Zürcher Hochschule
für Angewandte Wissenschaften

School of
Engineering
IDP Institut für
Datenanalyse und
Prozessdesign

Prototype Environment for Financial Risk Modeling

Prof. Wolfgang Breymann
Zurich University of Applied Sciences

Artificial Intelligence in Industry and Finance
Focus Session on Fintech-Driven Automation in the Financial Industry.
ZHAW, Winterthur, September 6th, 2018

Outline

- Introduction:
  Why an R – ACTUS interface and why a visual demonstrator
- The R – ACTUS interface
- A proof of concept using the R – ACTUS interface
- An ACTUS-based visual demonstrator for stress testing and systemic analysis
- Summary – Conclusion

Introduction

- Up to now:
  - The economy as a network of contracts
  - ACTUS: concepts
  - Smart contracts
  - Requirements for stress testing
  - Automated reporting: concept and demo

- Here something to play around with ACTUS-based modeling:

  - R-packages targeted to the technically savvy
  - An interactive demonstrator for visualization

ACTUS Contract Types

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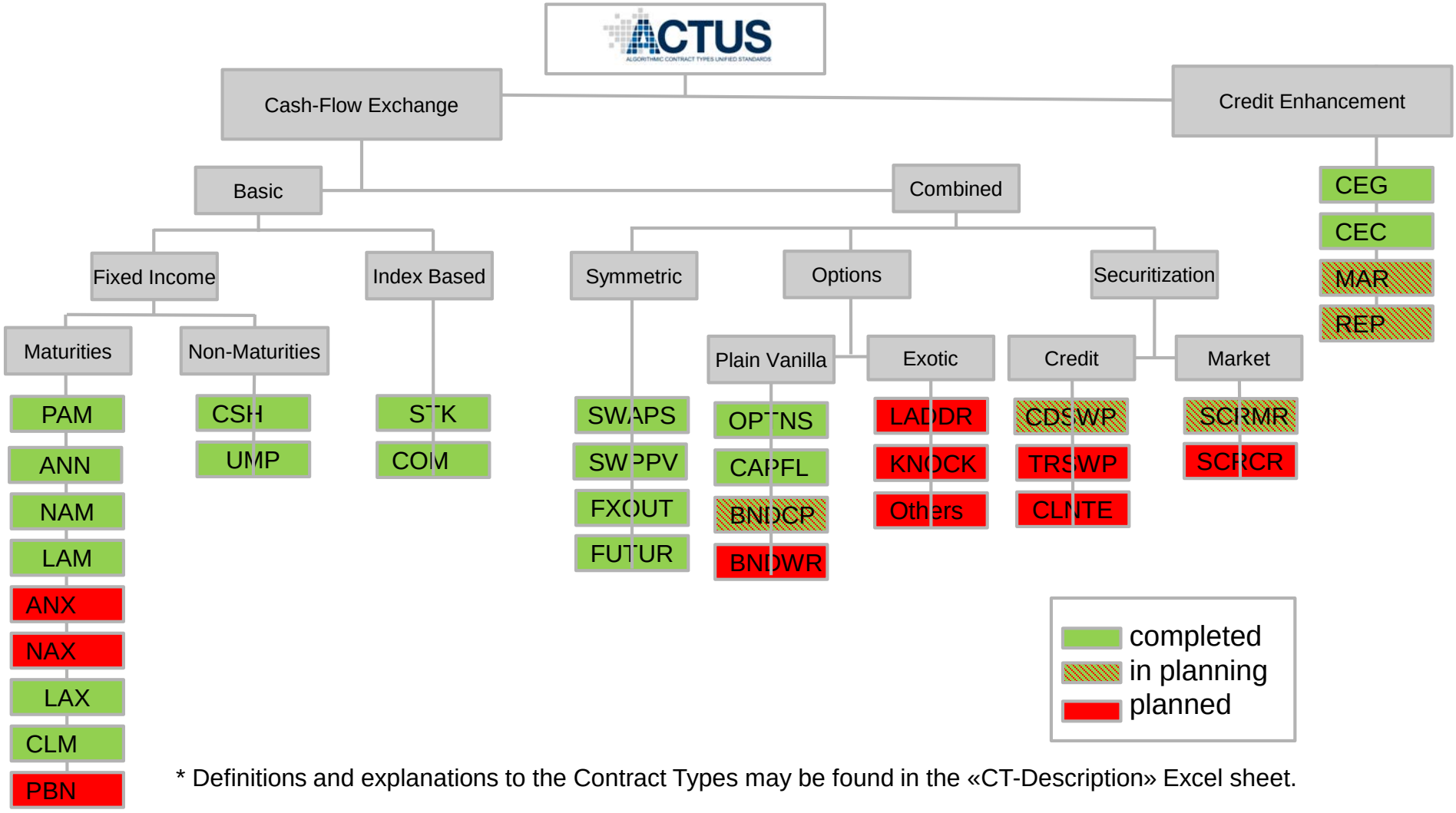

* Definitions and explanations to the Contract Types may be found in the «CT-Description» Excel sheet.

The ACTUS – R Interface: The Philosophy

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- Provide the means for using ACTUS contract types on a prototyping level to the mathematically educated user
- Add the analytical power of R to enable rapid prototyping of sophisticated models

The ACTUS Logic

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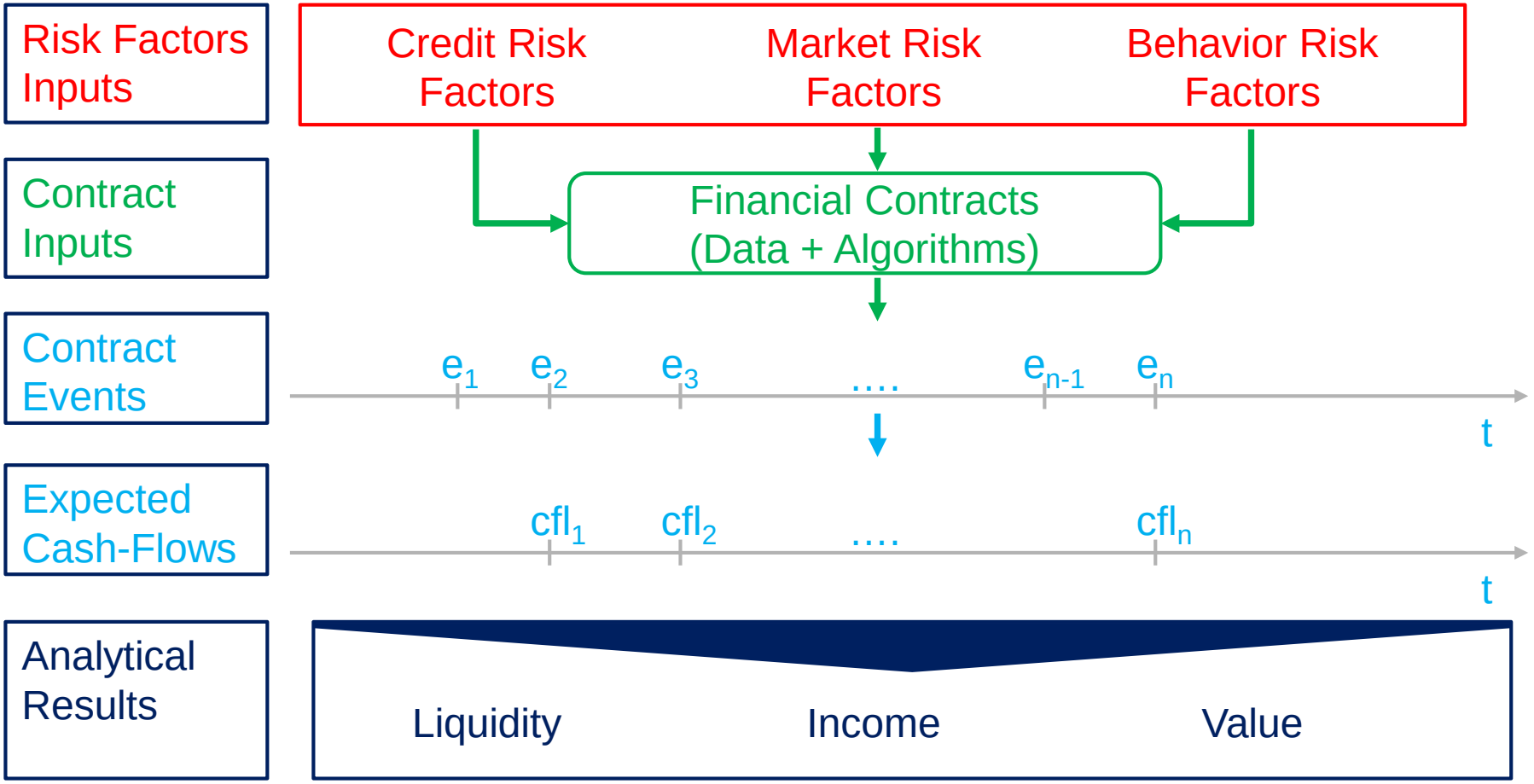

