A Model-based approach for scenario design:
stress test severity and banks' resiliency

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Motivation

- In 2009 The European Banking Authority (**EBA**) decided to update the regulatory framework and outlined how banks and local regulators should approach stress testing going forward. One of the main areas the regulatory authority focused on was **scenario design** as the adverse scenarios turned out not to have been severe enough.

- Since then, **stress-test scenarios have been designed to be more severe**. One fundamental issue is therefore **how to measure the severity of a scenario**, given the large number of variables involved.

- Due to regulatory and supervisory pressure, banks took **risk management actions** to reduce their sensitivity to adverse shocks. We ask - were these actions **successful in making banks more resilient**? And, as a starting point, how do we **define resiliency**?

Main Goals

We **propose an operational approach for scenario design and to evaluate resiliency,** consistent with the guidelines of the regulators. Our approach is based on a Large Bayesian VAR estimated on Italian macroeconomic, banking, and financial data, **the IBASE**.

Differently from traditional stress tests (micro-pru), **our modelling strategy follows the macro-prudential approach**. Main differences: 1) dynamic balance sheet 2) potential spillovers between macro-financial and bank variables 3) data at banking sector level.

We propose a **metric to evaluate the severity** of a variable in a stress scenario and an aggregate measure of the severity of a scenario. We then rank the 2014, 2016, 2018 EBA exercises according to this metric.

We define a measure of resiliency and investigate whether **the resiliency of Italian banks to adverse shocks has increased over time**. To do so we run a **counterfactual analysis**, where we look at the **response of banking variables** to the stress scenarios calibrated to have the same severity.

Definitions & Concepts

Two operational definitions and how they compare with the Regulators'

SEVERITY

REGULATORS' DEFINITION	OUR DEFINITION
*"[...] the **deterioration** of the scenario expressed in terms of the underlying macroeconomic and financial variables" (EBA, 2018)* *"[...] A stress test scenario also needs to be **plausible** [...]" (BCBS, 2009a)).*	We measure the severity of all the variables as the **likelihood of the deviation** of the macroeconomic and financial variables from the baseline We then measure the **severity of the overall scenario** as the weighted average of the severity of all macro-financial variables

RESILIENCY

REGULATORS' DEFINITION	OUR DEFINITION
*"[...] the ability to **absorb** shocks arising from financial and economic stress, whatever the source, thus **reducing the risk of spillover** from the financial sector to the real economy" (BCBS, 2009b)*	A bank that reduces credit to meet capital requirements might generate **potential "second-round" effects**, exacerbating the size of the shock. Therefore, **a more resilient bank is not only a bank with adequate capital levels** but also one that is able to support the economy under a stressed scenario.

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Main findings

- Adverse scenarios on Italian Real GDP are very severe, while the scenarios on financial variables are more likely.
- The 2018 exercise is the most severe for Real GDP, 3-month Euribor and stock market, while the 2014 exercise is the most severe for the BTP-Bund spread
- According to our aggregate severity index, **the 2018 exercise was the most severe**
- In the 2018 counterfactual exercise Italian banks respond by reducing loans to the private sector by a smaller amount than in the previous exercises. We interpret this result as **an increase in the resiliency of the Italian banking sector.**

Literature review

- Medium-large scale **LBVAR** to address and overcome the curse of dimensionality (Banbura et al., 2015, 2010, De Mol et al., 2008, Giannone et al., 2012).
  - Interaction between monetary policy, the real economy and the banking sector (Giannone et al., 2012, Altavilla et al., 2015).
  - Conti et al. (2018): developed a LBVAR on the Italian credit market to study the impact of bank capital shocks on credit supply and economic activity.
- **Alternative approaches to stress testing**. The traditional methodology might not be the most efficient early warning tool; more effective as a crisis management and resolution tool (Borio et al., 2014, Arnold et al., 2012).
  - Dees and Henry (2017) three main limitation of the traditional approach: static balance sheet, exogenous macro-financial shocks, no sector interactions. Budnik et al. (2019)
  - Alternative VAR approaches applied to European data (Hoggarth et al. (2005), Dovern et al. (2010))
  - Top-down capital stress model for the US (Hirtle et al. (2016) CLASS model) and European economy (Henry et al. (2013), Dees and Henry (2017) STAMP€ model).
  - Alternative methodology (V-Lab stress test) employing only publicly available market data (Acharya et al. (2014))
- Scenario design and **stress test severity evaluation** (Breuer et al. (2009), Henry et al. (2013), Yuen (2015), Durdu et al. (2017) and Bonucchi and Catalano (2019))

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The IBASE model

MAIN FEATURES

- **Large Bayesian VAR,** as in Bańbura et al. (2010)*.
- Macro-financial and banking variables are **endogenous and interconnected**
- Estimated on monthly data from January 1999 to March 2019

TESTS ON THE MODEL

- **Impulse Response Analysis:** to check the consistency with a priori belief/theory of the response of banking variables to a one time shock in macro-financial variables
- **Performance Analysis:** good out-of-sample performance up to 3–years ahead, evaluated with iterative estimation of the model against different benchmarks

*Banbura, M., D. Giannone, and L. Reichlin (2010). Large bayesian vector auto regressions. *Journal of Applied Econometrics* 25 (1), 71-92.

