors and the Varimax approach applied to the same dataset.

Extending to risky assets - Stock market

- Sovereign risk and risk-shift factor (with Eurostoxx) are correlated (0.8)

- There are still strong outliers where the two are disconnected that suggest different factors at play
  - With only four factors, Varimax groups them..
  - But if asked to disaggregate further, it separates the two

Date	Italian 10Y - German 10Y	Eurostoxx 50	Sovereign Risk	Risk-shift
November 2002	0	-1.6%	-1.2	2.7
July 2009	2	-1.7%	-1.0	2.9
December 2011	16	-1.1%	3.8	0.0
August 2012	40	-2.8%	6.9	1.2
September 2012	-14	1.2%	-3.0	-0.7
October 2015	-6	2.0%	-0.9	-2.7
December 2015	10	-3.6%	1.7	4.1
March 2020	46	-4.0%	5.1	3.6
June 2020	-23	0.0%	-3.6	1.1

Corporate risk dimension

Date	Target	QE	Sovereign Risk	Policy Uncer-tainty	Corporate Risk	Corp. Bond Spread IG NFC	Corp. Bond Spread IG Fin	Corp. Bond Spread HY NFC	Corp. Bond Spread HY Fin
March 2020	3.3	0.8	5.9	-0.5	7.2	12	19	82	59
October 2008	-0.6	-0.3	-1.2	0.4	5.2	8	2	37	200
May 2010	0.5	-0.1	0.4	0.8	4.1	9	14	31	31
May 2009	-1.6	0.9	1.5	0.2	-4.0	-4	-10	-34	-106
December 2008	1.5	-0.2	0.5	1.7	2.5	7	10	12	17
July 2008	-1.6	-1.9	-1.3	-1.3	2.5	3	3	62	29
June 2020	0.0	-0.4	-1.0	1.2	-2.4	-8	-8	-11	-15
March 2009	0.5	0.1	-0.2	-0.6	2.4	0	13	36	-3
February 2023	0.4	-3.4	0.3	-0.5	-2.0	-4	-7	-6	-7
January 2002	0.7	-1.1	0.3	-0.5	-1.8	-3	-1	-41	-21

Table: Monetary policy risk-extended factors and changes in corporate bond spreads on the days with the largest movements in *corporate risk*.

Financial propagation

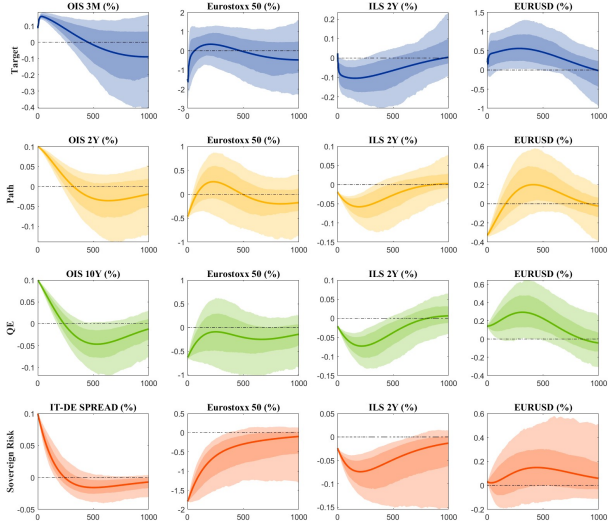

Figure: Daily financial Proxy VAR with the Varimax baseline monetary policy factors as instruments.

Risk appetite index

Variable	Transformation	Index Loading
Eurostoxx 50	Daily log changes	0.61
VSTOXX	Daily change	-0.60
Corporate Bond Spread High Yield Financial	Daily change in percentage points	-0.22
EUR/USD	Daily log changes	0.20
Italian-German 10-year Spread	Daily change in percentage points	-0.42