The ACTUS – R Interface: The R-Packages

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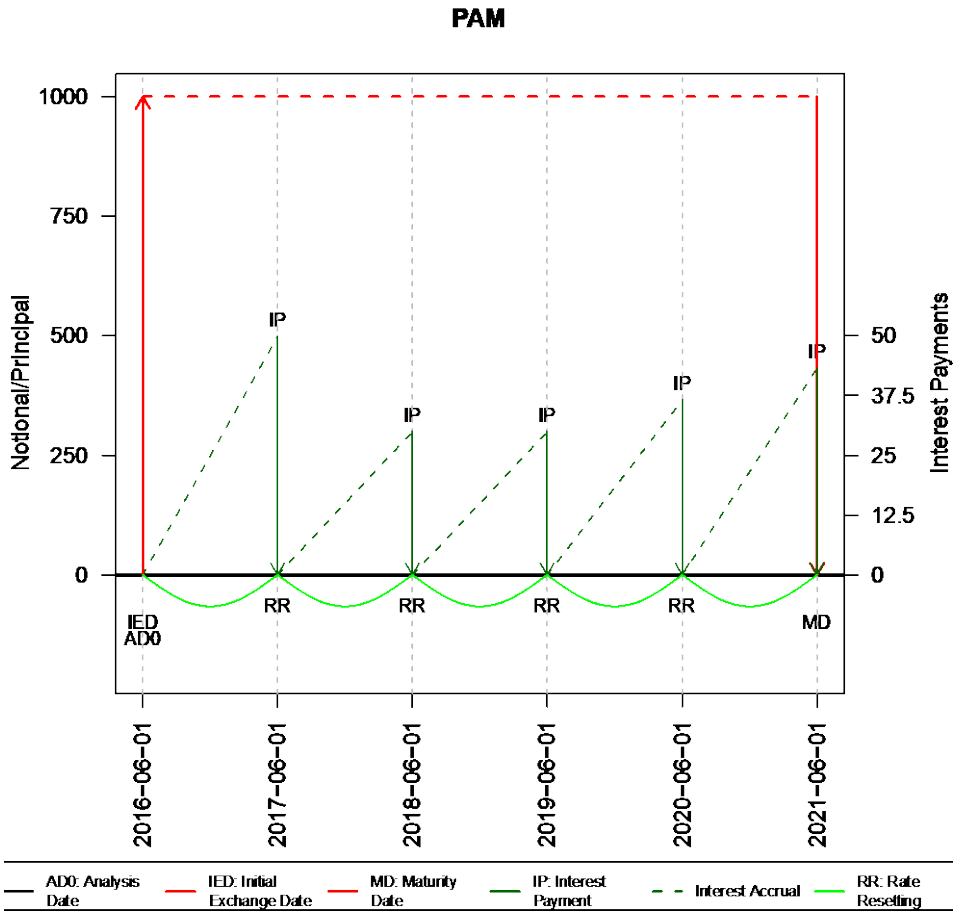
- rActus
  - R-Interface to the ACTUS Java library
  - Gives access to contract types
    - PAM
    - ANN
    - LAM
    - SWAPS
    - STK
  - User can create contract, define market environment, create the contract events and visualize the cash flows
  - No analytics
- A simple example

The R-Packages: Examples



The ACTUS – R Interface: The R-Packages

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- rflPortfolio
  - Supports analysis of whole portfolios
- rflContracts
  - Supports demonstration of single contracts

- Parallel execution at R-level possible with
  - SparkR -> Bachelor thesis
  - Directly in R (example?)

The ACTUS – R Interface: The Bottleneck

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- The bottleneck:
  R – Java communication
  - R is written in C/C++
  - Java and C/C++ are “disjunct worlds”
  - The communication passes through the Java Native Interface (JNI),
  - The JNI is slow
  - rActus requires a lot of communication between R and Java, which makes it slow
  - Can only be used for a handful of contracts
- Work-around:
  - Pass a whole portfolio in one chunk to the java library
  - Use parallel computing, directly in R or through SparkR

- This bottleneck can only be overcome through transferring the source code to C++.

Proof of Concept
with a Portfolio of Real Bonds

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~/Documents/idp/Projekte_svn/Actus&RFL/poc_ecb - master - RStudio

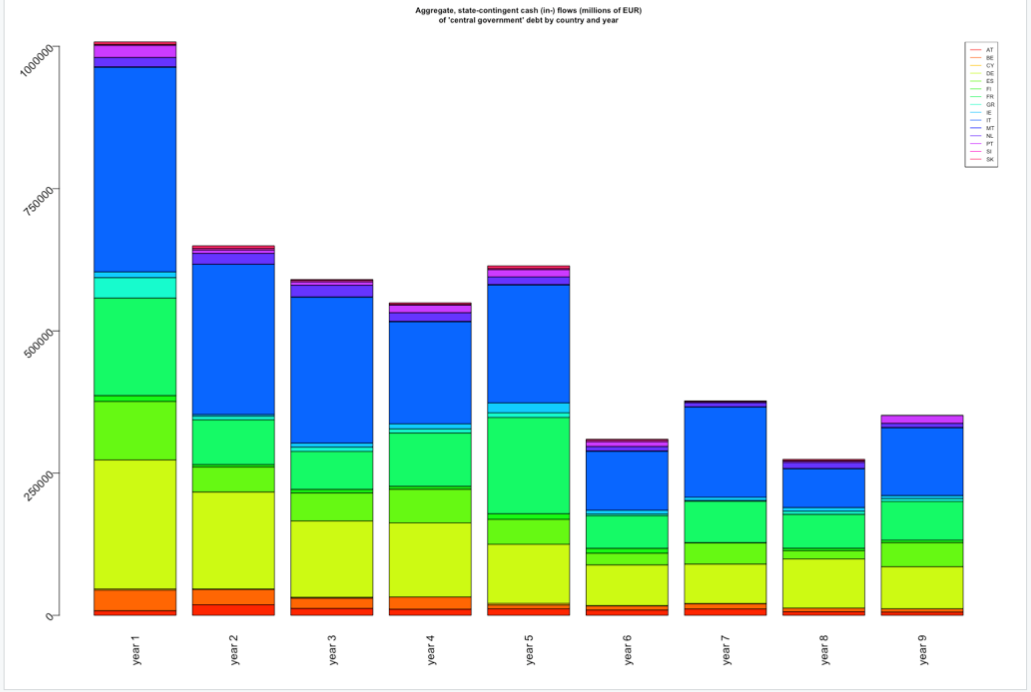
```
colnames(liq.ts) <- c("All", levels(s1311.dat$Country))

# check whether country-wide liqiudity calculation correct
all.equal(as.numeric(liq.ts[,1]),as.numeric(apply(liq.ts[,2:ncol(liq.ts)],1,sum)))
# plot
temp <- t(data.frame(liq.ts[,-1]))/1000000
colnames(temp) <- paste("year", 1:9)
cols <- rainbow(length(levels(s1311.dat$Country)))
barplot(temp, col=cols, las=2, yaxt="n")
marks <- seq(0,1000000,by=250000)
axis(2, at=marks, labels=FALSE)
text(y = marks, par("usr")[1], labels = format(marks, scientific=FALSE), srt = 45, pos = 2, xpd =
title(main=list(
  "Aggregate, state-contingent cash (in-) flows (millions of EUR)\nof 'central government' debt by
  cex=0.7))
legend("topright", legend=levels(s1311.dat$Country), col=cols, lty=1, horiz=FALSE,inset=c(0,0), ce


# now liquidity by type of cash flow
liq.ts = fapply(x=s1311.ts, from=from, to=to, FUN=sum)
for(tpe in c("IP", "MD")) {
  temp <- subset(s1311.dat, Type==tpe)
  liq.ts <- cbind(liq.ts,fapply(x=timeSeries(temp$CF, temp$tdate), from=from, to=to, FUN=sum))
}
liq.ts
colnames(liq.ts) <- c("All", "Interest", "Principal")

# check whether liqiudity calculation correct
all.equal(as.numeric(liq.ts[,1]),as.numeric(apply(liq.ts[,2:ncol(liq.ts)],1,sum)))
# plot
```

```
> temp <- t(data.frame(liq.ts))/1000000
> colnames(temp) <- paste("year", 1:9)
> cols <- rainbow(ncol(temp)-1, start=2/6)
> df.bar <- barplot(temp[-1,], col=cols, las=2, yaxt="n")
> marks <- seq(0,1000000,by=250000)
> axis(2, at=marks, labels=FALSE)
> text(y = marks, par("usr")[1], labels = format(marks, scientific=FALSE), srt = 45, pos = 2, xpd = TRUE)
> lines(x = df.bar, y = liq.exp/1000000, col="red", lwd=2)
> arrows(df.bar,apply(temp[-1,],2,sum), df.bar, liq.exp/1000000-liq.err/1000000,
+        angle=90, code=3, length=0.1, col="red")
> title(main=list(
+   "Aggregate, state-contingent cash (in-) flows (millions of EUR)\nof 'central government' debt by credit rating and ye
ar\nand its expectation under a stochastic default model",
+   cex=0.7))
> legend("topright", legend=c(colnames(liq.ts)[6:2], "Expectation"),
+        col=c(cols[5:1],"red"), lty=1, horiz=FALSE,inset=c(0,0), cex=0.7)
>
```



to	Formal class timeDate
ts.survival	num [1:10, 1:15] 1 1 1 0.999 0.999 ...
ts.survival.var	num [1:10, 1:15] 0 0.0001 0.0004 0.0007 0.000999 ...
vs.ts	num [1:9, 1:15] 0.0001 0.0004 0.0007 0.000999 0.001298 ...
Values	
ad	"2015-05-01T00"
cntry	"SK"
cols	chr [1:8] "#00FF00FF" "#00FF76FF" "#00FFEDFF" "#009BFFFF" "#0024FFFF" "#5…
countries	chr [1:15] "AT" "BE" "CY" "DE" "ES" "FI" "FR" "GR" "IE" "IT" "MT" "NL" "P…
df.bar	num [1:9] 0.7 1.9 3.1 4.3 5.5 6.7 7.9 9.1 10.3
ecb.rts	num [1:6] -0.0028 -0.0026 -0.0021 0.0003 0.002 0.0042
ecb.tnr	chr [1:6] "3M" "1Y" "2Y" "5Y" "7Y" "10Y"
i	100L
input	"./data/"
liq.2	Formal class timeSeries
liq.err	Named num [1:9] 24458686801 21407357945 25894629617 23118483471 321046346…
liq.exp	Named num [1:9] 998709925671 645070097137 583391050539 540871710839 60216…
liq.ts	Formal class timeSeries
marks	num [1:5] 0 250000 500000 750000 1000000

Proof of Concept: The Portfolio

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Sample overview: Number of Observations =3809

Sector (according to European System of Accounts 2010 issued by the European Union)

All observations of the General Government (S_13) sector which is subdivided into

Central Govt. (S_1311) l State Govt. (S_1312) l Local Govt. (S_1313) l Social security funds (S_1314)

N-Obs:	1290	1944	491	84

Country (according to ISO 3166-1 system)