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The IBASE model: Data

	IBASE
METHOD	Large Bayesian VAR (LBVAR) Monthly frequency (1999:1-2019:3)
VARIABLES	
Macro	Real GDP; CPI (core); unemployment rate, Italian stock market index
Market rates	3-month euribor; 10-year BTP yield; 10-year BTP-BUND spread; 5-year Euro Swap EMU
Loans and other assets	Net loans and rates on non financial corporations, households and other sectors (only stock), non performing loans, sovereign bond holdings, the interest rate differential between the average rate on short-term loans (< 1 year) and the minimum rate on new loans under one year
Funding	Stocks and rates on deposits, bonds, ECB funding (stock)
Capital	Tier-1 capital ratio

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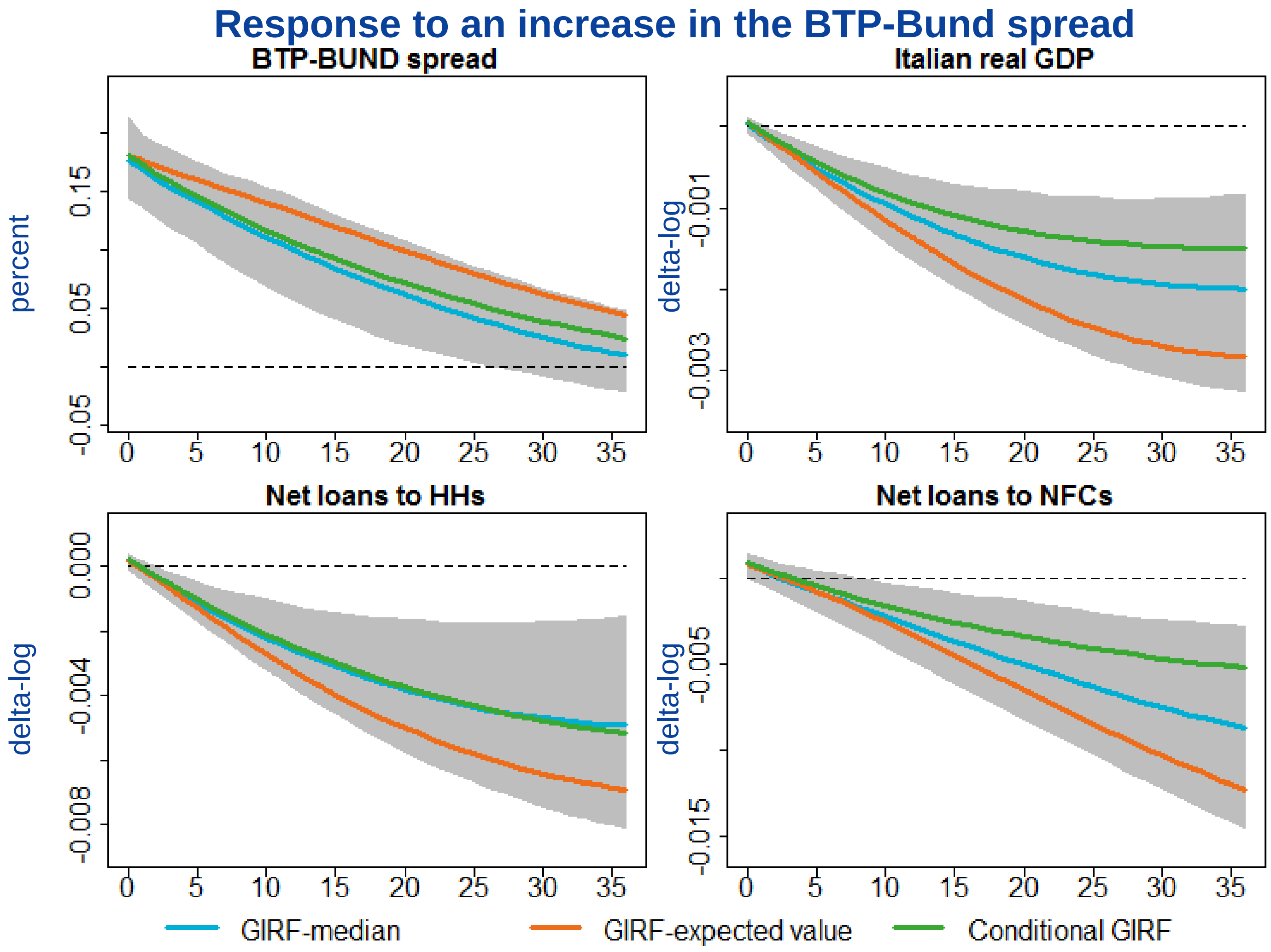
IBASE: Impulse Response Analysis

Response to an increase in the BTP-Bund spread: GDP and net loans to households and firms decrease



NOTE: The figure represents the impulse response function to a 15bp increases in the BTP-BUND spread and the corresponding 90% confidence interval from bootstrap (1000 draws). The blue line represents the median of all bootstrapped responses; the orange line is the GIRF from the estimated model and the green line is conditional GIRF

