How severe are the EBA macroeconomic scenarios for the Italian Economy?
A joint probability approach

Manuel Bonucchi, **Michele Catalano**

Paris, 27th november 2019

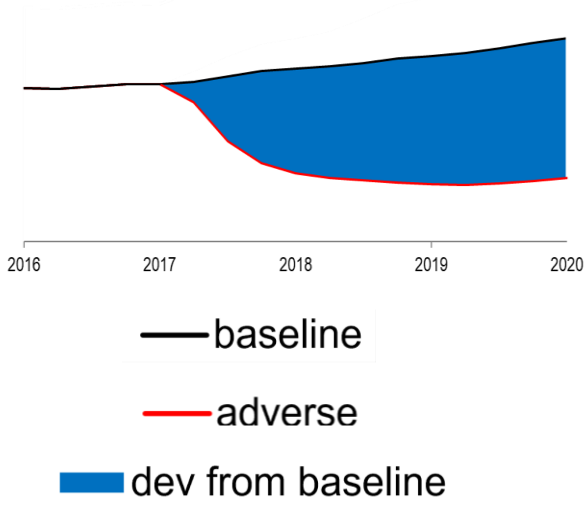
- **Approach and motivations**
- **Methodology**
- **Applications**
- **Extensions**

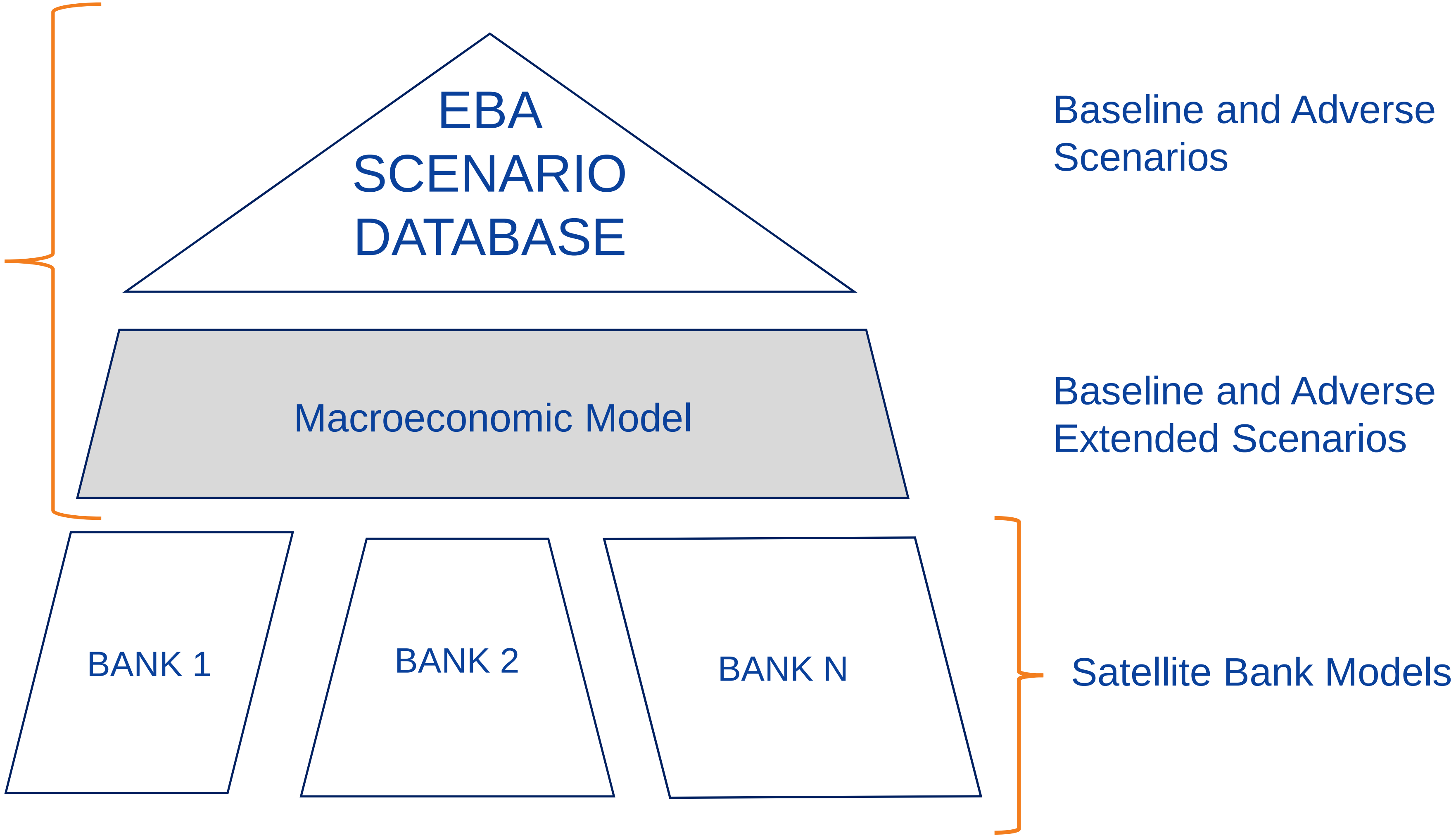
- **Approach and motivations**
- Methodology
- Applications
- Extensions