	AT	BE	CY	DE	ES	FI	FR	GR	IE	IT	MT	NL	PT	SI	SK
N-Obs:	149	413	46	1712	346	31	478	102	29	219	81	108	42	33	20

Contract Deal Date

Earliest	Latest
1986-06-20	2015-03-31

Maturity Date

Earliest	Latest
2015-04-01[1]	2090-11-08[2]

Cycle Of Interest Payment

1M-	1Q-	1Y-	6M-	NULL[3]
4	391	2237	474	703

Notional Principal (note, different currencies)

Min	Median	Max
0.0[4]	76,690,000.0	38,530,000,000.0

Nominal Interest Rate

Min	Mean	Max
0.0[3]	0.0155	0.2319

[1] Matured bonds, [2] Data quality issue, [3] Zero coupon bonds, [4] Data quality issue

Proof of Concept: Cash Flow Evaluation

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Sample contract events with cash flows per 5/1/15

Contract ID	Event Date	Event Type	Event Value	Time (in years)	Nominal Value	Nominal Rate	Nominal Accrued	Currency	Country	Sector
DE0000000001	2015-05-01T00:00Z[UTC]	AD0	0.0	0.086111	50000000.0	0.0352	151555.6	EUR	DE	S_1312
DE0000000001	2015-12-02T00:00Z[UTC]	IP	1183111.0	0.586111	50000000.0	0.0352	0	EUR	DE	S_1312
DE0000000001	2016-12-02T00:00Z[UTC]	IP	1760000.0	1	50000000.0	0.0352	0	EUR	DE	S_1312
DE0000000001	2017-12-04T00:00Z[UTC]	IP	1769778.0	1.05556	50000000.0	0.0352	0	EUR	DE	S_1312
DE0000000001	2018-12-03T00:00Z[UTC]	IP	1755111.0	0.997222	50000000.0	0.0352	0	EUR	DE	S_1312
DE0000000001	2019-12-02T00:00Z[UTC]	IP	1755111.0	0.997222	50000000.0	0.0352	0	EUR	DE	S_1312
DE0000000001	2019-12-02T00:00Z[UTC]	MD	50000000.0	0	0.0	0	0	EUR	DE	S_1312
GR0000000001	2015-05-01T00:00Z[UTC]	AD0	0.0	0.038889	3000000000.0	0.0475	5541667	EUR	GR	S_1311
GR0000000001	2016-04-18T00:00Z[UTC]	IP	142895833.0	0.963889	3000000000.0	0.0475	0	EUR	GR	S_1311
GR0000000001	2017-04-17T00:00Z[UTC]	IP	142104167.0	0.997222	3000000000.0	0.0475	0	EUR	GR	S_1311
GR0000000001	2018-04-17T00:00Z[UTC]	IP	142500000.0	1	3000000000.0	0.0475	0	EUR	GR	S_1311
GR0000000001	2019-04-17T00:00Z[UTC]	IP	142500000	1	3000000000.0	0.0475	0	EUR	GR	S_1311
GR0000000001	2019-04-17T00:00Z[UTC]	MD	3000000000	0	0.0	0	0	EUR	GR	S_1311

The 4,000 bonds generate a total of 3,866,785 contract events.

Processes ca. 4000 contracts/sec on MBP with 2.5GHz Intel Core i7.

Proof of Concept: Liquidity Analysis

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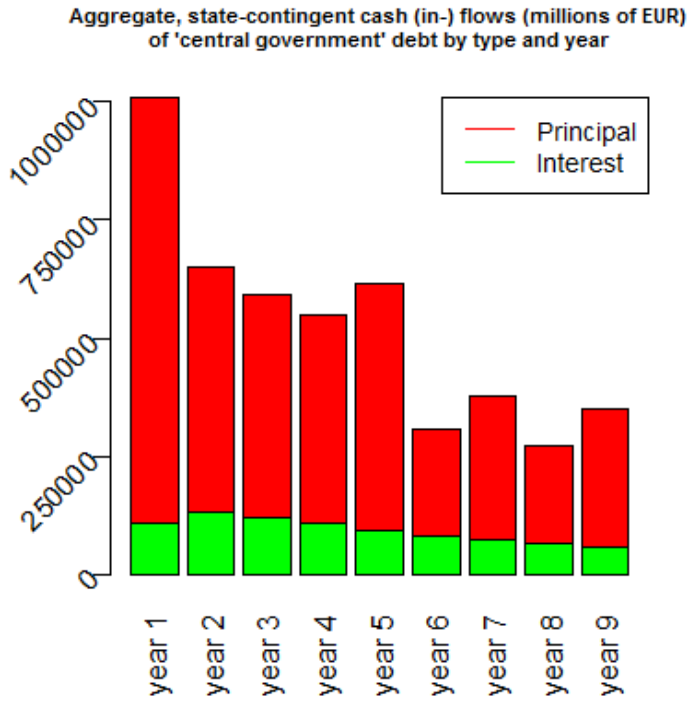
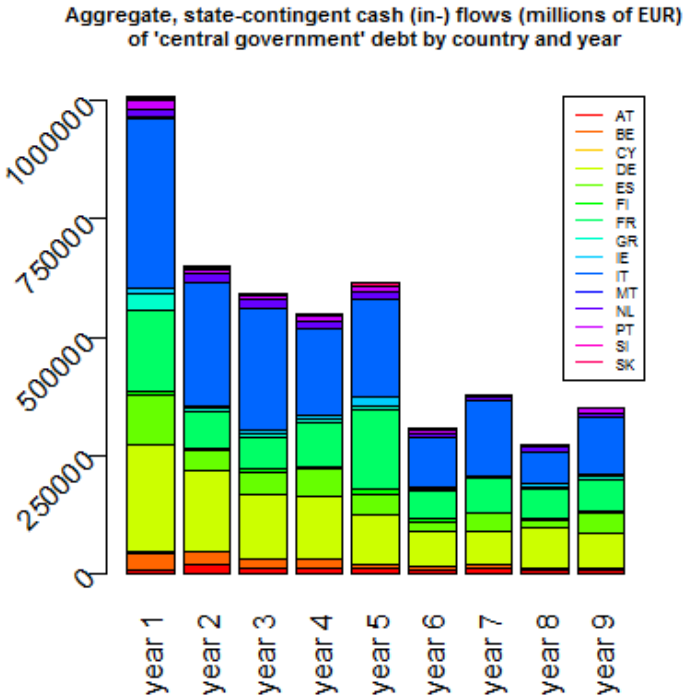
Aggregate liquidity (i.e. state-contingent cash flows) from central government issued bonds expected over the next years:

by cash flow type (interest or principal)



by country of issuance



Proof of Concept: Market Exposure Stress Testing

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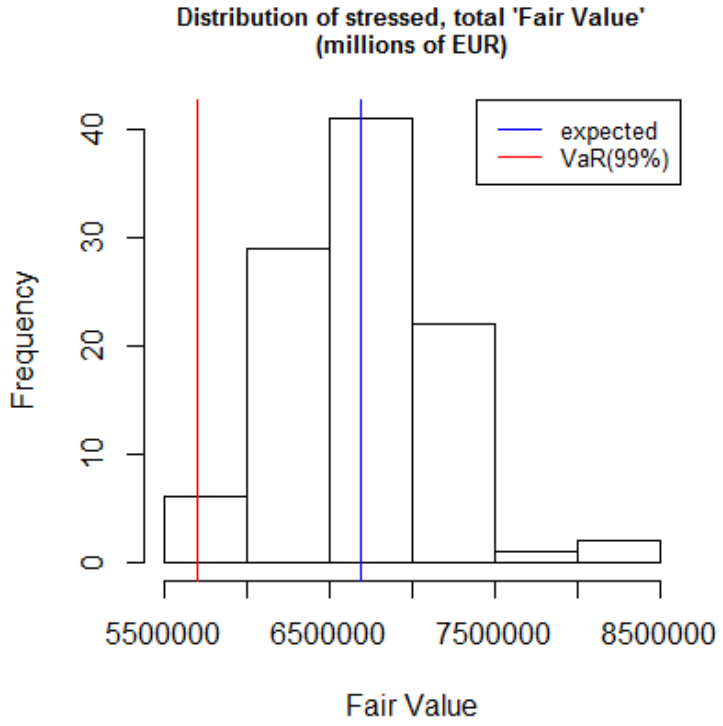
Stress testing 1: Market exposures

Base scenario:

Use Euro-area yield curve observed on 5/1/15 for discounting

Stress scenarios:

We apply 100 yield curve “shocks” (shift, steepening, bending, etc.) in order to assess the impact on “Fair value”



Proof of Concept: Credit Exposure

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Analysis of central government credit exposures:

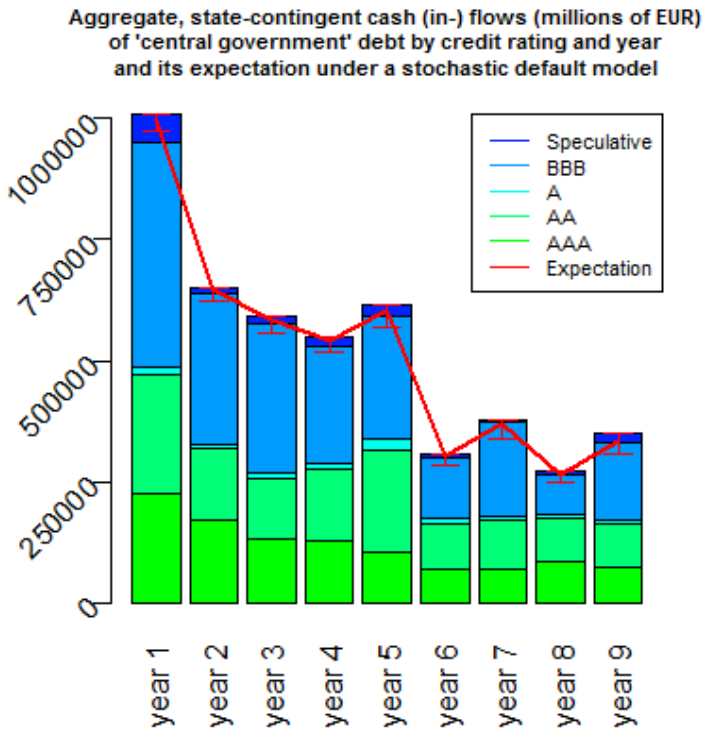
We show the aggregate, yearly cash flows by central government's credit rating (S&P).

