Deep-Stress:
A deep learning approach for dynamic balance sheet stress testing

Banking Supervision Department
Internal Models & Stress Test

2019 EBA Policy Research Workshop

Bank of Greece

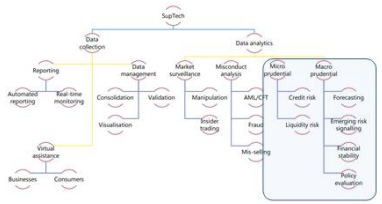
Who we are

BANK OF GREECE

Internal Models & Supervisory Exercises Section

Banking Supervision Department

- Monitor Internal Models for A-IRB & IMA institutions
- Develop & Implement Stress Testing Methodologies for SIs and LSIs
- Participate on WGs for Stress Testing:
  - STTF, AGOST, Top Down Models, MTF
- Suptech
  - Data Analytics



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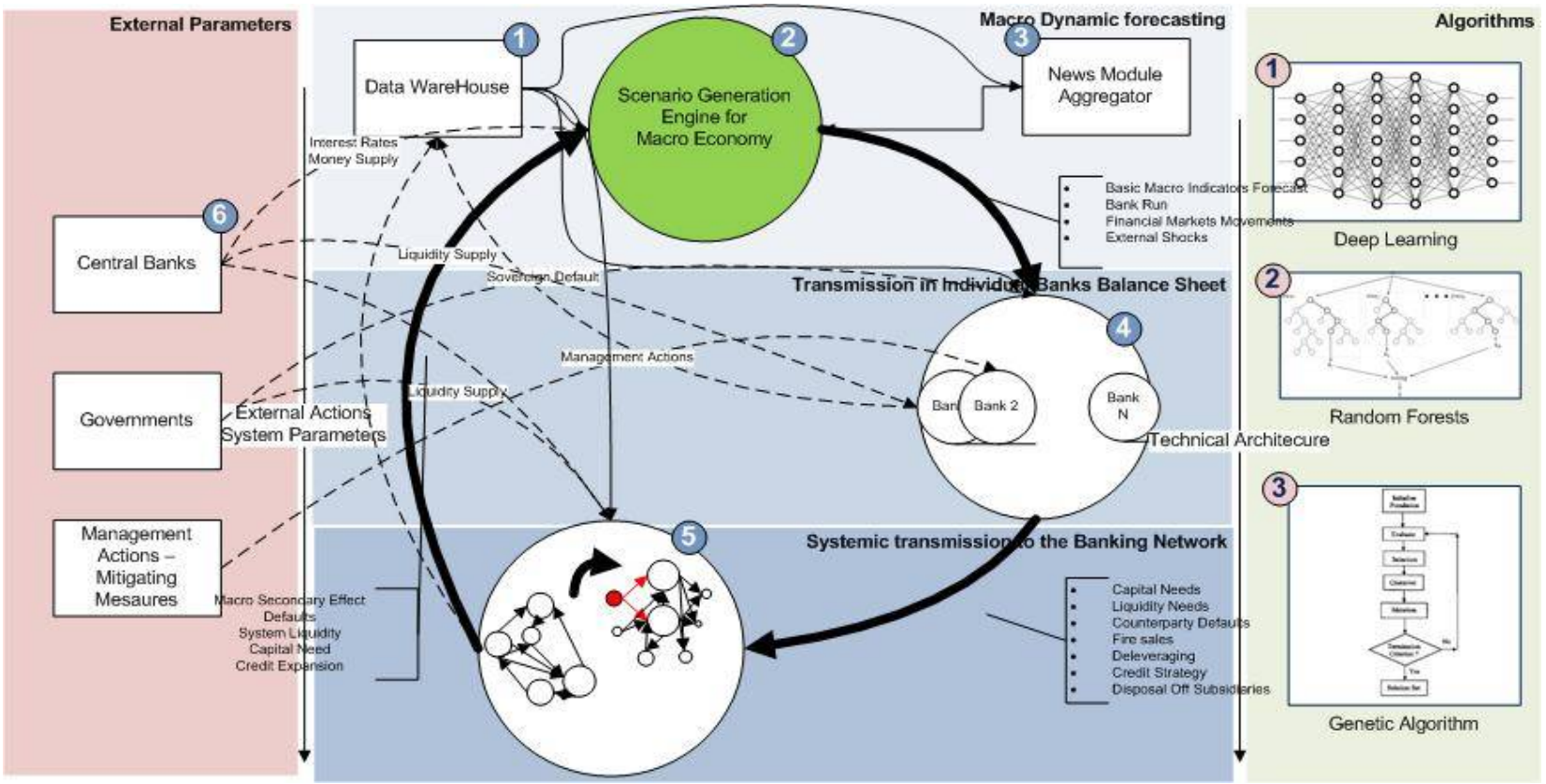
Stress Test