Approach and motivations

Scenario severity assessment: graphical description of a stress test

Severity





Approach and motivations

The severity of the macroeconomic scenario

- ✓ **Our innovative approach allows to calculate the joint probability of the whole scenario avoiding to use the marginal probabilities**
- ✓ In evaluating EU-wide stress tests, a central issue is to quantify the **severity and plausibility** of the macroeconomic scenario, both in absolute and relative terms compared to past versions
- ✓ In Baudino et Al. (2018): the size of shocks can be calibrated to replicate stressful past experience. This can be based on **statistical** approaches or be **narrative-driven**. Comparing a scenario (or parts of it) to similar historical scenarios may also help to provide an intuition about its severity
- ✓ Severity (Durdu et Al. 2017): Comparing stressed variable (GDP, Unemployment rate, etc.) w.r.t Great Recession. Then, they aggregate to a weighted score
- ✓ There's no clear findings in literature for probability used for assessing severity (and plausibility). Informally, professional stress-testers use marginal probabilities and then aggregate
- ✓ The joint probability calculation can be applied to any scenario. This probability is conditioned by the deterministic (baseline or average or median scenario) realization of the model used, which defines the central path, and is obtained by assessing the deviation of the scenario from the reference one

- Approach and motivations
- **Methodology**
- Applications
- Extensions

prometeia ASSOCIAZIONE

Methodology

From the model to the multipliers

- Let's consider the Structural Model and its simultaneous deviation format representation:

$$\mathcal{A}_0 \mathcal{Y}_{t+1} = \mathcal{A}_1 \mathcal{Y}_t + \mathcal{B}\mathcal{Z}_t + \mathcal{E}_t \quad \longrightarrow \quad \boldsymbol{Y} = \boldsymbol{M}\boldsymbol{Z} + \boldsymbol{E}.$$

Y = endogenous
Z = exogenous
Ɛ = shocks

- Let's obtain the reduced (**dev. from baseline**) form: $\Gamma_y = \mathcal{A}_0^{-1}\mathcal{A}_1 \quad \Gamma_Z = \mathcal{A}_0^{-1}\mathcal{B} \quad ; \ \Gamma_E = \mathcal{A}_0^{-1}$

$$\mathcal{Y}_T = \Gamma_y^T \mathcal{Y}_t + \sum_{i=0}^{T} \Gamma_y^{i-1}[\Gamma_Z \mathcal{Z}_{t+i} + \Gamma_E \mathcal{E}_{t+i}]$$

- The multiplier matrix could be written down as: $\frac{Y_{t+i}}{Z_t} = M_i$

$$\boldsymbol{M} = \begin{bmatrix} M_t & 0 & \cdots & 0 \\ M_{t+1} & M_t & \cdots & 0 \\ \vdots & \ddots & \cdots & 0 \\ M_T & M_{T-1} & \cdots & M_t \end{bmatrix} \qquad \boldsymbol{Y} = \begin{bmatrix} Y_t \\ Y_{t+1} \\ \vdots \\ Y_T \end{bmatrix}, \boldsymbol{Z} = \begin{bmatrix} Z_t \\ Z_{t+1} \\ \vdots \\ Z_T \end{bmatrix}, \boldsymbol{E} = \begin{bmatrix} E_t \\ E_{t+1} \\ \vdots \\ E_T \end{bmatrix}.$$

(Ny x T) x (Nz x T) *(Ny x T) x 1* *(Nz x T) x 1* *(Ny x T) x 1*

prometeia ASSOCIAZIONE

Methodology

Building the model…

- Assuming the first and second moments of the shocks and the exogenous variables and their Gaussian multivariate distributions, we obtain:

$$\boldsymbol{\Xi} = \begin{bmatrix} \Xi_t & \Xi_{t,t+1} & \cdots & \Xi_{t,T} \\ \Xi_{t+1,t} & \Xi_{t+1,t+1} & \cdots & \Xi_{t+1,T} \\ \vdots & \ddots & \cdots & \vdots \\ \Xi_{T,t} & \Xi_{T,t+1} & \cdots & \Xi_{T} \end{bmatrix}$$