Stress testing:

Assuming default of e.g. all "speculative" bonds in year 1 will lead to a loss of the dark blue colored aggregate cash flows (no recovery).

Monte-Carlo:

Simulation of defaults based on a stochastic credit rating migration matrix model provides an expected value for liquidity (no recovery).



Interactive Graphical Financial Risk Demonstrator

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- **Philosophy**
  - To provide a graphical, interactive tool for demonstration purposes using the ACTUS contracts.
  - The tool should be extendable in a simple way.
  - Programming the tool should not require extensive resources.

- **The solution**
  - R is used at rapid prototyping platform.
  - A simulation and analysis engine has been built using the R – ACTUS interface.
  - A graphical frontend has been build using the R-Shiny package.
  - This work was the contents of a Bachelor's thesis:
    Denis Iseli, Dominique Neff: *Real-Time Monitoring of Financial Systems with ACTUS*, Winterthur, June 2018, unpublished.

Financial Risk Demonstrator: Key Points

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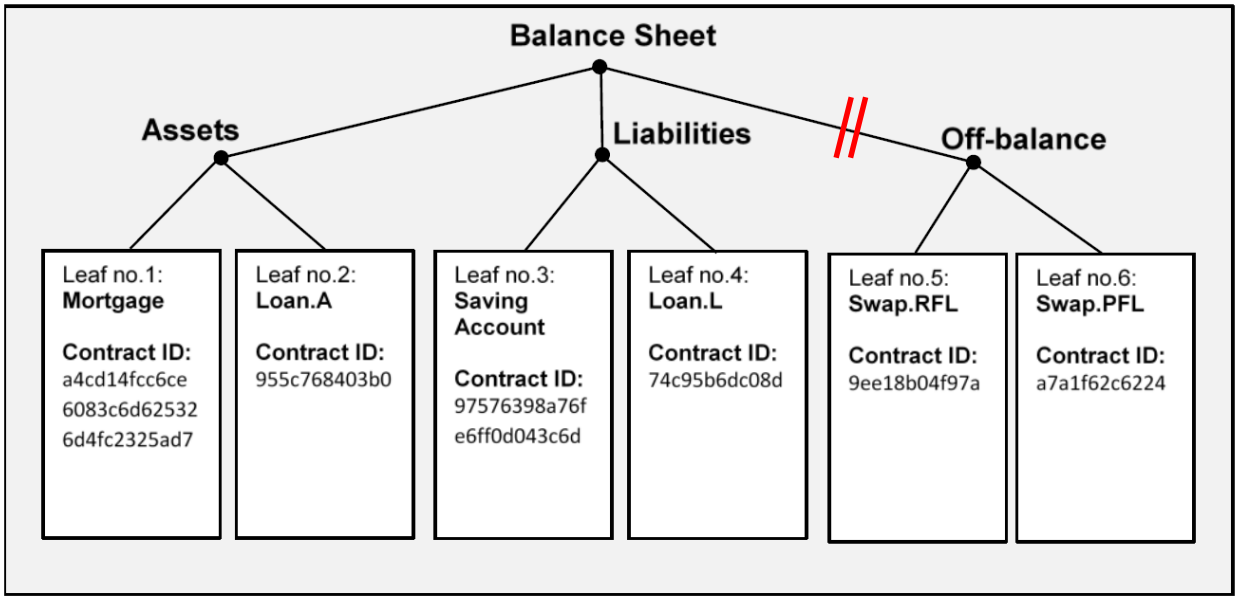
- Models different banks (currently 8 banks)
- Has a database of ACTUS contracts
- At present restricted to the contracts types PAM, ANN, LAM, SWAPS
- Banks modeled by a simple balance sheet:



Financial Risk Demonstrator: Key Points

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- Key performance indicators:
  - Liquidity
  - Nominal value
  - Fair value (net present value)
  - Interest income
  - Equity ratio
- Stress testing:
  - 4 interest rate scenarios:
    Parallel shift, steepening/flattening, user defined, stochastic
- Systemic analysis:
  - Representation of the interdependencies of the system of banks
  - Simple illustration of contagion by computing the effect on solvency if one bank goes bankrupt

Financial Risk Demonstrator: The Tool

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- Can be run locally
- In principle accessible through the internet: http://finlab.engineering.zhaw.ch/shiny/BA_FS2018/ (at the moment not operational)
- Because of R – Java bottleneck, slow performance
  - ➢ Screenshots

Financial Risk Demonstrator: Screenshots

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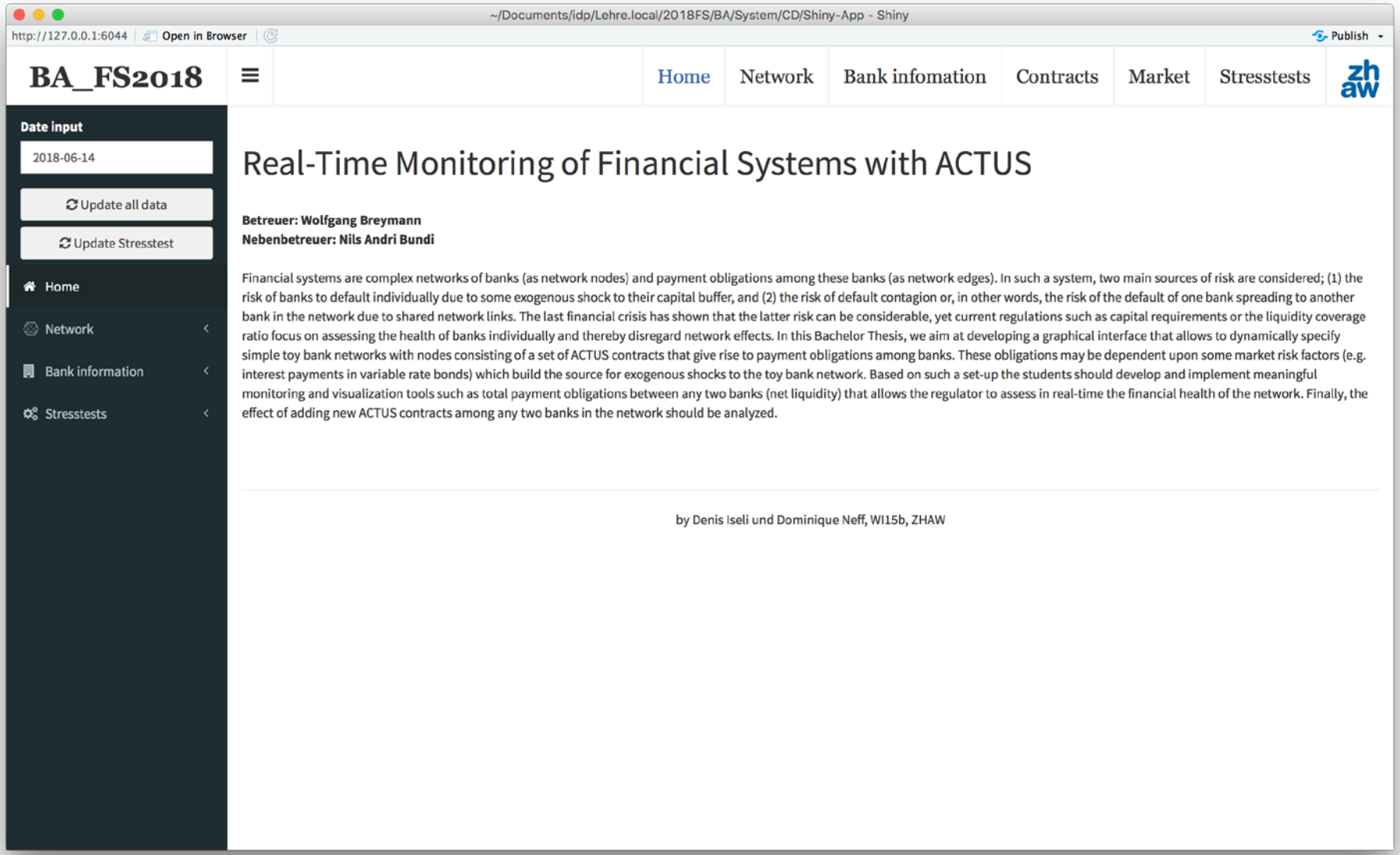