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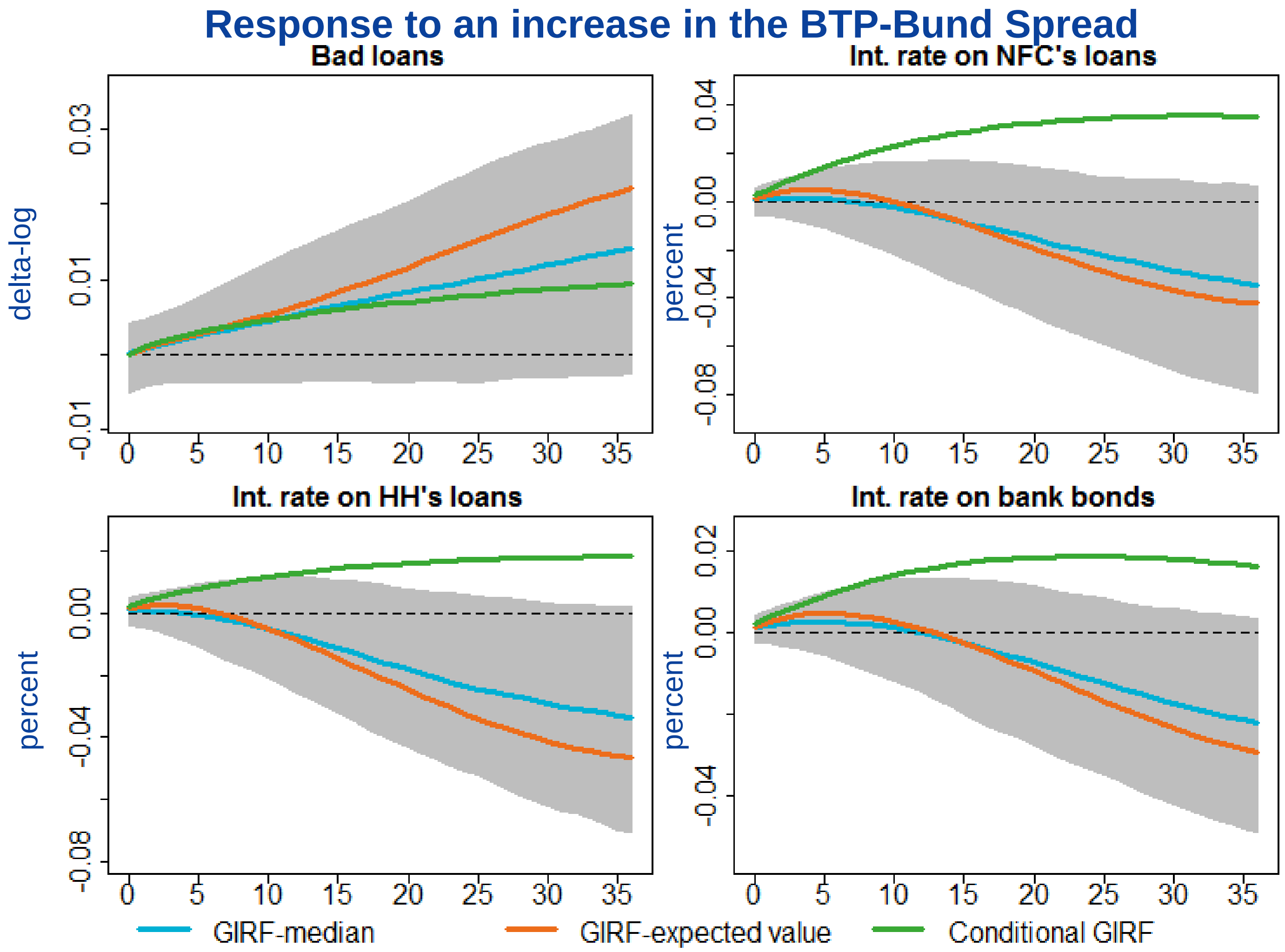
IBASE: Impulse Response Analysis

Response to an increase in the BTP-Bund spread: different responses on rates depending on the path of the Euribor



NOTE: The figure represents the impulse response function to a 15bp increases in the spread BTP-BUND and the corresponding 90% confidence interval from bootstrap (1000 draws) for BTP-BUND spread, Real GDP, net loans stock and interests rate to HHs and NFCs, bad loans and bank bonds' interest rate. The prior on the sum of coefficients has been added with the hyperparameter tau = 10. The blue line represents the median of all bootstrapped responses; the orange line is the GIRF from the estimated model and the green line is conditional GIRF

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Assessing the severity of the stress test scenario variables

Step-by-step procedure

OUR DEFINITION

Severity of a variable Y^k at horizon h in a stress scenario is the probability that Y^k is equal or lower (greater) than the level defined by the EBA in the adverse scenario $\tilde{Y}^k_{T-1+h}$, conditional on $\mathrm{E}\left(Y^k_{T-1+h}\right) = \bar{\bar{Y}}^k_{T-1+h}$, where $\bar{\bar{Y}}^k_{T-1+h}$ is the EBA baseline scenario

$$SEV^k_{T-1+h} = Prob\left(Y^k_{T-1+h} \lesseqgtr \tilde{Y}^k_{T-1+h}\right)$$

CALCULATION PROCEDURE

1. Estimate **the model up to the date of the exercise**
2. Generate S = 10000 **3-year ahead simulations** conditional on the EBA baseline scenario by
   i. **Sampling coefficients** from the posterior distribution of the LBVAR
   ii. **Conditional Forecasts and Montecarlo extraction of the residuals using Kalman Smoother** (Banbura et al., 2015)
3. Measure severity (see above)

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Aggregate severity of the scenarios

Synthetic index of aggregate severity

How to measure the aggregate severity of a scenario?