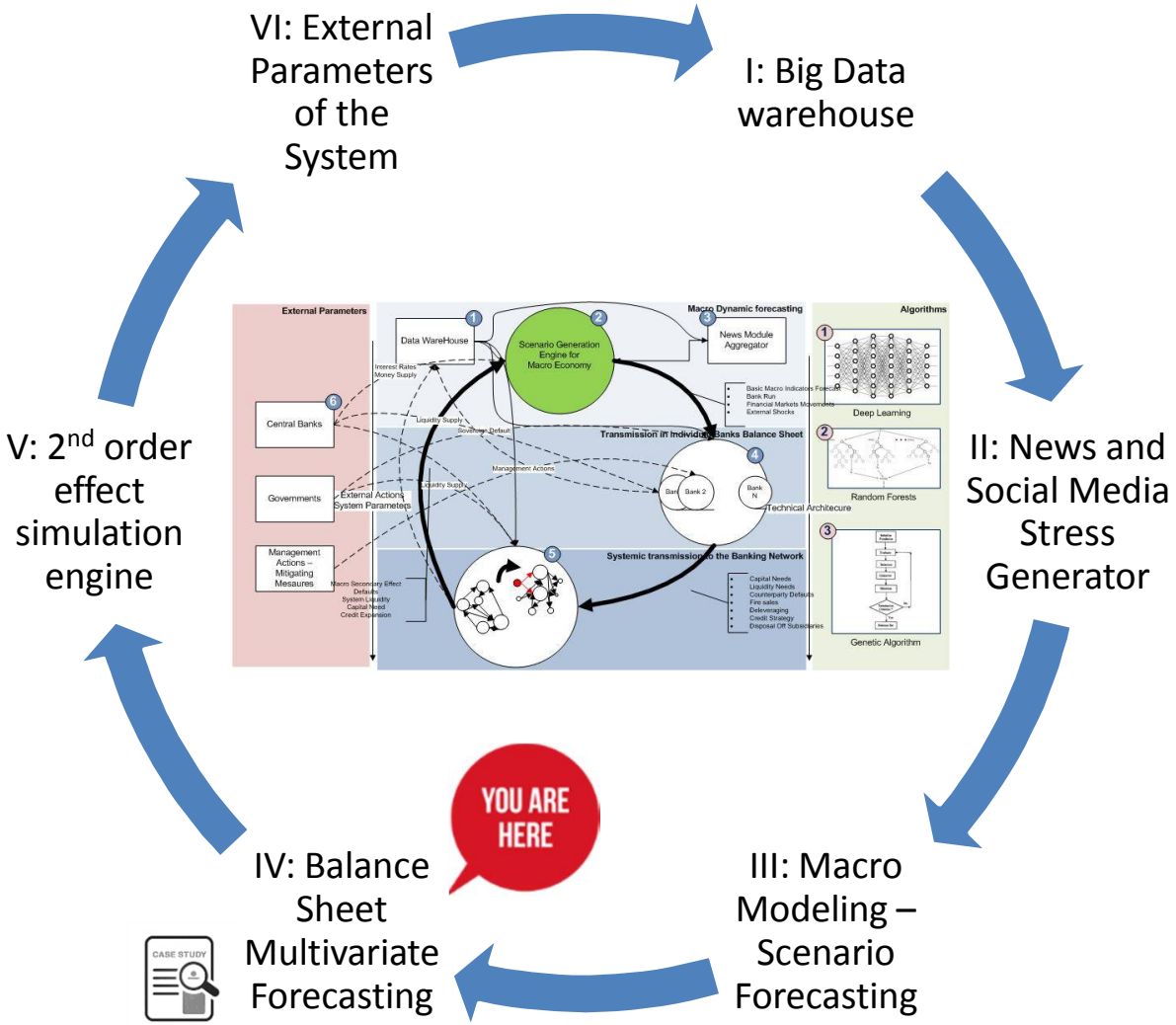
Our Vision: A holistic network simulator for performing ST