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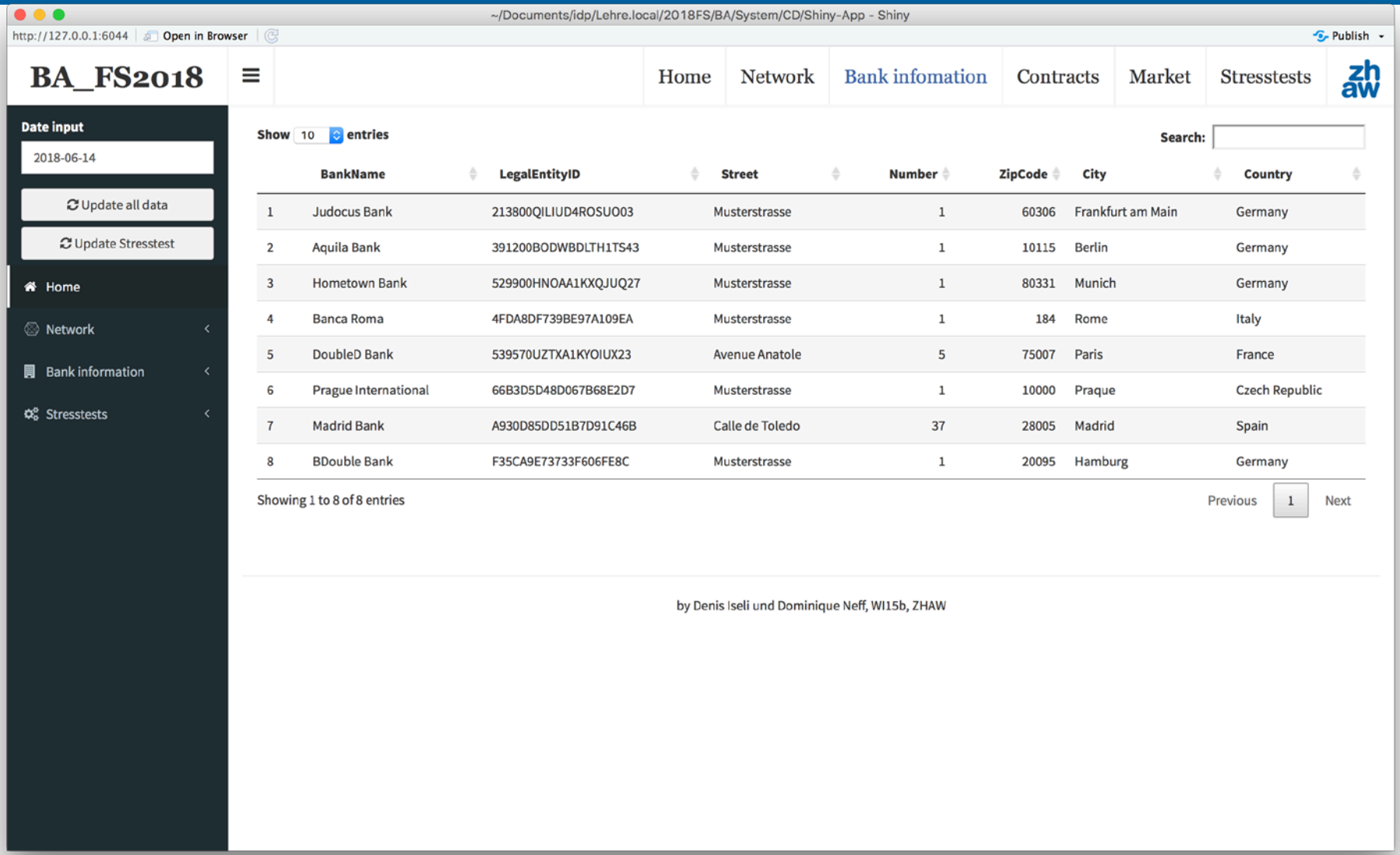

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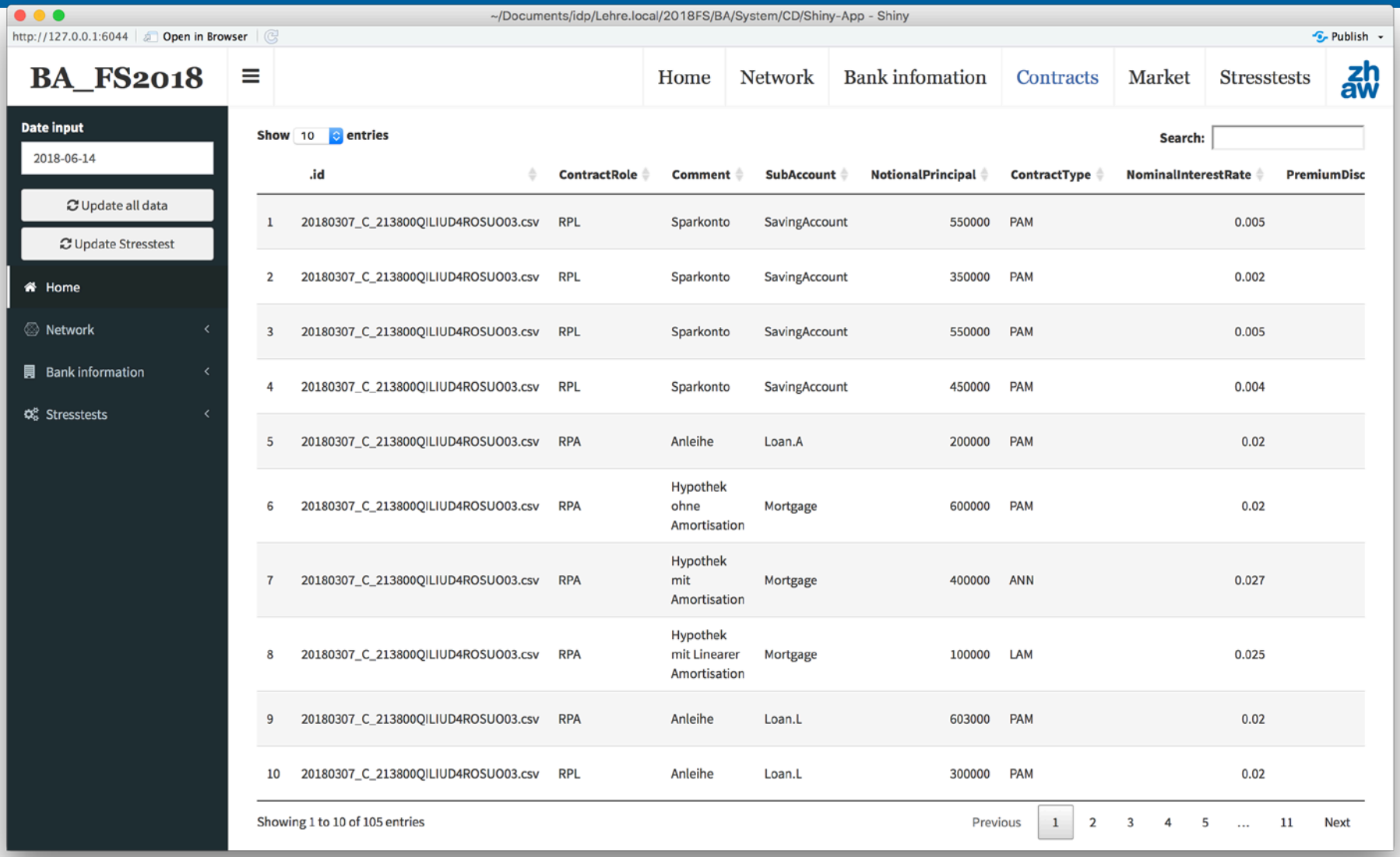

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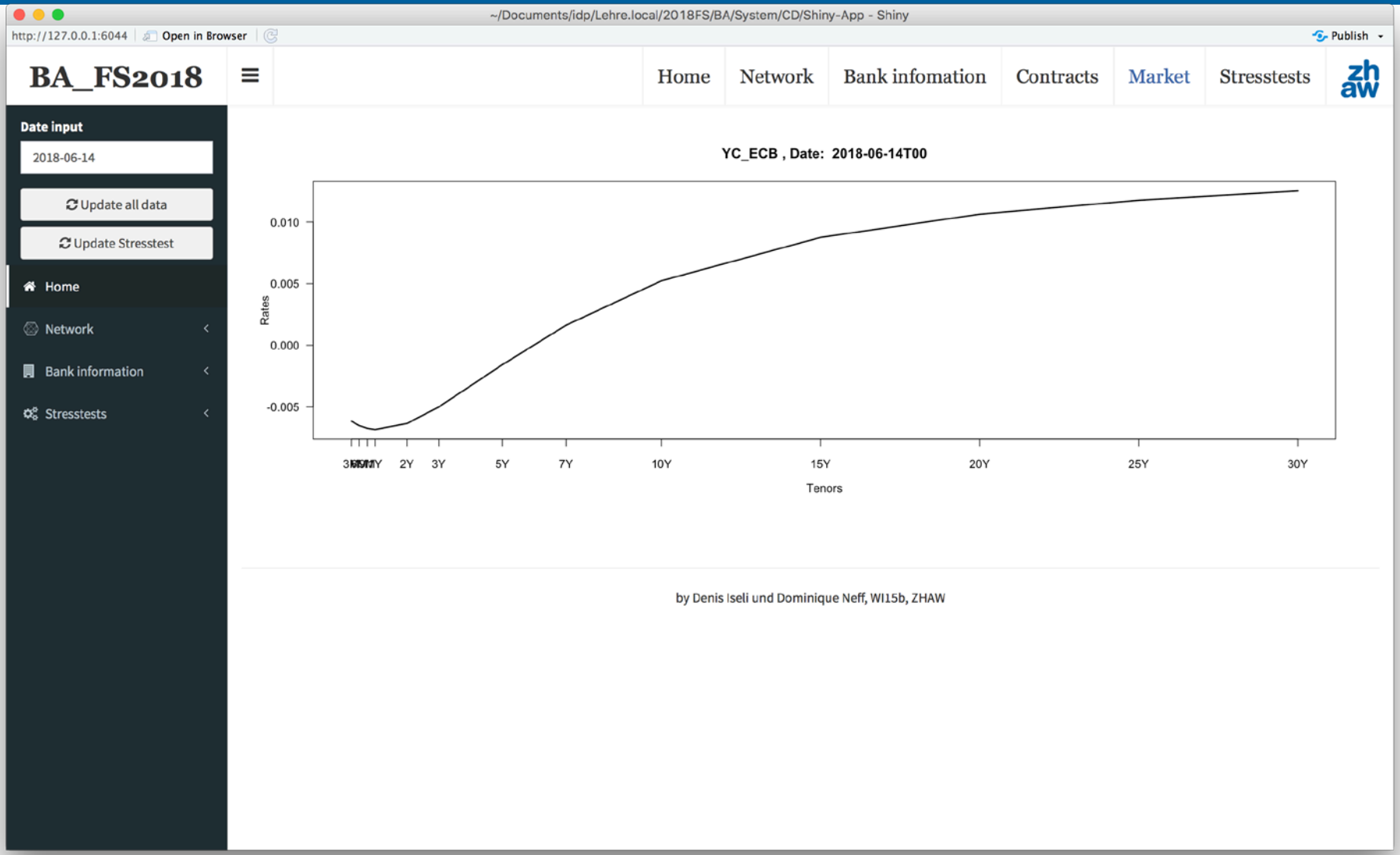

