

Federated Modeling

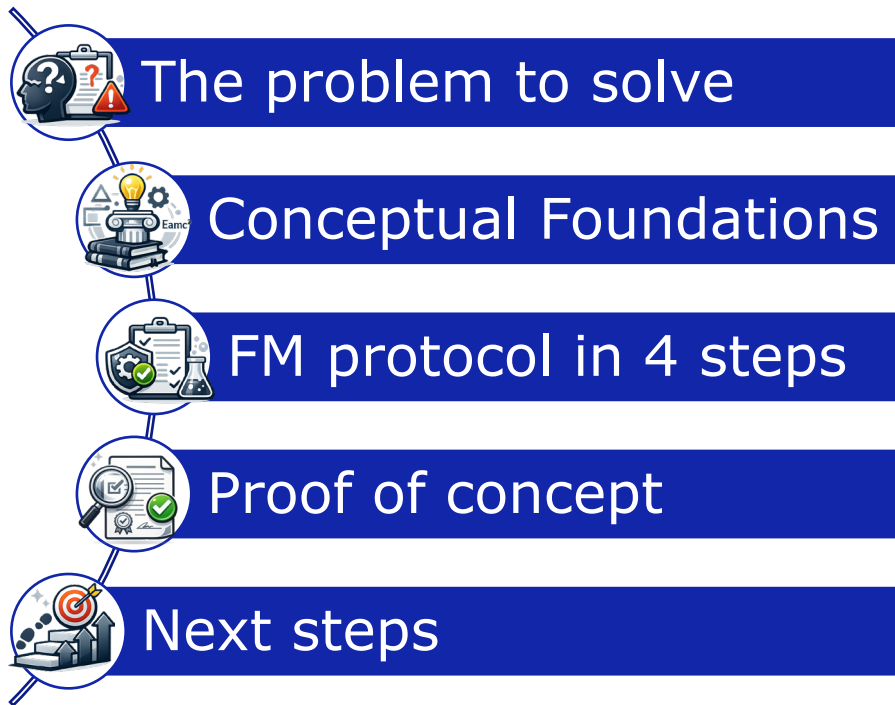
A decentralized framework for system-wide stress testing

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- **Data confidentiality constraints**

Legal and institutional frameworks (GDPR, ESCB rules) prohibit the sharing of granular data and internal models, including any information that could enable reverse engineering.

- **Fragmented stress-testing landscape**

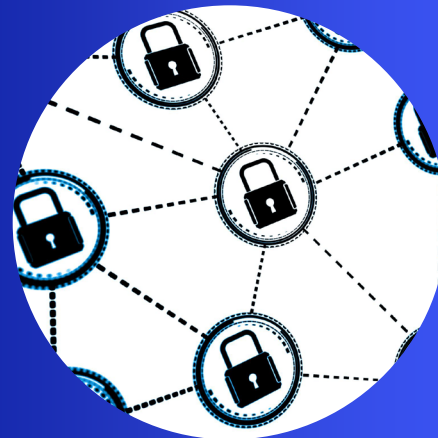
Stress tests remain largely siloed by sector or jurisdiction, limiting the assessment of cross-sectoral spillovers and system-wide risks.

- **Limits of current modelling frameworks**

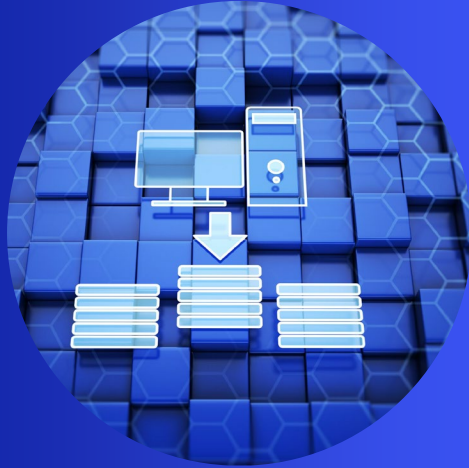
Existing approaches rely heavily on static, exogenous assumptions and high-level aggregation. Modern stress testing increasingly requires dynamic, endogenous modelling based on granular information, as illustrated by centralised top-down frameworks such as ECB-ISA.

There is a critical gap between the impossibility of centralizing data and the growing need for granular, dynamic modelling.