A system is not fragile when a large financial shock materializes, but when a small negative change in financial and macro variables is amplified through the different dynamic system relationships, and can lead to a systemic shock. Bario

Stress Test

Our Vision: A holistic network simulator for performing ST



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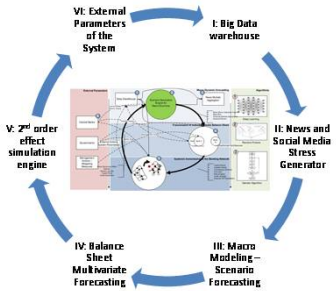
Basic Principles

- The cyclical structure is one of the major innovations in our vision



- Layer output = Input for successive module
  - continuous process in a recurrent way.
- Information flows as a vector of macro, micro and financial variables
  - The vector describes the system at any time during the forecast period
- The mechanics of the propagation is based on a vector of systemic variables which is passed through each module's functionality and adjusted simulating the whole economy one step ahead.
- The vector tracks the state the global economic system so based on the values at every iteration we predict if a recession is eminent

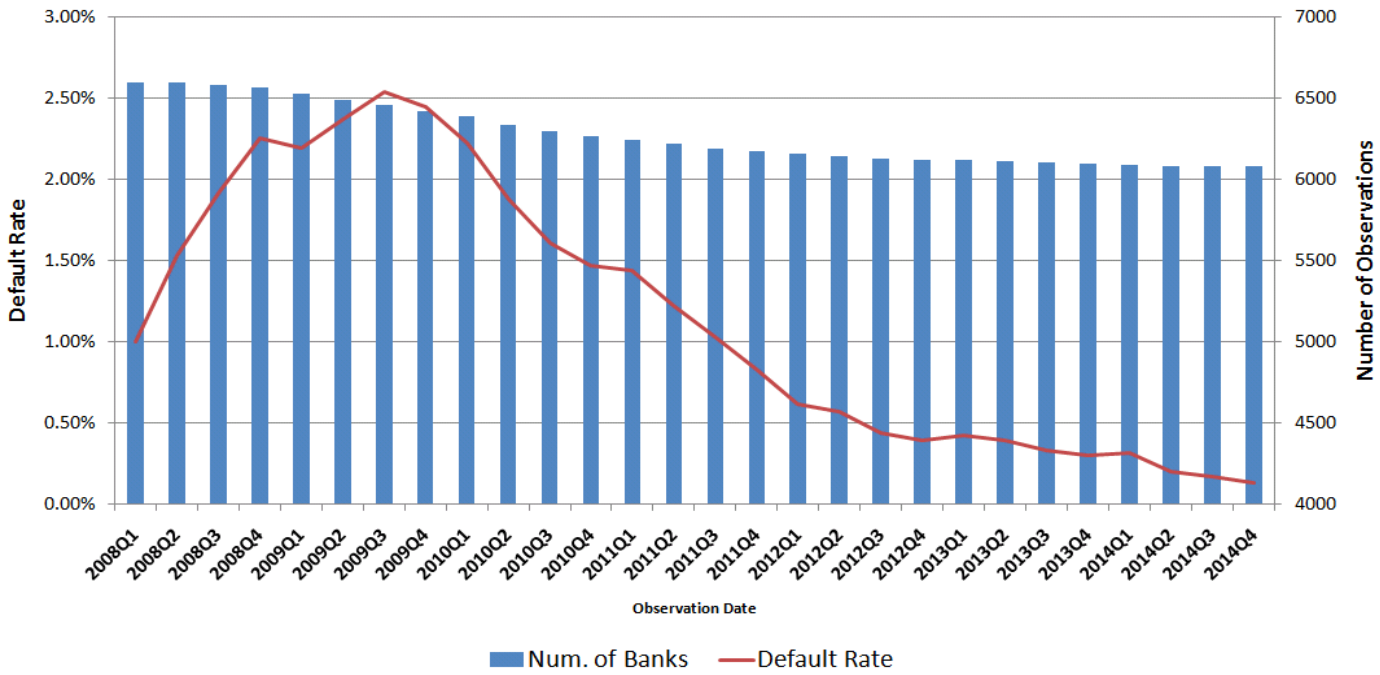
Stress Test

Key considerations

- **Static vs Dynamic balance sheet approach**