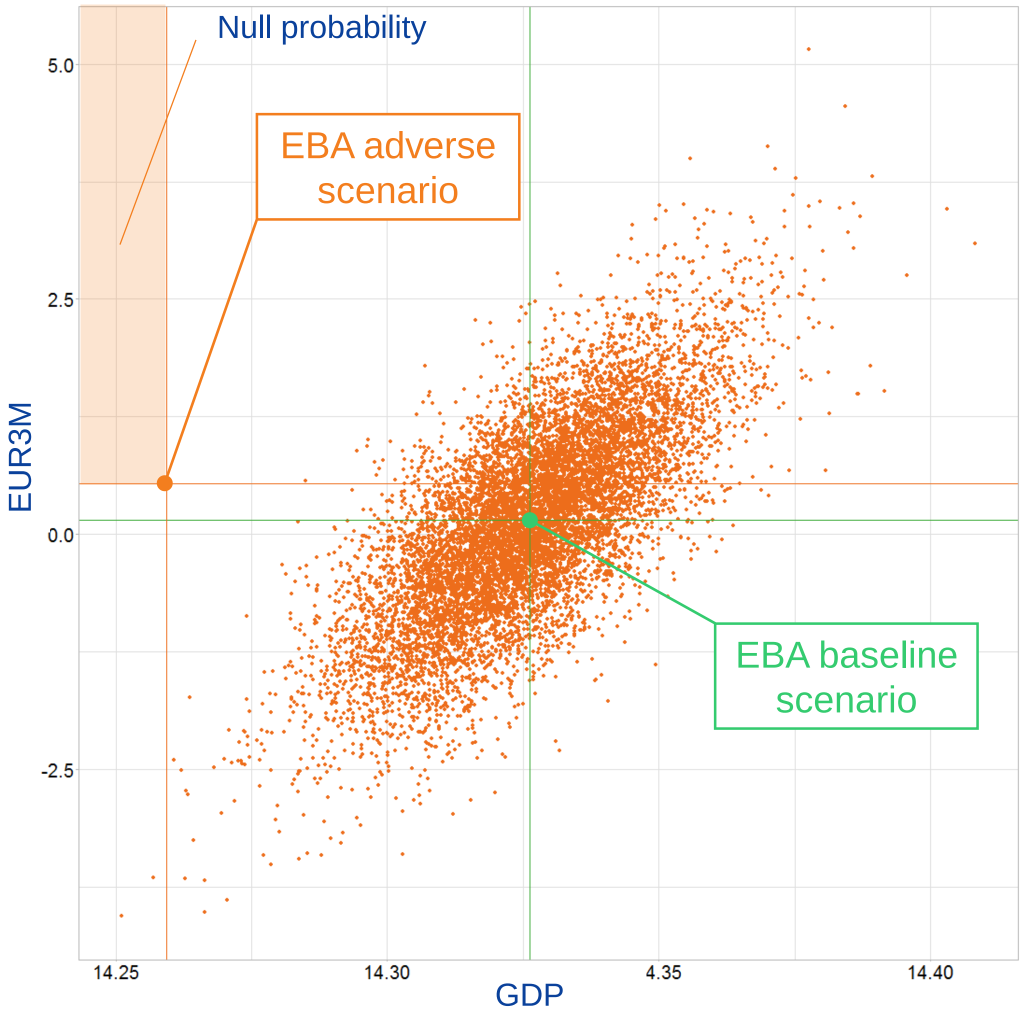
→ In our setup, the calculation of the joint probability of the shocks on all variables is inconclusive

→ We **measure aggregate severity as the weighted average of the marginal probabilities** of each variable

$$SEV_{h,s} = \sum_{j \in J} \omega^{j}_{h,s} Prob\left(Y^{j}_{s+h} \leqslant \overline{Y^{j}_{s+h}}\right)$$

- J: set of input variables
- Y^{j}_{s+h}: variable j at horizon h during exercise s
- $\overline{Y^{j}_{s+h}}$: variable j at horizon h during exercise s in the adverse scenario
- $\omega^{j}_{h,s}$: contribution of variable j at horizon h during exercise s, computed from variance decomposition of the model