System-Wide Stress Testing is a challenge



Conceptual Foundations of Federated Modelling



Core Principles of Federated Modelling:

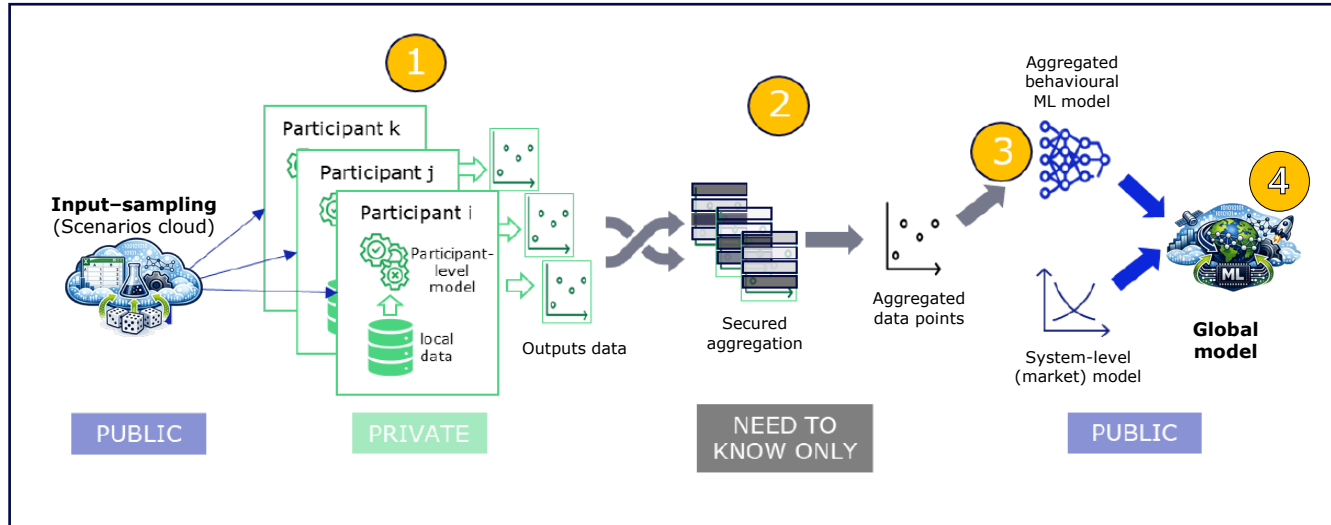
Model decomposition: The global model combines a shared system-level equilibrium model (here the market price model) with participant-specific behavioral models. Behavioral models remain private.

Function sampling: Private models are treated as functions and approximated through selected input-output evaluations over the relevant scenario space.

Privacy-preserving aggregation: Secure protocols aggregate these functional outputs without disclosing individual data or model details.

Machine learning can replicate the aggregated functions without needing access to the underlying data or logic.

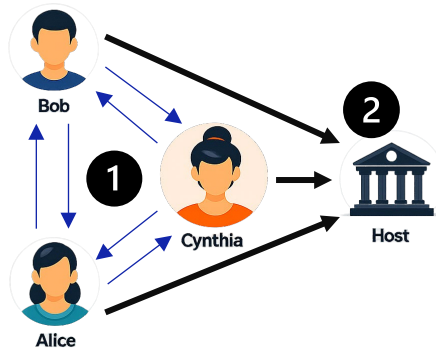
Federated Modelling protocol in Four Steps



- 1. Local Simulation** – Each participant runs stress scenarios on private data to produce outputs.
- 2. Secured Aggregation** – Outputs are shared via privacy-preserving protocol; only aggregated data is visible.
- 3. Global Learning** – Host uses machine learning to approximate participant behavior from aggregated outputs.
- 4. System Integration** – Combine ML model with system-level model to capture market reactions and feedback loops.

FOCUS: 2. Secured aggregation

Group average salary calculation without violating individual privacy, an illustrative example with the Secure Multi-Party Computation (SMPC) technic



1

Each employee splits their salary amount into 3 random parts and then sends also randomly 2 parts to other participants, keeping one part for themselves.

2

Every participant sums up the received parts along with their own remaining portion and forwards the total to a host.

Finally, The host sums up every amounts and divide by 3

Proof of concept definition: FSAP “fire-sales” model

This proof of concept simulates a “fire sale” stress test inspired by the Federal Reserve model (Cetorelli et al., 2023).

- **Model 1 (Selloff Model):** Estimates asset sales by institutions to maintain leverage after prices drop.
- **Model 2 (Market Model):** Updates asset prices based on total sales and market depth; this model uses non-sensitive data and is shared among participants.

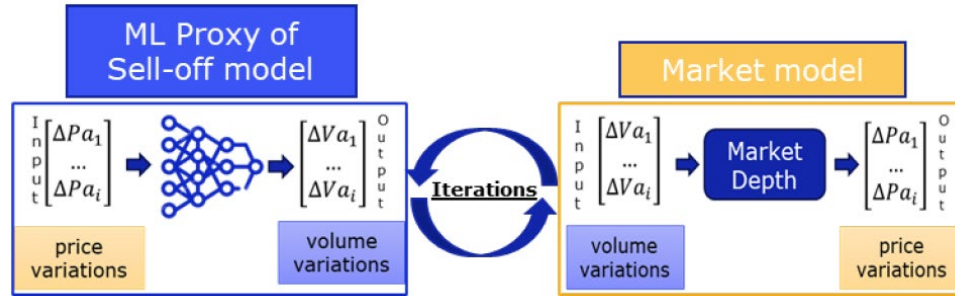
The system iteratively runs both models to find new price equilibrium seen as a shock amplification.