- With the compact system and covariance matrix we get at the final **multivariate joint distribution**:

$$\boldsymbol{Y} \sim \mathcal{N}(\boldsymbol{0}, \boldsymbol{M}'\boldsymbol{\Xi}\boldsymbol{M}).$$

- The tail of the multivariate Gaussian distribution* is compared with the policy maker's preference set $\bar{Y}$

$$P(\mathbf{Y}_k \in \bar{\mathbf{Y}})$$

$$\bar{\mathbf{Y}} = \{y_{1t} > a_1, y_{2t} > a_2\} \qquad \bar{\mathbf{Y}} = \{y_{1t} < a_1, y_{2t} < a_2\} \qquad \bar{\mathbf{Y}} = \{y_{1t} < a_1, y_{2t} > a_2\}$$

* We use the Python scipy.stats.mvn.mvnun implementing Genz (1992) fortran routine MVNDST

Methodology

Joint probability

- Markovian Models → Joint probability of the scenario Y collapses to zero very quickly in time (and space …) as time or the number of variables grows

$$P(Y) = P(Y_1, Y_2, ..., Y_t) = P(Y_t|Y_{t-1}) \cdots P(Y_2|Y_1) \cdots P(Y_1)$$

- Non-Markovian Models (Structural models seen in a particular way…)

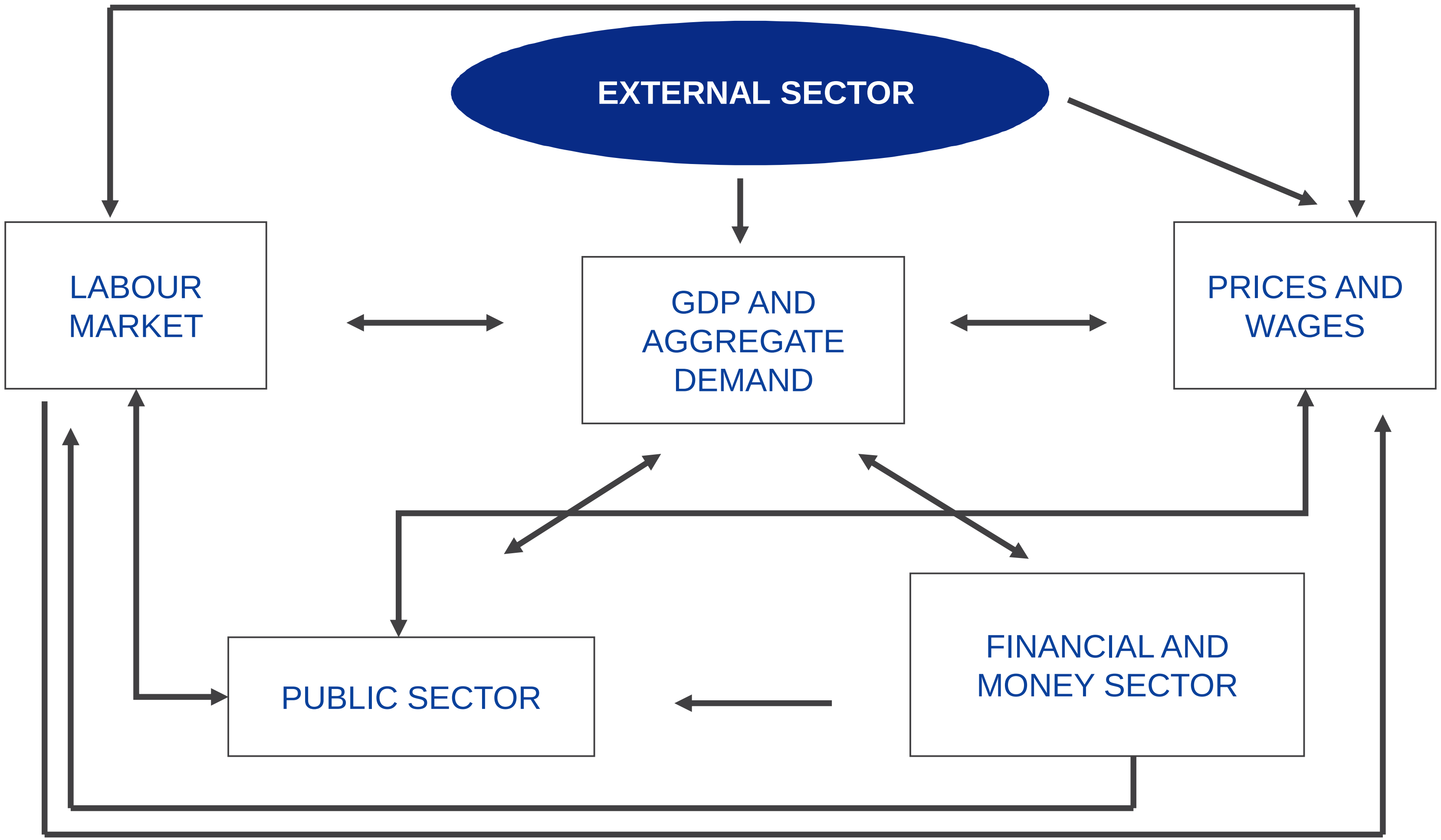
P(Y) = ???