Scenarios distribution of euribor3m and GDP 3 years ahead in the 2018 exercise



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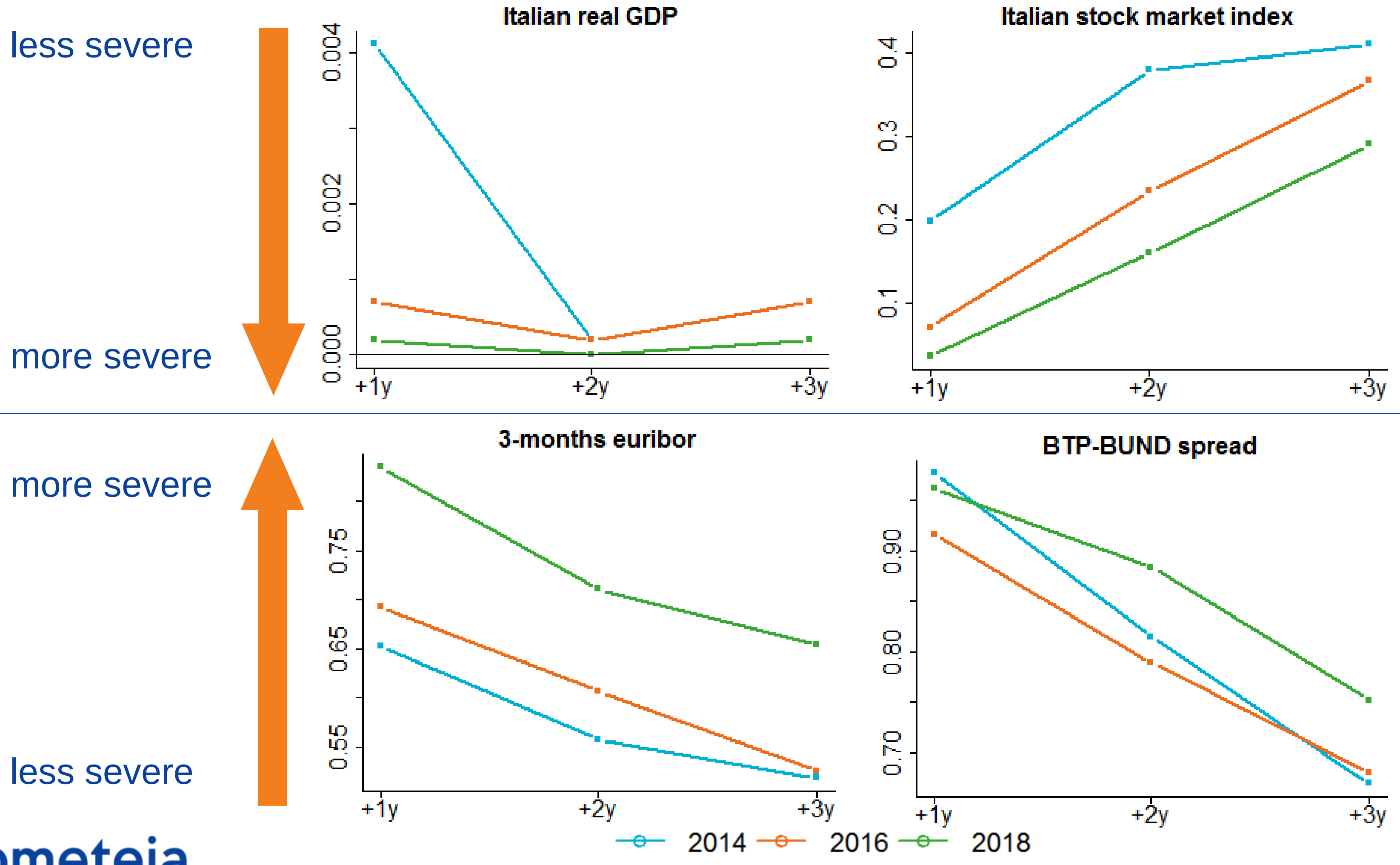
Severity of the stress scenarios: input variables

GDP and stock market very severe in 2018, in 2014 the increase in the spread was very unlikely

Probability of a variable to be equal or lower the value in the adverse scenarios



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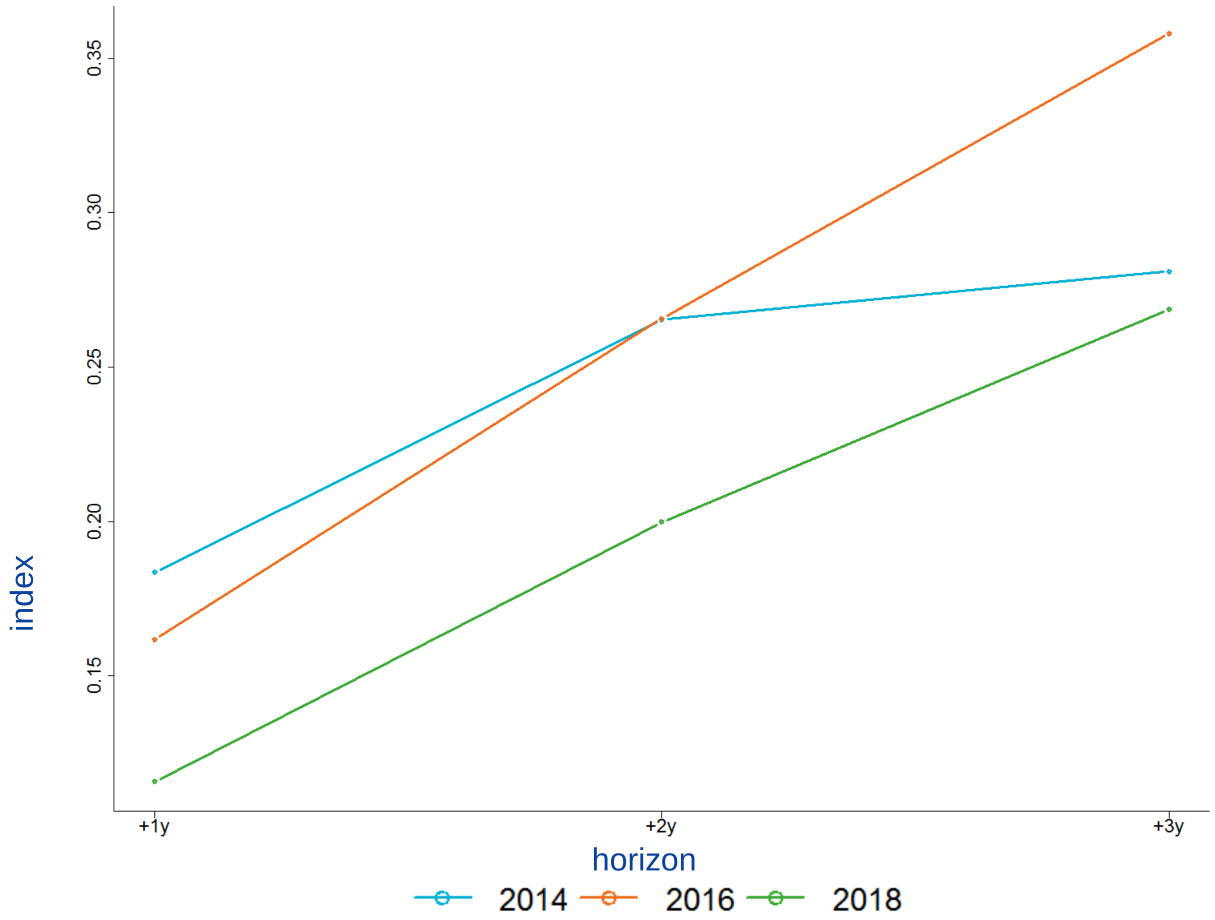
Severity of the stress scenarios: input variables

