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

Manuel Bonucchi, Michele Catalano

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- 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

EBA SCENARIO DATABASE

Macroeconomic Model

Baseline and Adverse Scenarios

Baseline and Adverse Extended Scenarios

Satellite Bank Models

BANK 1

BANK 2

BANK N

2019 EBA Policy Research Workshop / 4
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
Methodology
From the model to the multipliers

• Let’s consider the Structural Model and its simultaneous deviation format representation:

\[ A_0 Y_{t+1} = A_1 Y_t + B Z_t + \varepsilon_t \]

\[ Y = M Z + E. \]

• Let’s obtain the reduced (dev. from baseline) form:

\[ Y_T = \Gamma_y Y_t + \sum_{i=0}^{T} \Gamma_y^{i-1} [\Gamma Z Z_{t+i} + \Gamma E \varepsilon_{t+i}] \]

• The multiplier matrix could be written down as:

\[ \frac{Y_{t+i}}{Z_t} = M_i \]
Methodology

Building the model…

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

\[
\Xi = \begin{bmatrix}
\Xi_t & \Xi_{t,t+1} & \cdots & \Xi_{t,T} \\
\Xi_{t+1,t} & \Xi_{t+1,t+1} & \cdots & \Xi_{t+1,T} \\
\vdots & \ddots & \ddots & \vdots \\
\Xi_{T,t} & \Xi_{T,t+1} & \cdots & \Xi_T
\end{bmatrix}
\]

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

\[Y \sim \mathcal{N}(0, M'\Xi M).\]

• The tail of the multivariate Gaussian distribution* is compared with the policy maker’s preference set \(\bar{Y}\)

\[P(Y_k \in \bar{Y})\]

\[\bar{Y} = \{y_{1t} > a_1, y_{2t} > a_2\} \quad \tilde{Y} = \{y_{1t} < a_1, y_{2t} < a_2\} \quad \bar{Y} = \{y_{1t} < a_1, y_{2t} > a_2\}\]

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

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

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

$\lambda = \text{eigenvalues}$
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%

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* The fan chart is calculated with stochastic simulations of Prormeteia 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:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Price</td>
<td>rhs</td>
</tr>
<tr>
<td>Exchange Rate €/$</td>
<td>rhs</td>
</tr>
<tr>
<td>Bund Rate</td>
<td>rhs</td>
</tr>
<tr>
<td>Emerging Countries GDP</td>
<td>lhs</td>
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<td>US GDP</td>
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<td>Stock Market</td>
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<td>Italy GDP</td>
<td>lhs</td>
</tr>
<tr>
<td>Unemployment Rate</td>
<td>rhs</td>
</tr>
<tr>
<td>Spread Btp-Bund 10Y</td>
<td>rhs</td>
</tr>
<tr>
<td>Euribor 3M</td>
<td>rhs</td>
</tr>
</tbody>
</table>
➢ 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:

$$E(Z_k|Y_k) = (M'M)^{-1}M'Y_k$$
Extensions
Conditioned scenario - EBA 2018

• Conditioning scenario probability to the business cycle phase:

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

\[ P(Y^-) \quad P(Y^+) \]

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

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