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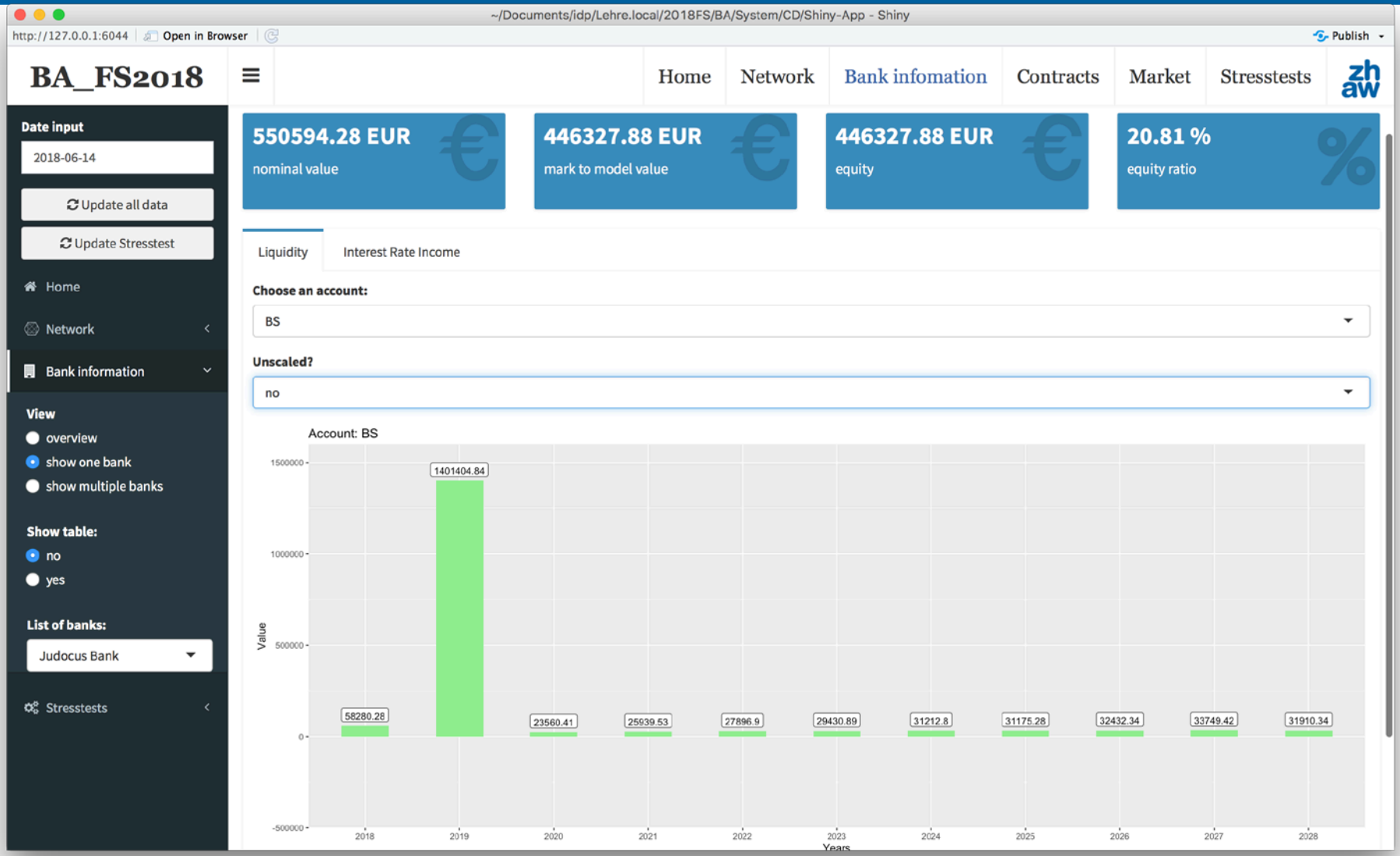

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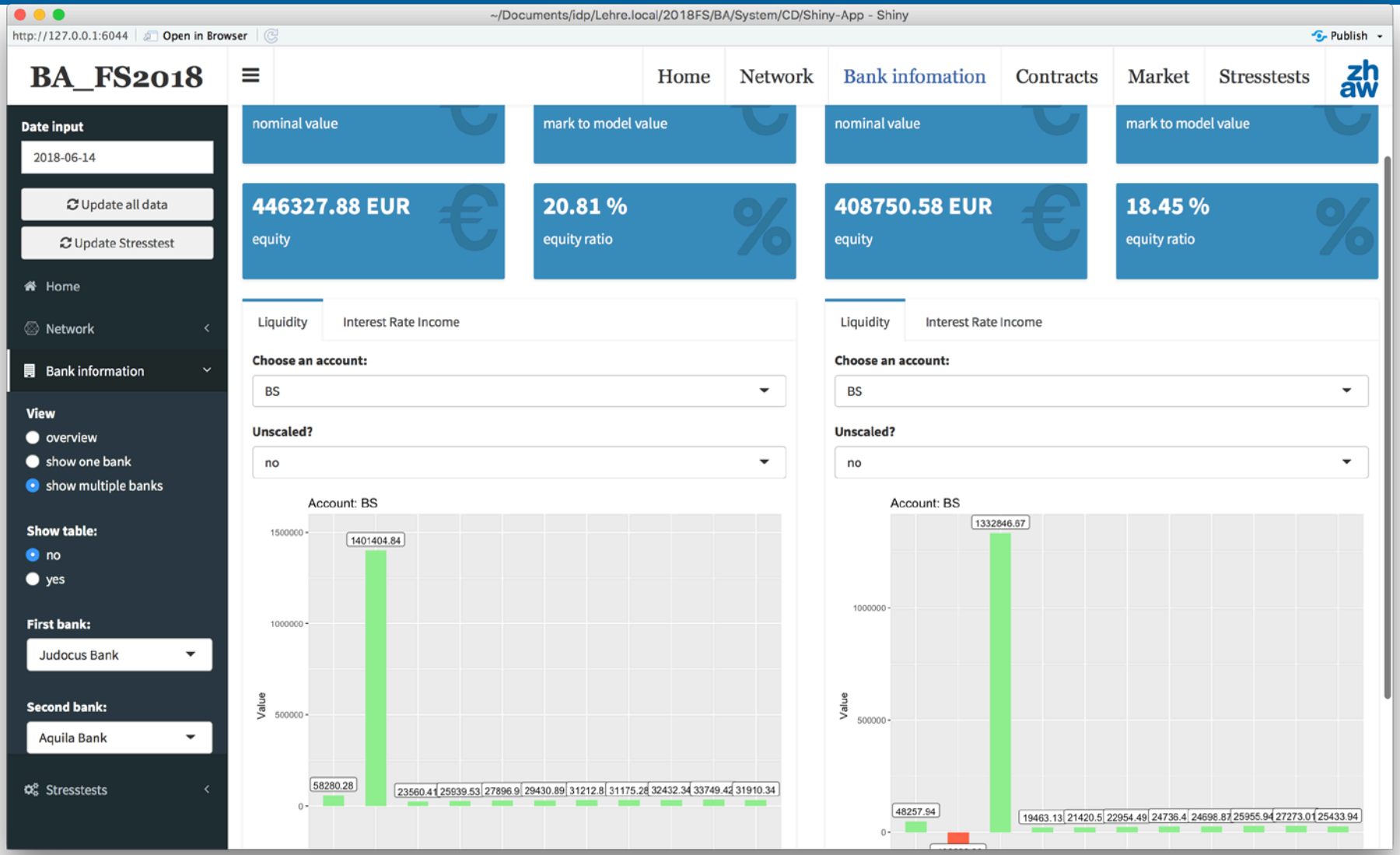

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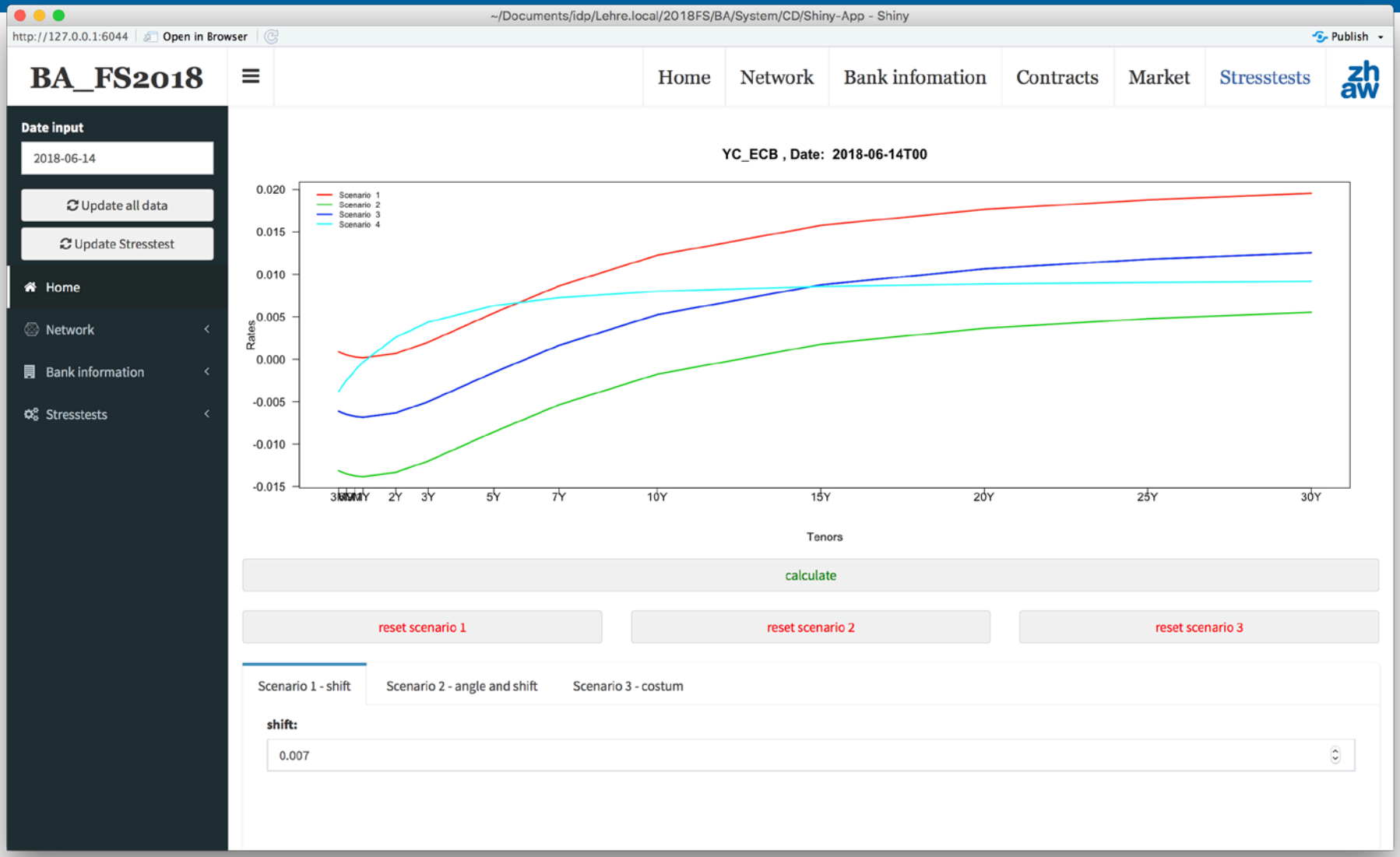