- **Satellite models are used for univariate estimations of the impacts vs a unified model taking into account interdependencies**
- Non linearity's and structural breaks are not captured in most models
- No validation or back testing process exist to assess their efficacy
- Their calculation is composed of individuals block of different impacts combined in a hierarchical order and do not account for simultaneously channels of transmission.
  - Network simulation and second round effects may not be a part of their architecture
- They do not account for macroeconomic feedback effects
- Most stress testing frameworks do not include a module for news exploration of as possible financial shocks early indicators

Deep Stress

Dataset employed



- Data: FDIC data related to all US banks.
- Default Definition: bank failures and assistance transactions of all FDIC-insured institutions.
- Sample: 2007-2015 period. Training was performed on 2010-2013 sample (80% train, 20% validation for hyper-parameter tuning) with 1-3 year lagged variables.
- Out-of-sample period 2014-2015.

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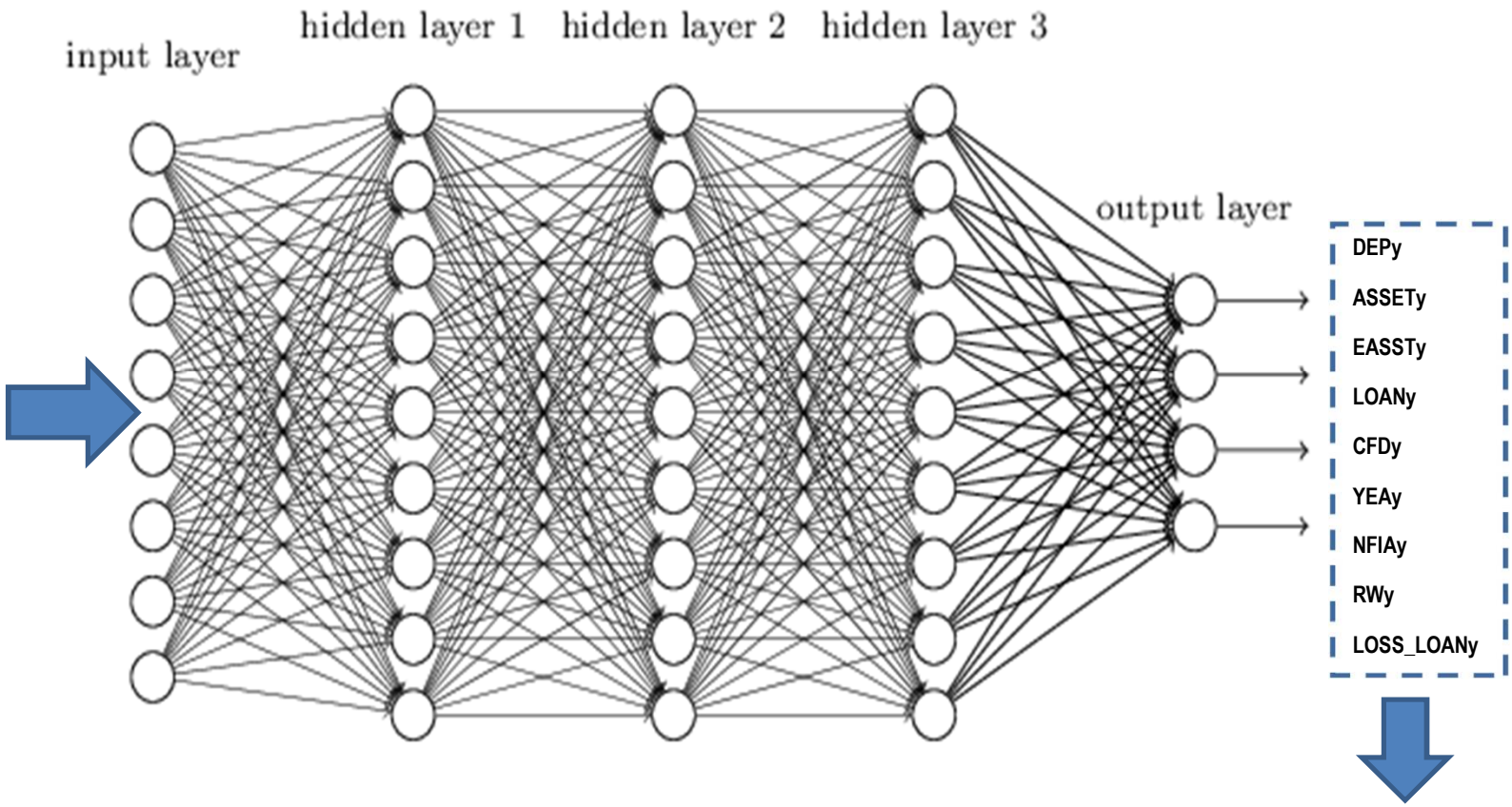
Structure of a holistic model (MXNET)