Simplifying Assumptions:

- Proportional asset sales based on original portfolios.
- Immediate leverage ratio adjustment. Leverage ratios are sourced from COREP (banks) and Solvency II (insurers)
- Assets are grouped into 14 standardized categories balancing realism and computational efficiency.



Proof of concept using FSAP “fire-sales” model



Endogenous amplification of initial price shocks through multiple iterations of both models

Proof of concept: Results for selloffs replication

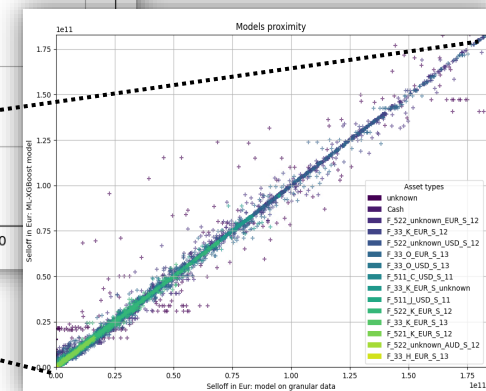
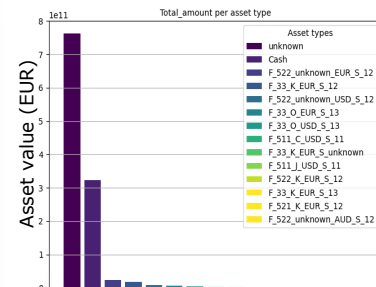
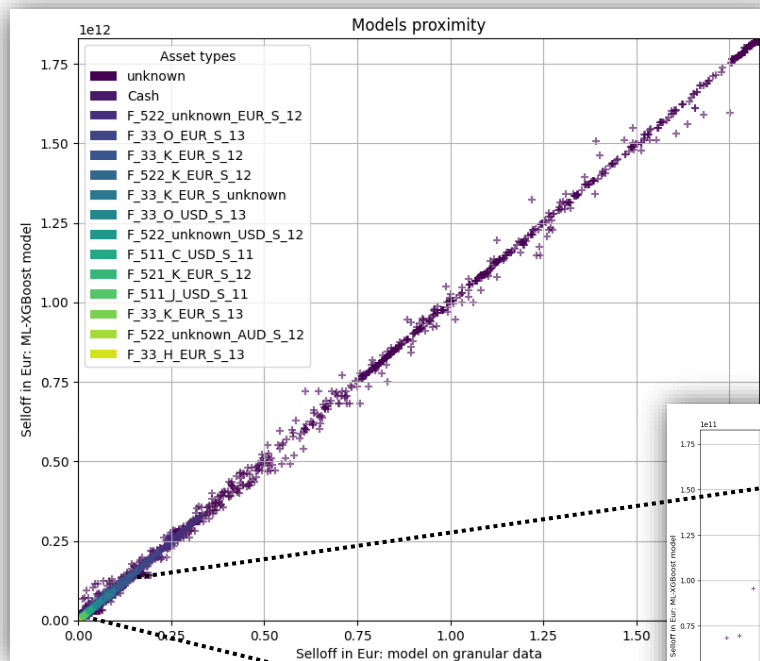
Modeling information:

- 5000 vectors of shocks on prices for 14 asset categories paving possible scenario developments
- Behaviour models "constant leverage" of Dutch FIs
 - 14 banks
 - 22 insurers
 - 47 pension funds

Producing selloff amounts per price shock vector

Machine Learning information:

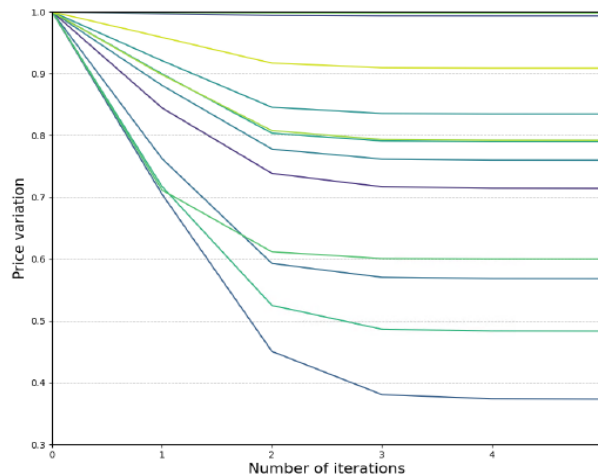
- ML model trained to produce selloff amounts based on input vector of price shock (14 asset categories)
- 'Scikit-Learn' python package for XGBoost as ML model. Hyperparameters of the model was optimized with 'Optuna'
- 4000 learning points
- 1000 test points