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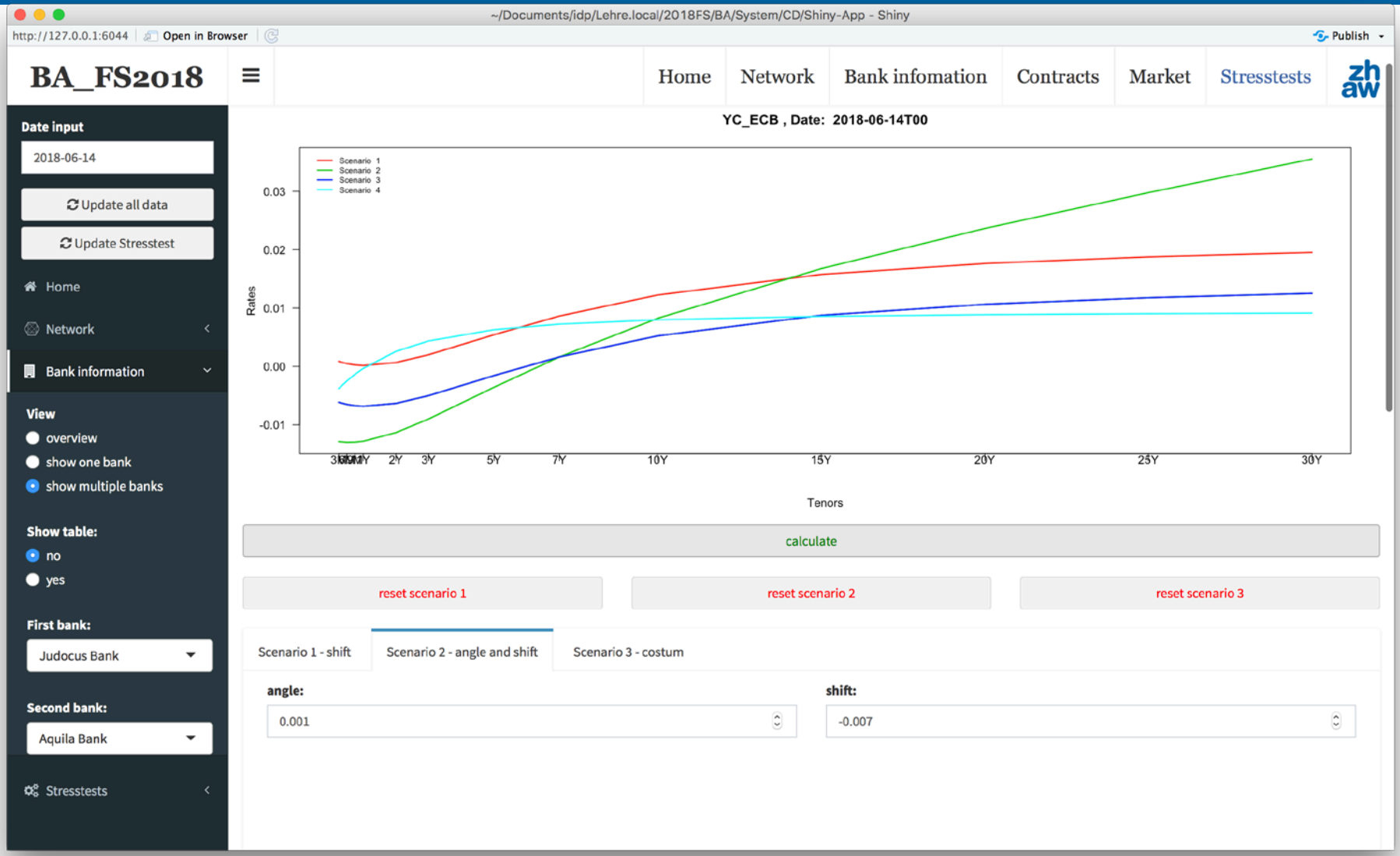

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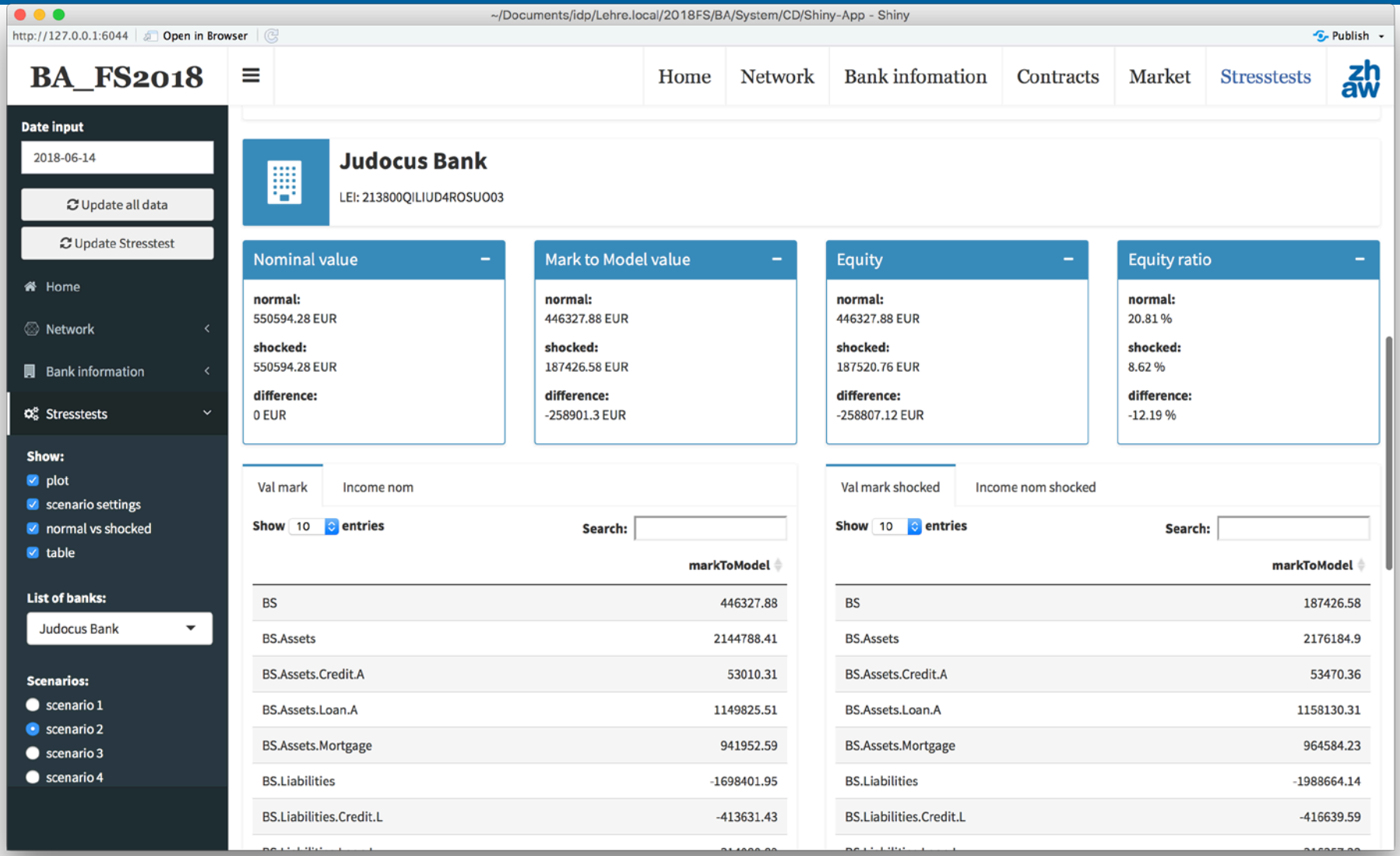

