#### OST Eastern Switzerland University of Applied Sciences

### **Deep Asset-Liability-Management**

7<sup>th</sup> European COST Conference on Artificial Intelligence in Industry and Finance

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28 September 2022

Centre for Banking & Finance

## Pricing & Hedging



- complex *d*-dimensional stochastic price dynamics  $S = (S_t)_{0 \le t \le T}$
- transaction cost
- liquidity constraints
- 2 COST Conference on AI in Industry and Finance



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### Pricing & Hedging / Asset-Liability-Management

#### Balance Sheet Roll-Forward\*



- \* Deep Replication of a Runoff Portfolio (2020) T.K., Josef Teichmann <u>arXiv:2009.05034</u>
- 4 COST Conference on AI in Industry and Finance



### Deep Asset-Liability-Management (ALM)

Simply put, one tackles **high-dimensional stochastic optimisation problems** under **constraints** and **frictions** by means of techniques inspired by reinforcement learning.



input layers: state of the market and the balance sheet, latent variables output layers: restructuring of the balance sheet from «pre» to «post»



#### The Gas Storage Problem





- business model: exploitation right for 1y, «buy low, sell high»
- stochastic elements: natural gas prices (spot and forward markets)
- control variable:  $h_k > 0$  refers to as «injection»,  $h_k < 0$  to «withdrawal»
- constraints:  $\ell_k \stackrel{!}{\leq} h_k \stackrel{!}{\leq} u_k, \quad 0 \stackrel{!}{\leq} H_k \stackrel{!}{\leq} c$
- frictions:  $H_k$ -dependent transaction cost, penalty if  $H_{350} > 0$
- objective: optimise the terminal wealth distribution



#### The Gas Storage Problem (restricted to «Spot Trading»)

We aim at maximising

$$\mathbb{E}\left[U\left(W_{N-1}^{S}\right)\right] = \mathbb{E}\left[U\left(\sum_{k=0}^{N-1} -h_{k}F(k,k+1) - |h_{k}F(k,k+1)| \cdot \kappa\right)\right]$$

subject to  $\max\{\ell_k, -H_k\} \le h_k \le \min\{u_k, c - H_k\}$ , where

- $U(\cdot)$  utility function controlling the risk appetite,
  - k time index over the trading horizon  $\{0, 1, 2, \dots, N-1\}$ ,
  - $h_k$  action on the day k (injection/withdrawal),

$$egin{aligned} & \mathcal{H}_{k+1} = \sum_{i=0}^k h_k & ext{ storage fill level on the day } k+1, \ & \mathcal{F}(k,k+1) & ext{ day-ahead gas price}, \end{aligned}$$

 $\kappa$  proportional transaction cost.



#### The Gas Storage Problem (restricted to «Spot Trading»)



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#### Nota Bene

- Our artificial financial agent does not learn to act under all configurations but rather for a given **initial state** and a **«bundle**» of scenarios. This restriction is key to tame the «curse of dimensionality».
- The time axis is **not** necessarily **equidistant**.
- «Deep ALM» does **not** attempt to **predict** the future; one rather adapts best to the future while accounting for the uncertainty.
- The artificial learning process is only one out of many ingredients to «Deep ALM»; the **main challenge** are the **scenarios**.
- «Deep ALM» neither relieves work nor responsibility.
- A **preliminary study** can clarify whether the sophisticated approach and the additional complexity do pay off in the end; this is not always the case!







#### Constraints

• Cash & Cash Equivalents  $\geq$  Minimal Reserve (MR)

 $MR = 2.5\% \times (Sight Deposits + IFELSE[SARON \ge 0, 20\%, 100\%] \times Savings)$ 

- Maximal Allowance =  $30 \times MR_{\emptyset 36M}$
- Minimum Capital Ratio = Equity / RWA ≥ Internal Guideline
- LCR = HQLA / Net Outflows<sub>30D</sub>  $\geq$  100%
- NSFR = ASF / RSF  $\geq 100\%$
- Interest Rate Sensitivity: Relative change in equity in the event of a parallel shift of the yield curve by  $\pm 100 bps$
- «No Short Selling»



#### Stylised Swiss Retail Bank

Assets	Liabilities
Cash	Deposits
Investments	Non-maturing Deposits
Loans	Term Deposits
Mortgages	Borrowings
Loans to Enterprises	Equity
Swaps	

#### HJM-Framework with Term-Dependent Volatilites

$$df(t, T) = \sum_{k=1}^{M} \sigma_{k}(t, T) \left( \int_{t}^{T} \sigma_{k}(t, s) \, ds \right) dt + \sum_{k=1}^{M} \sigma_{k}(t, T) dW_{k}(t)$$
  
$$\sigma_{k}(t, T) = \beta_{k,0} + \beta_{k,1}(T - t) + \beta_{k,2}(T - t)^{2} + \beta_{k,3}(T - t)^{3}$$





### **Preliminary Results\***





Liquidity- & Funding-Risk





- \* Deep ALM (Work in Progress) Swiss Retail Bank, T.K., Konrad Müller
- 13 COST Conference on AI in Industry and Finance



#### **Preliminary Results**



and many more ...

In the light of all the uncertainty and the numerous constraints, how should a Swiss retail bank

- have ideally structured its B/S last Wednesday (before SNB's termination of negative interest rates)?
- ideally structure its B/S today?

How would you justify your choice?



### Contact

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