GDPx0,-1,-2,-3
EXPORTSx0,-1,-2,-3
DEBTx0,-1,-2,-3
GOVEXPx0,-1,-2,-3
INFLATx0,-1,-2,-3
RREx0,-1,-2,-3
UNRx0,-1,-2,-3
YIELD10x0,-1,-2,-3
STOCKx0,-1,-2,-3
NLOANSx-1,-2,-3
DEPx-1,-2,-3
ASSETx-1,-2,-3
EQUITYx-1,-2,-3
LOANx-1,-2,-3
CFDx-1,-2,-3
YEAx-1,-2,-3
NFIAx-1,-2,-3
RWx-1,-2,-3
LOSS_LOANx-1,-2,-3



$Capital_t$ = Earnings from $Assets_t$ – loans loss $provisions_t$ + Net fees and $commissions_t$ – cost of funding from $deposits_t$+ $Capital_{t-1}$

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Deep-Stress:

Benchmarking results

Satellite models and Constant Balance sheet assumption underestimate stressed capital ratios in Out-of-sample testing

All banks in the dataset	Out of Sample CAR	In Sample CAR
Satelite Modelling(BMA)	20.61	17.07
Deep Learning (MXNET)	18.01	17.89
Constant Balance Sheet	20.03	17.49
Actual	19.33	18.73
Large Banks (>200bl)	Out of Sample CAR	In Sample CAR
Satelite Modelling(BMS)	15.07	11.04
Deep Learning (MXNET)	12.77	11.12
Constant Balance Sheet	15.11	11.48
Actual	13.75	14.16

All Banks	Out of Sample (2014Q1 - 2015Q4)		
	RMSE	MAPE	MAE
Satelite Modelling(BMS)	8.28	15.15%	2.88
Deep Learning (MXNET)	7.23	11.93%	2.36
Constant Balance Sheet	7.88	15.25%	2.85
	In sample (2010Q1 - 2013Q4)		
	RMSE	MAPE	MAE
Satelite Modelling(BMS)	9.16	15.79%	2.58
Deep Learning (MXNET)	9.70	15.00%	2.55
Constant Balance Sheet	11.15	15.40%	2.55

Deep Learning provides lower errors on an out - of sample basis compared to Satellite models and Constant Balance sheet assumption