The stress test exercise in 2018 is the most severe

Synthetic index of aggregate severity



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Counterfactual stress-testing

- **We build counterfactual stress paths for EUR3M, GDP, BTP-Bund spread and Swap 5y** in 2016 and 2018 by choosing the scenarios derived from the simulations for these years that have the same probabilities of 2014
- **We track the response of loans, interest rates, funding and capital ratio** under these alternative paths to check whether the resilience of the Italian banking sector has increased over time

CALCULATION PROCEDURE

- For each input variable k and each horizon $\mathrm{h} \in \{2016, 2018\}$, we **calculate an alternative path** $\hat{Y}^{k}_{T-1,+h}$ as

$$\hat{Y}^{k}_{T-1,+h} = \left\{ y \in \left\{ Y^{k}_{T-1+h,s} \right\}_{s=1,\dots S} \middle| Prob\left(Y^{k}_{T-1+h,s} \lesseqgtr y \right) = Prob\left(Y^{k}_{2014-1+h} \lesseqgtr Y^{k}_{2014-1,+h} \right) \right\}$$

- **Conditional Forecasts on the Counterfactual Adverse Scenario** to track the response of banking variables. The response is produced with estimated coefficients up to the date of the exercise to **incorporate the effects of risk management actions taken by the banks**.

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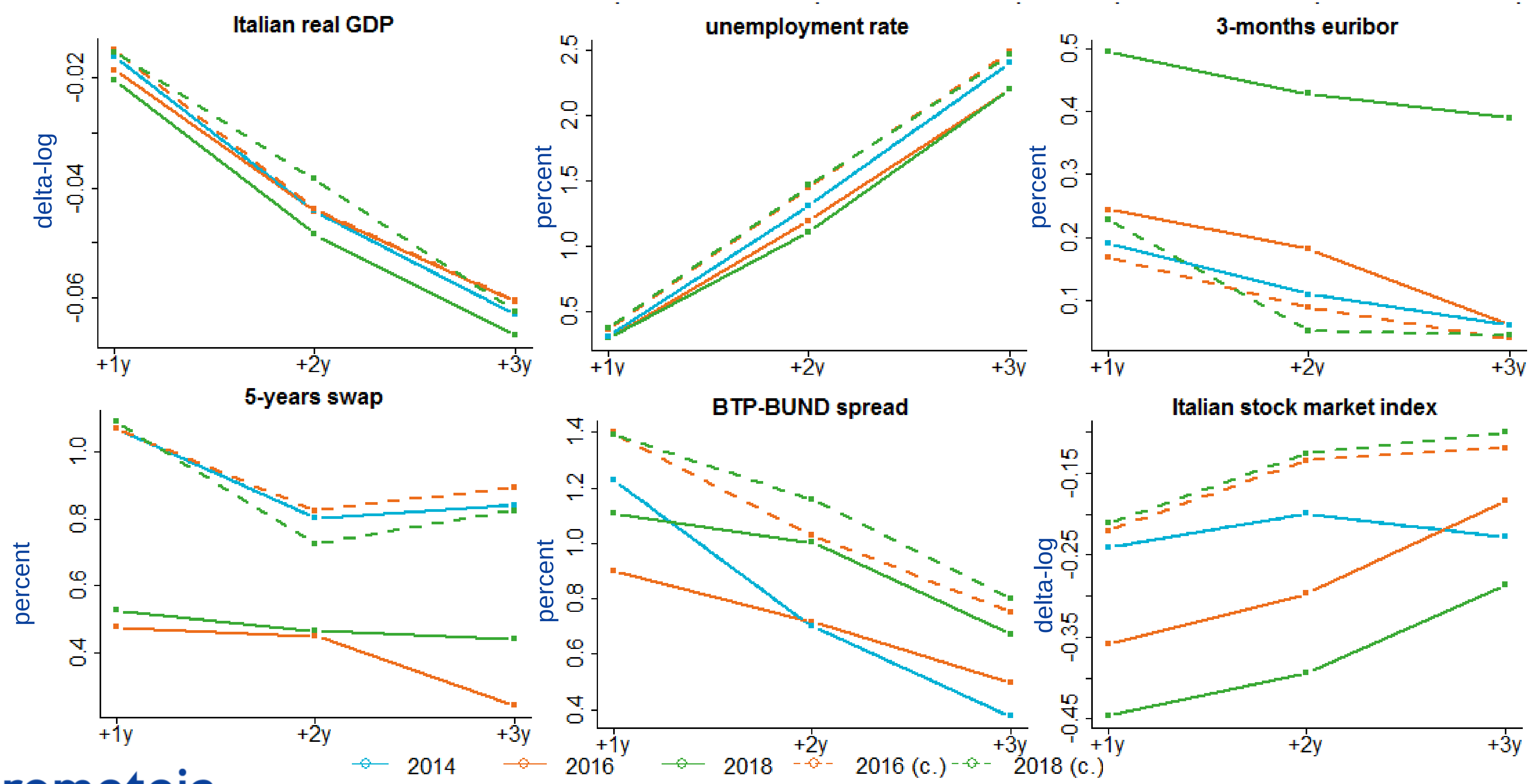
Counterfactual Stress Test: input variables