- Approach and motivations
- Methodology
- **Applications**
- Extensions

prometeia ASSOCIAZIONE

Applications

Prometeia Italian Quarterly model: a structural simultaneous equation system



- ✓ We use a top-down approach: among several sectors, the model includes a macro banking sector linked to households, firms and public sector
- ✓ Then, the macro-financial variables are projected to satellite models to get the PD estimation for the specific bank

prometeia ASSOCIAZIONE

Applications

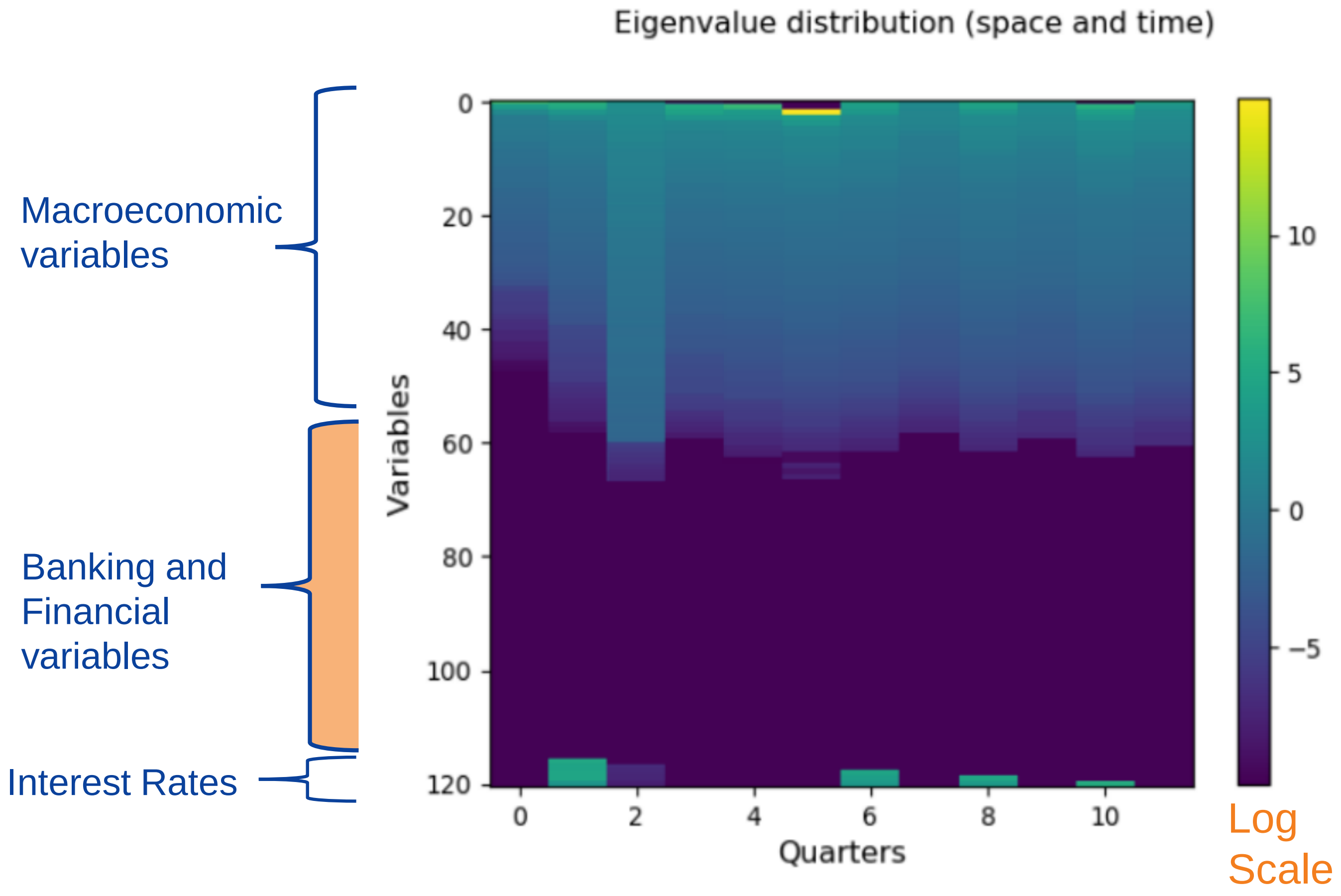
Eigenvalue distribution per variable and time