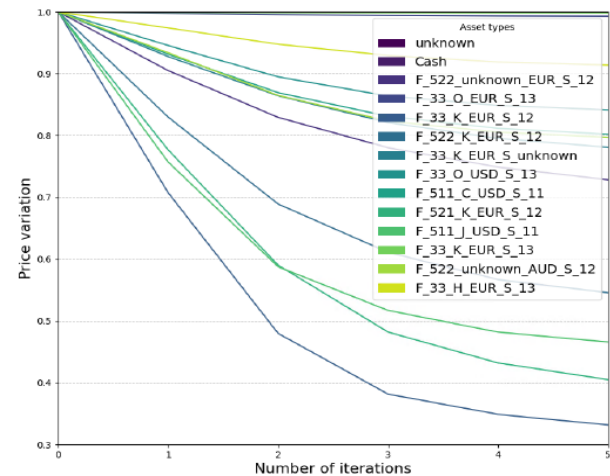
Proof of concept: Results for price equilibrium replication

Single point Random
set of prices Shock
Example

a) Original fire-sale model

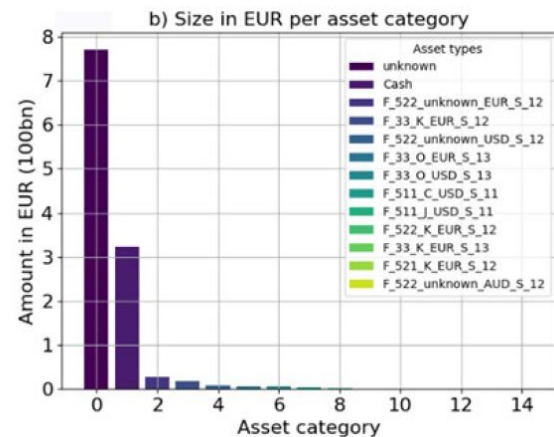
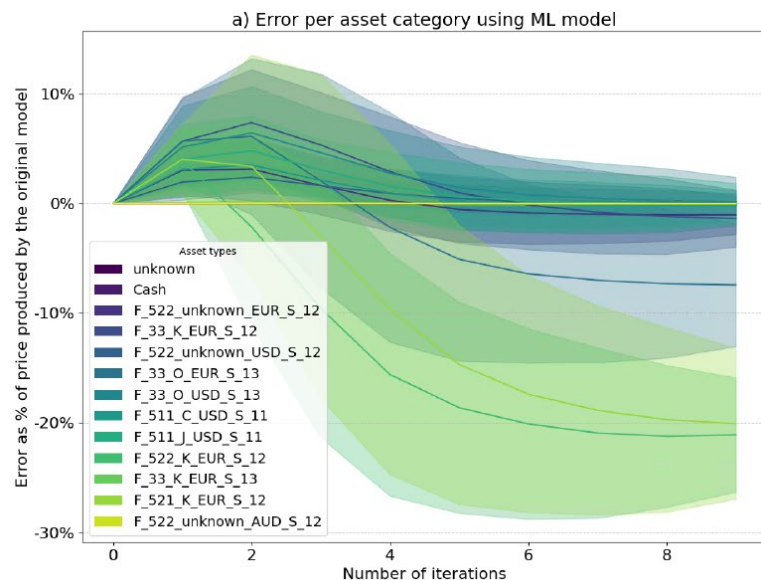


b) FM fire-sale model using ML



Proof of concept: Results for price equilibrium replication

Statistics on 1000
input price shocks



Future Enhancements

- **Stronger and smarter privacy protocol**

Use Paillier cryptography and/or blockchain to share encrypted results securely.

- **Compressed Data Exchange**

Replace point clouds with compact representations (e.g., polynomial, Fourier, or wavelet approximations) to limit the size of exchanged data sets and fit better with cryptography technology.

- **Optimized Machine Learning**

Explore advanced models, training strategies, and hyperparameter tuning to boost accuracy.

Proof of concept shows even basic approaches cover a wide range of use cases—enhancements will make it faster and leaner.

CONCLUSION

Facts

- Federated Modeling enables privacy-preserving, decentralized stress testing—avoiding legal issues.
- Runs efficiently on standard hardware with open-source Python tools.

Main issue

- Simple fire-sale model used for proof of concept. Future work should include more realistic dynamics.
- No full model available for global error estimation, participants must self-validate due to privacy protection. Need implementation of shared automatic validation test and benchmark models.

What next

- Ready for real-world pilots by 2027, advancing next-generation for financial stability analysis
- Broad applicability beyond stress testing. Supports international and interdisciplinary collaborations

Time for questions...