In 2018 shock on GDP would have been smaller

Deviation between adverse and baseline scenario: realized vs counterfactual



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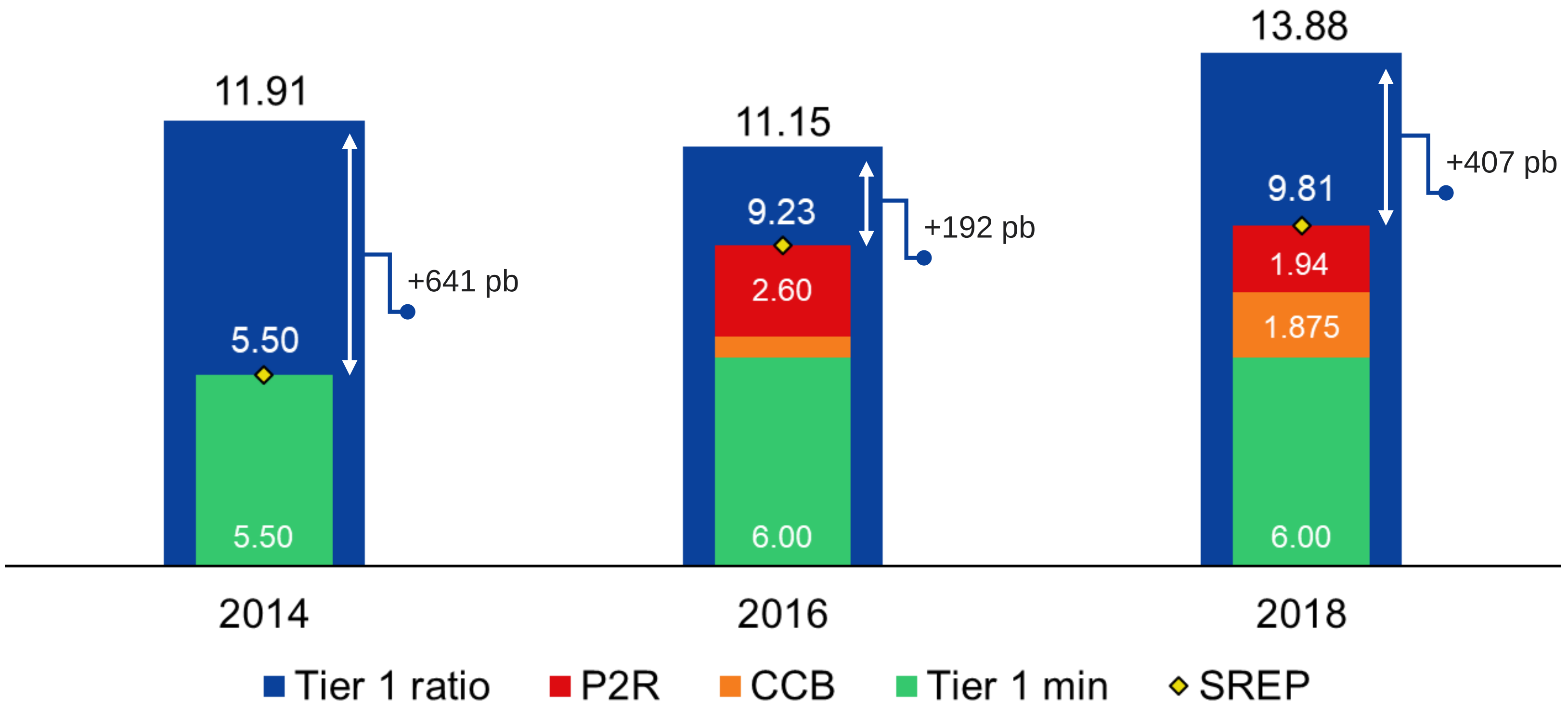
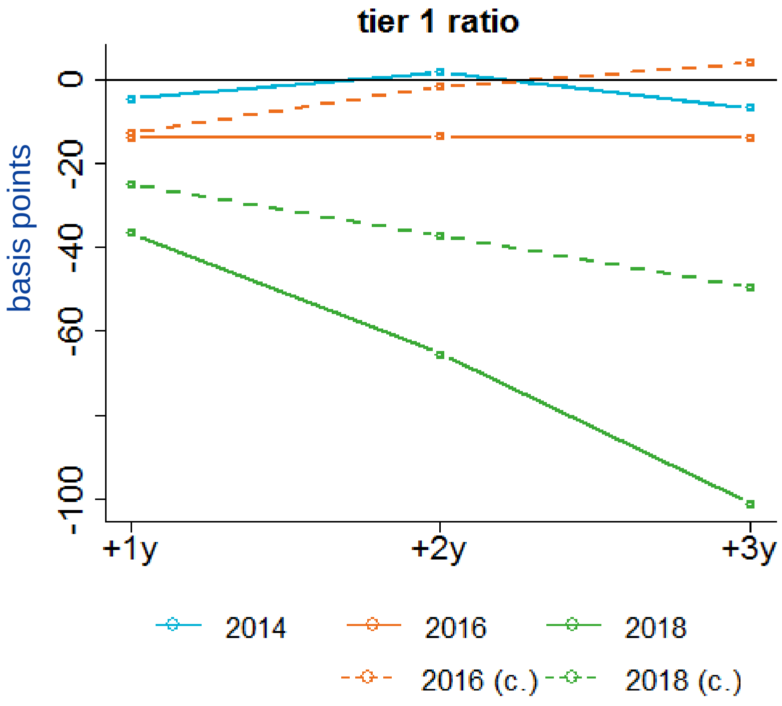
The banking system is resilient when looking at capital adequacy