- If there are common factors, we should observe large eigenvalues of the covariance matrix that allow the probability to be non-zero
- High values of the eigenvalues λ are a condition for a non-vanishing probability mass
- The presence of interdependence is equivalent to the presence in the system of a subset of common factors
- By looking at the covariance matrix, we can understand why the probability does not converge to zero:

$$P(x) = \int m e^{-1/2 x' \Sigma^{-1} x} dx = \int m e^{-1/2 \sum_i \frac{1}{\lambda_i} e_i^2 y_i} dy_i$$

$$m = \frac{1}{\sqrt{(2\pi)^k |\Sigma|}}$$

λ = eigenvalues

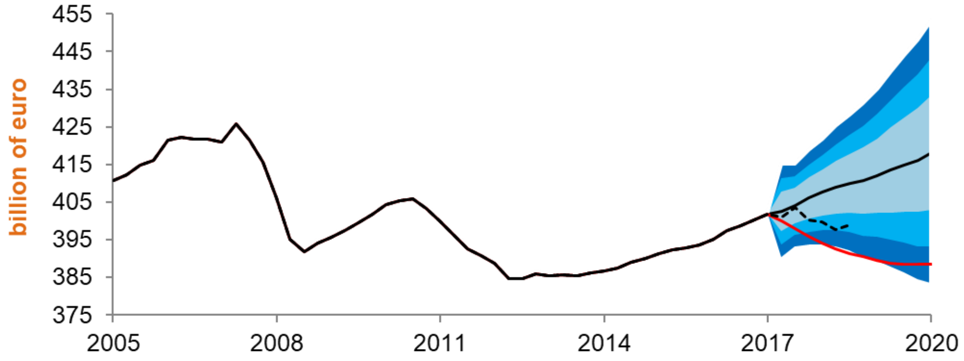


prometeia ASSOCIAZIONE

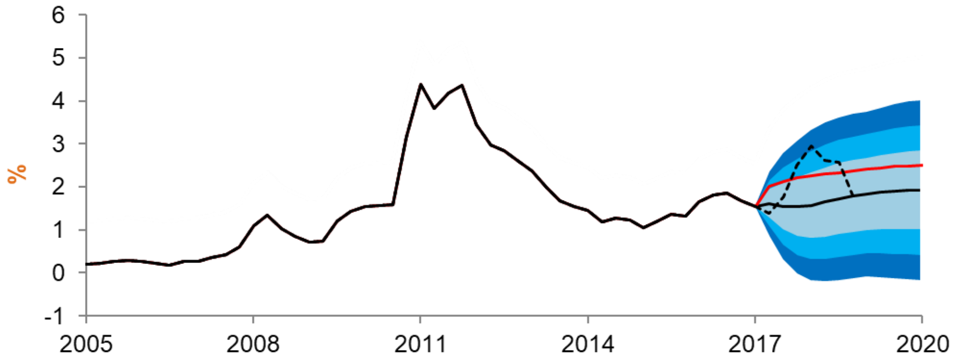
Applications

EBA 2018 scenario: marginal distribution* inspection for Italy

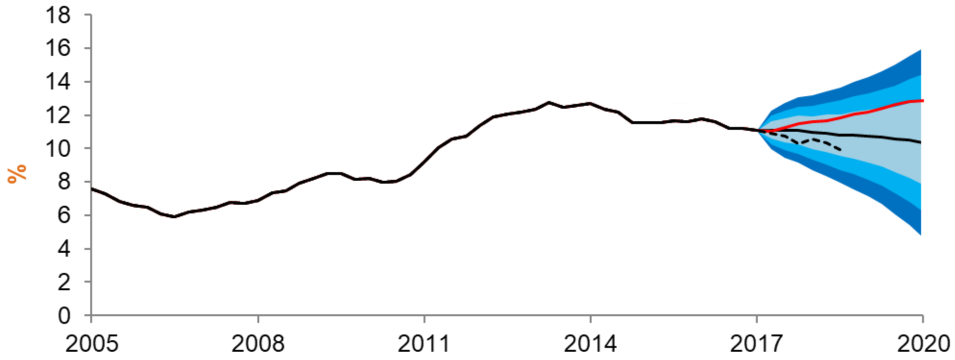
GDP: PROBABILITY 3.1%



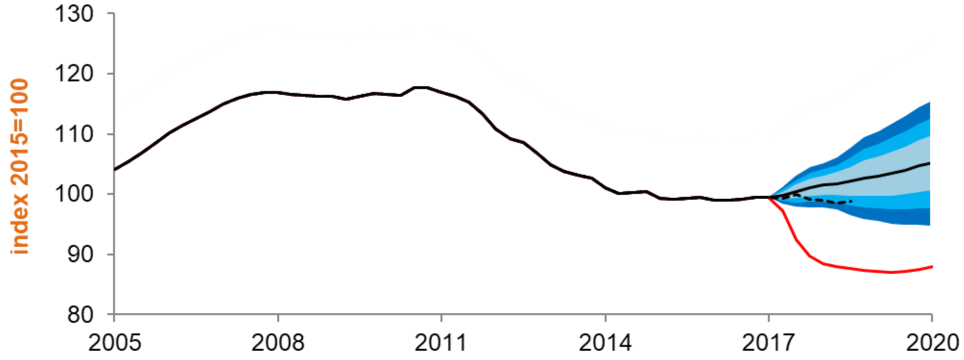
SPREAD BTP-BUND 10Y: PROBABILITY 22.3%



UNEMPLOYMENT RATE: PROBABILITY 30.3%



HOUSE PRICE: PROBABILITY 0%