Capital depletion under adverse counterfactual stress is smaller than the capital buffer

Tier 1 ratio of Italian banks and buffer over minimum capital requirements



Deviation between adverse and baseline scenario of Tier 1 ratio



Note: Weighted average Tier 1 ratio for 8 Italian banking groups (Unicredit, Intesa San Paolo, Banco BPM, Monte dei Paschi di Siena, UBI, BPER, Credem, BP Sondrio). In 2014, Pillar 2 Requirement (P2R) and Capital Conservation Buffer (CCB) were not included.

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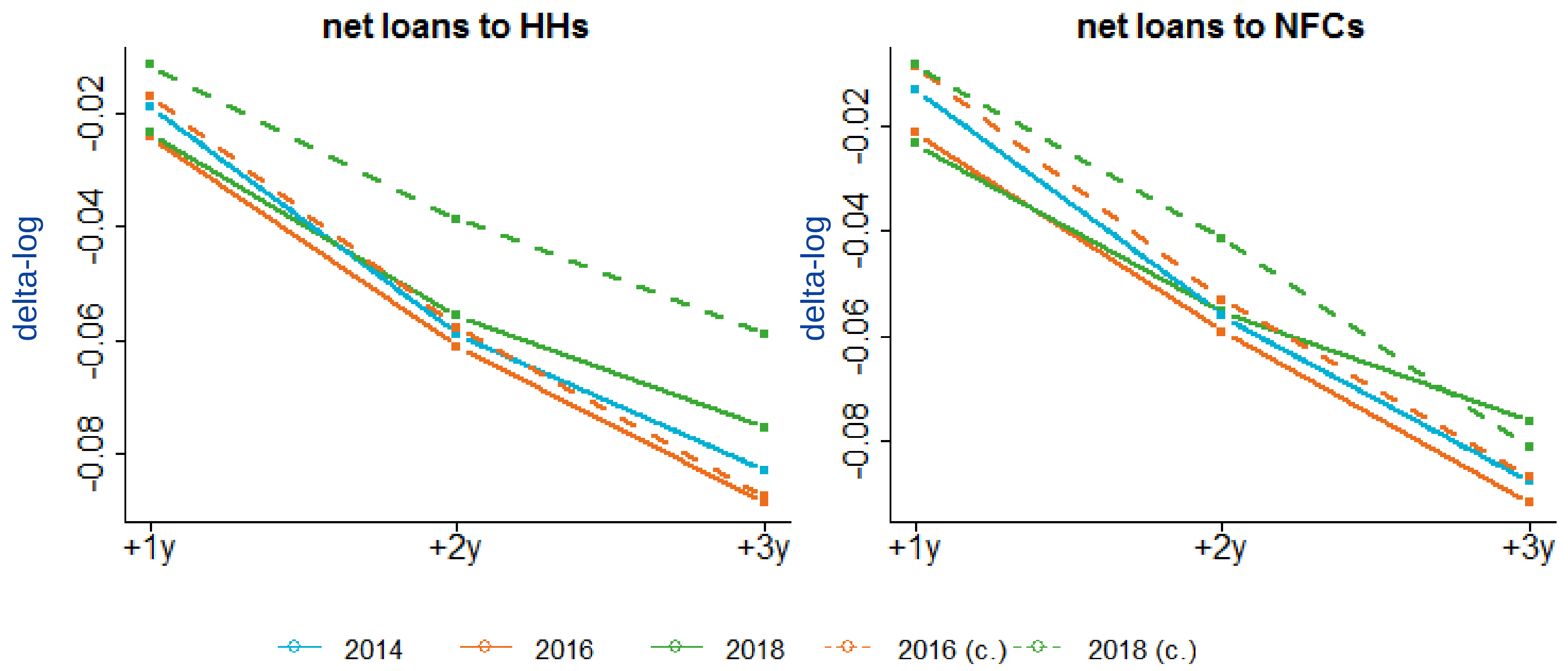
Banks are more resilient in 2018 when looking at lending capacity

If we had the same severity of 2014, the impact on loans in 2018 would have been smaller

Differences between adverse and baseline scenarios: realized vs counterfactual



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Conclusions

- We developed the Italian Banking System Scenario Evaluation (IBASE) model and showed that it is a valid tool for forecasting and scenario analysis.
- We use the model to evaluate the severity of the EBA/ECB stress test exercises in 2014, 2016 and 2018. We build an aggregate index of severity based on marginal probabilities and variance decomposition.
- We showed that the 2018 stress test is the most severe, due to the more adverse contributions of the shock to GDP, eur3m and stock prices.
- We run a counterfactual analysis where we look at the response of banking variables in the three stress scenarios calibrated on the same level of severity as the 2014 exercise. In 2018 the Tier 1 ratio still decreases but by less.
- In the counterfactual 2018 adverse scenario, despite a larger decline in the Tier 1 compared to previous exercises, lending decreases by less. We interpret this result as an increase in resiliency

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