70% 90% 99% baseline EBA adverse EBA historical data

prometeia ASSOCIAZIONE

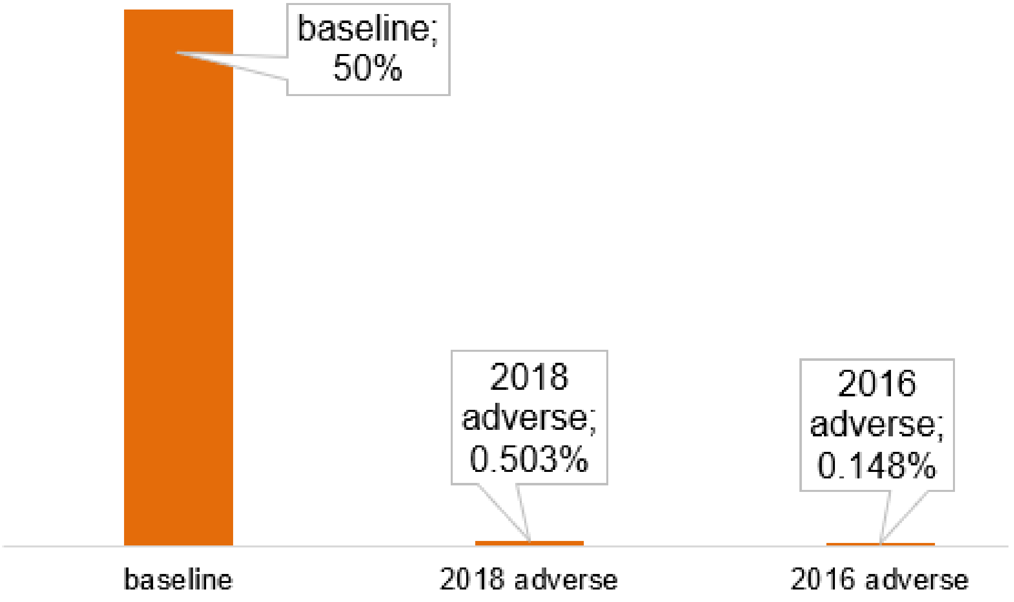
* The fan chart is calculated with stochastic simulations of Prometeia quarterly model and applied to the EBA baseline

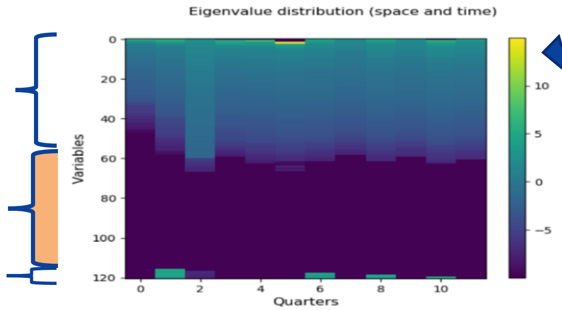
Applications

Joint probability of EBA adverse scenario

- In order to get a more precise probability for the scenarios, we select a subset of variables as indicated

- **Including house price:** we obtain a joint probability of **0% for adverse scenario** (both 2016 and 2018), as expected from preliminary inspection of marginal distribution. But **excluding house price:**





Variable	Tail
Oil Price	rhs
Exchange Rate €/$	rhs
Bund Rate	rhs
Emerging Countries GDP	lhs
US GDP	lhs
Euro Area GDP	lhs
Stock Market	lhs
Italy GDP	lhs
Unemployment Rate	rhs
Spread Btp-Bund 10Y	rhs
Euribor 3M	rhs

prometeia ASSOCIAZIONE

- Approach and motivations
- Methodology
- Applications
- **Extensions**

Extensions

Summary

- Reverse stress testing:

  ✓ Using the model to obtain an alternative profile of the exogenous variables guaranteeing the same degree of severity as the endogenous variables

- Conditioned scenario:

  ✓ To avoid the independence of the scenario probability to the state of the economy we can calculate joint probability conditioned to different phases of the economic cycle

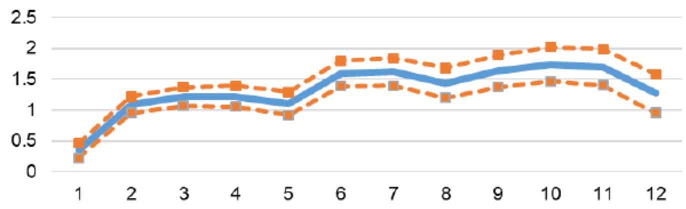
Extensions

Reverse stress testing

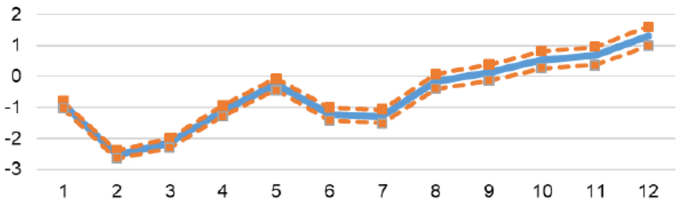
- Our framework allows us to determine reverse stress testing analytically. We can solve for the exogenous variables vector Z from the general system to get:

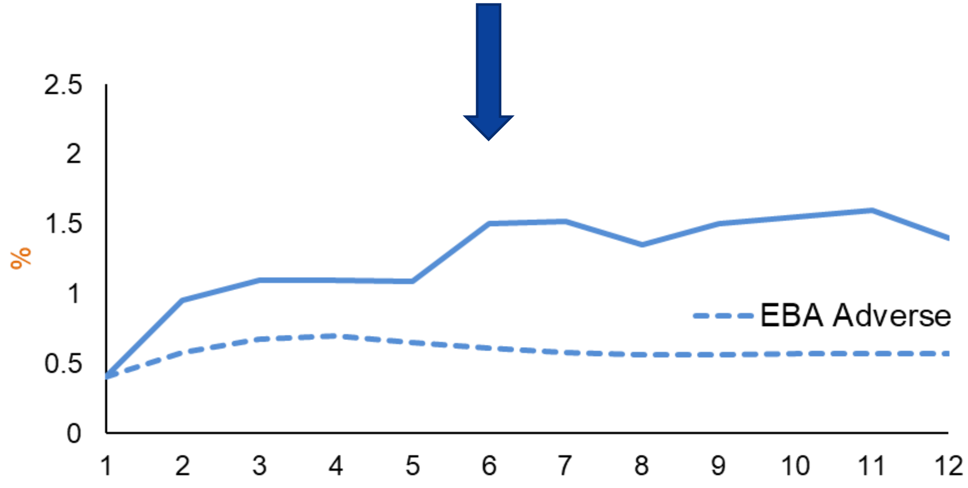
$$E(\boldsymbol{Z}_k|Y_k) = (\boldsymbol{M}'\boldsymbol{M})^{-1}\boldsymbol{M}'\boldsymbol{Y}_k$$

SPREAD BTP-BUND 10Y
Dev. from baseline*



PUBLIC EXPENDITURE
Dev. from baseline*





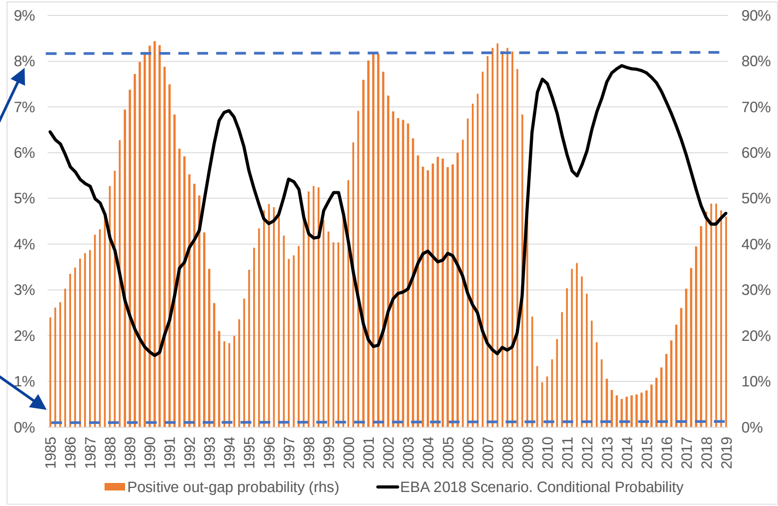
* Prometeia quarterly calculations on EBA annual data

Extensions

Conditioned scenario - EBA 2018

- Conditioning scenario probability to the business cycle phase:

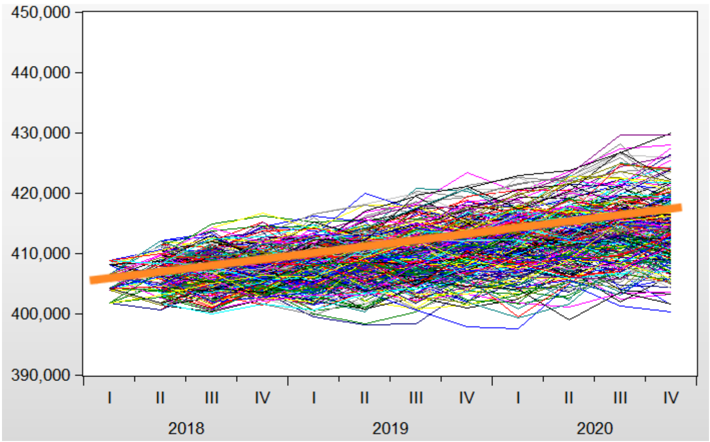
$$Y = \begin{cases} M^{-}Z + E^{-} & \text{with probability } p \text{ (negative output gap)} \\ M^{+}Z + E^{+} & \text{with probability } (1-p) \text{ (positive output gap)} \end{cases} \qquad \begin{matrix} P(Y^{-}) \\ P(Y^{+}) \end{matrix}$$



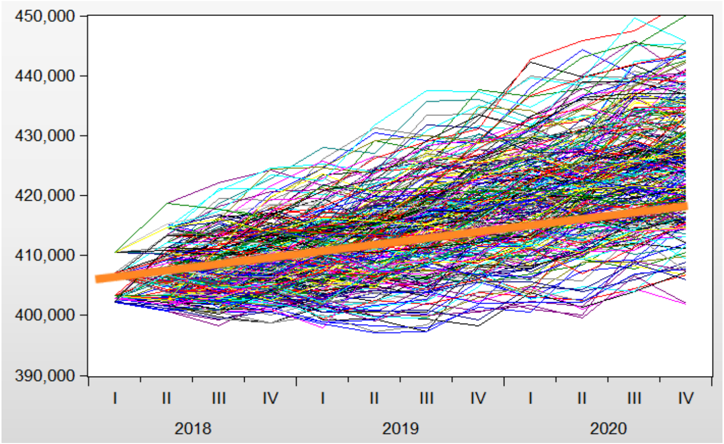
- Stochastic simulations of GDP level with model errors in different cycle phases:

million euro

POSITIVE



NEGATIVE



baseline

prometeia ASSOCIAZIONE

Conclusions

How severe are the EBA macroeconomic scenarios for the Italian Economy? A joint probability approach

- ✓ In order to design meaningful stress testing exercises, **severe** but **plausible** shocks has to be defined
- ✓ In the paper we evaluate the severity of stress test providing a joint probability measure of a scenario
- ✓ Our **general methodology** help to design stress test scenarios as it provides a quantitative measure to understand the plausibility of scenario. Potentially, it can be used in more general applications.
- ✓ We determine the joint probability for the EBA scenarios using the Prometeia Quarterly Macroeconometric model for the Italian economy
- ✓ Our assessment for the EBA 2018 suggests a **severe but plausible** profile for the majority of the macroeconomic variables except for a strict subset that is to a too much severe
- ✓ We provide a simple extension able to determine joint probability conditional to the business cycle phases
- ✓ We are able to further extend the probability model and in the future we will extend applications to other countries

Confidentiality

Contacts

Bologna
Piazza Trento e Trieste, 3
+39 051 6480911
italy@prometeia.com

Milan
Via Brera, 18
Viale Monza, 265
+39 02 80505845
italy@prometeia.com

Rome
Viale Regina Margherita, 279
italy@prometeia.com

London
Dashwood House 69 Old Broad Street
EC2M 1QS
+44 (0) 207 786 3525
uk@prometeia.com

Istanbul
River Plaza, Kat 19
Büyükdere Caddesi Bahar Sokak
No. 13, 34394
| Levent | Istanbul | Turkey
+ 90 212 709 02 80 – 81 – 82
turkey@prometeia.com

Cairo
Smart Village - Concordia Building, B2111
Km 28 Cairo Alex Desert Road
6 of October City, Giza
egypt@prometeia.com

Moscow
ul. Ilyinka, 4
Capital Business Center Office 308
+7 (916) 215 0692
russia@prometeia.com

Prometeia
@PrometeiaGroup
Prometeiagroup
Prometeia

www.prometeia.com

prometeia ASSOCIAZIONE