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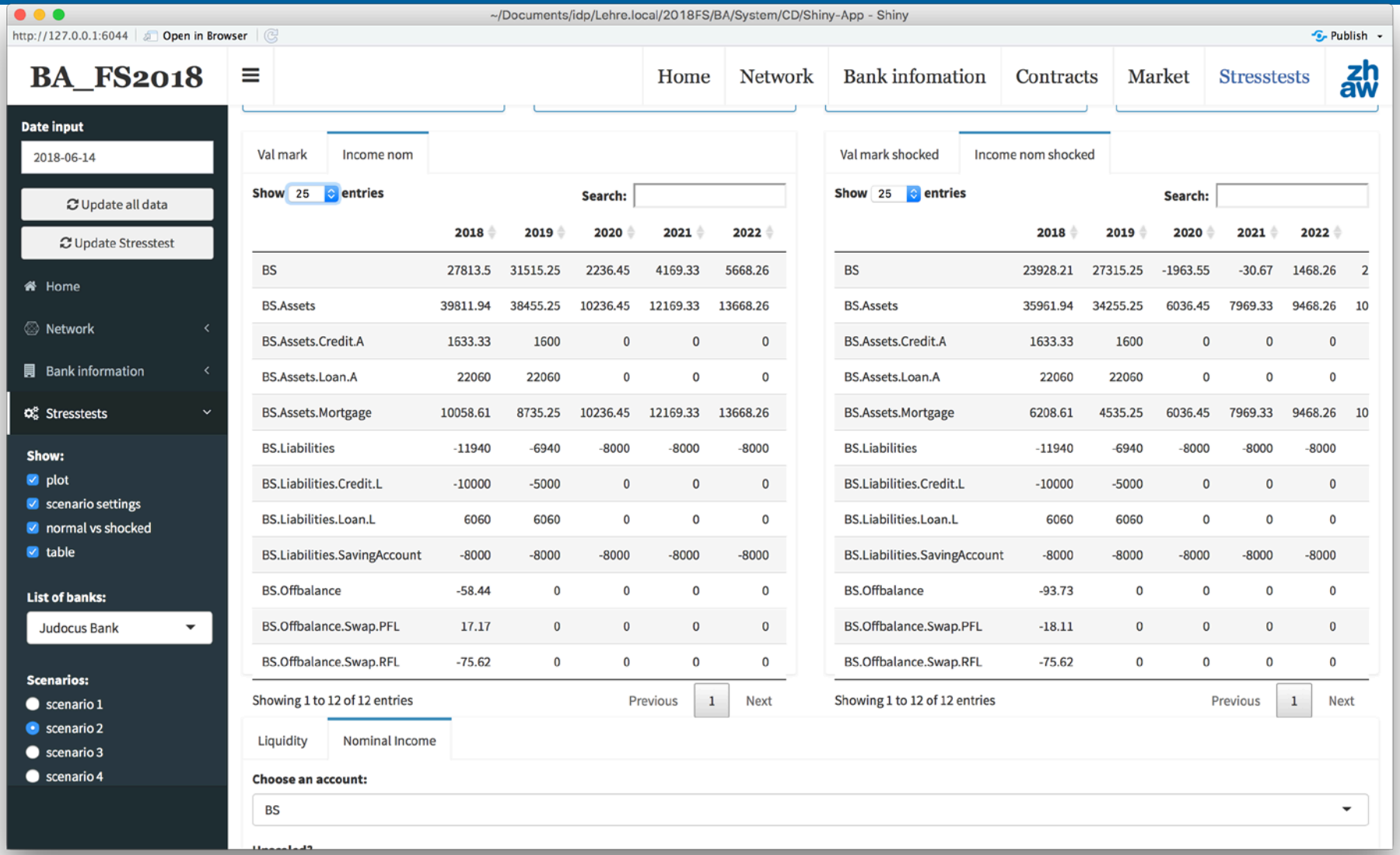

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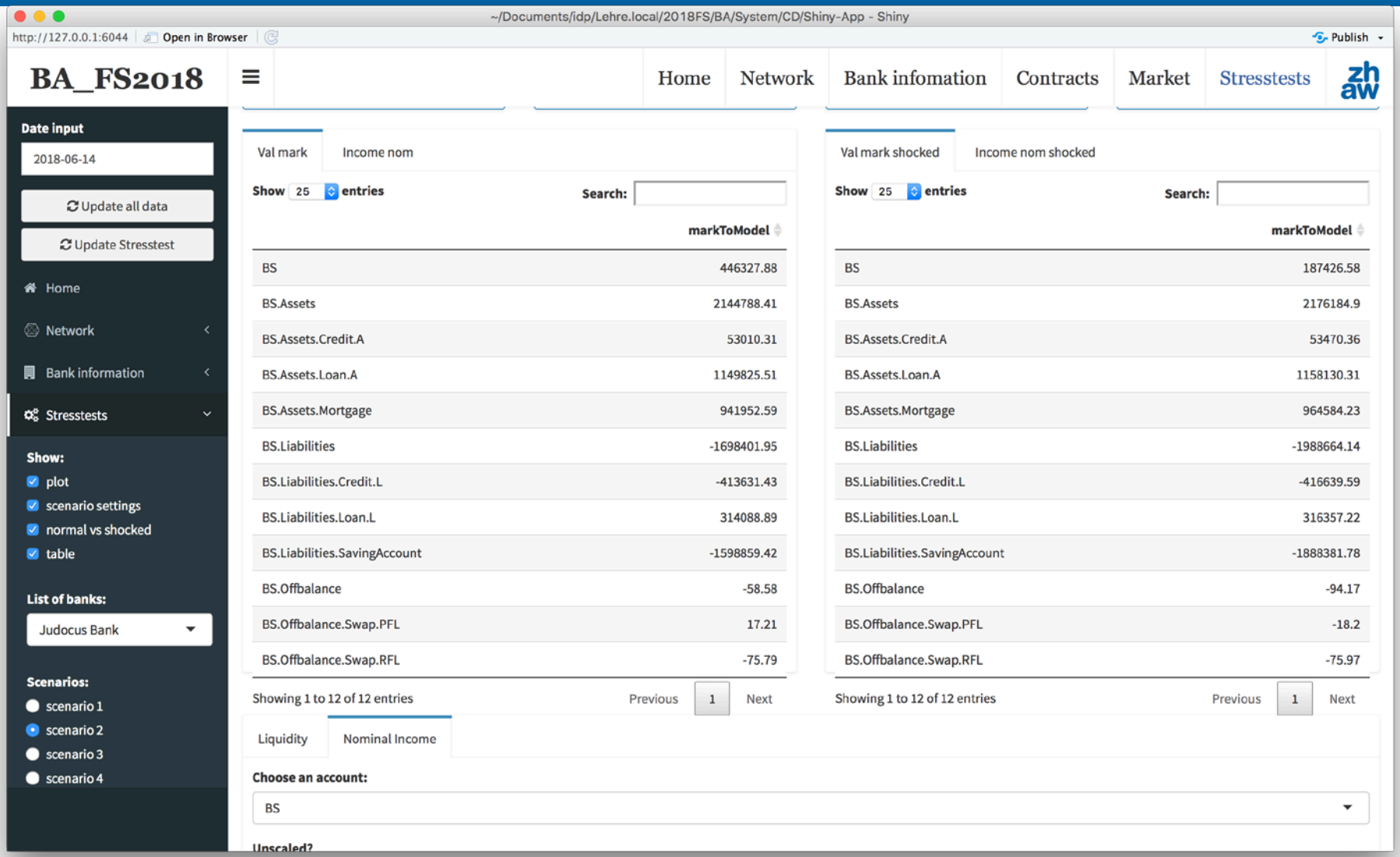

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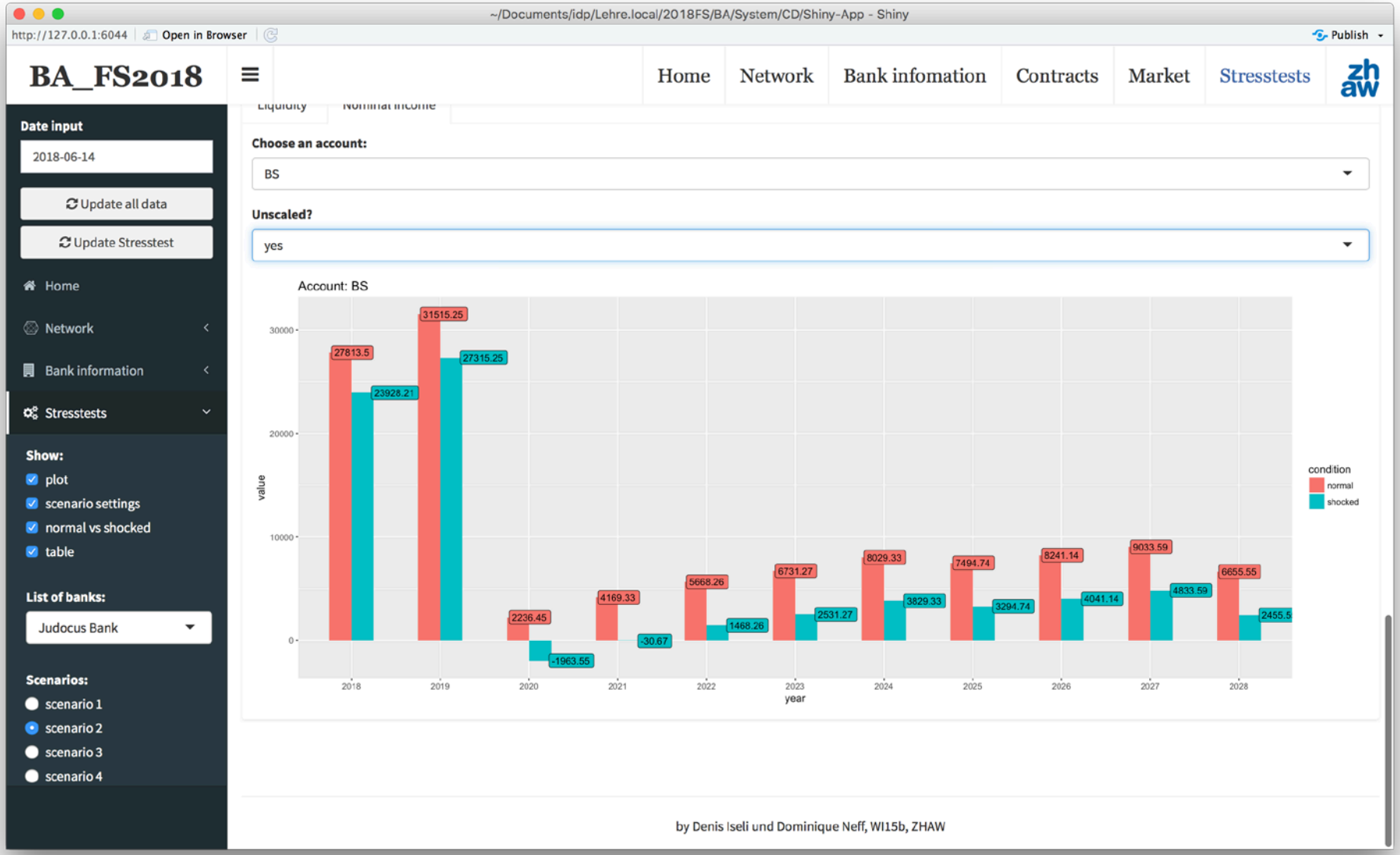

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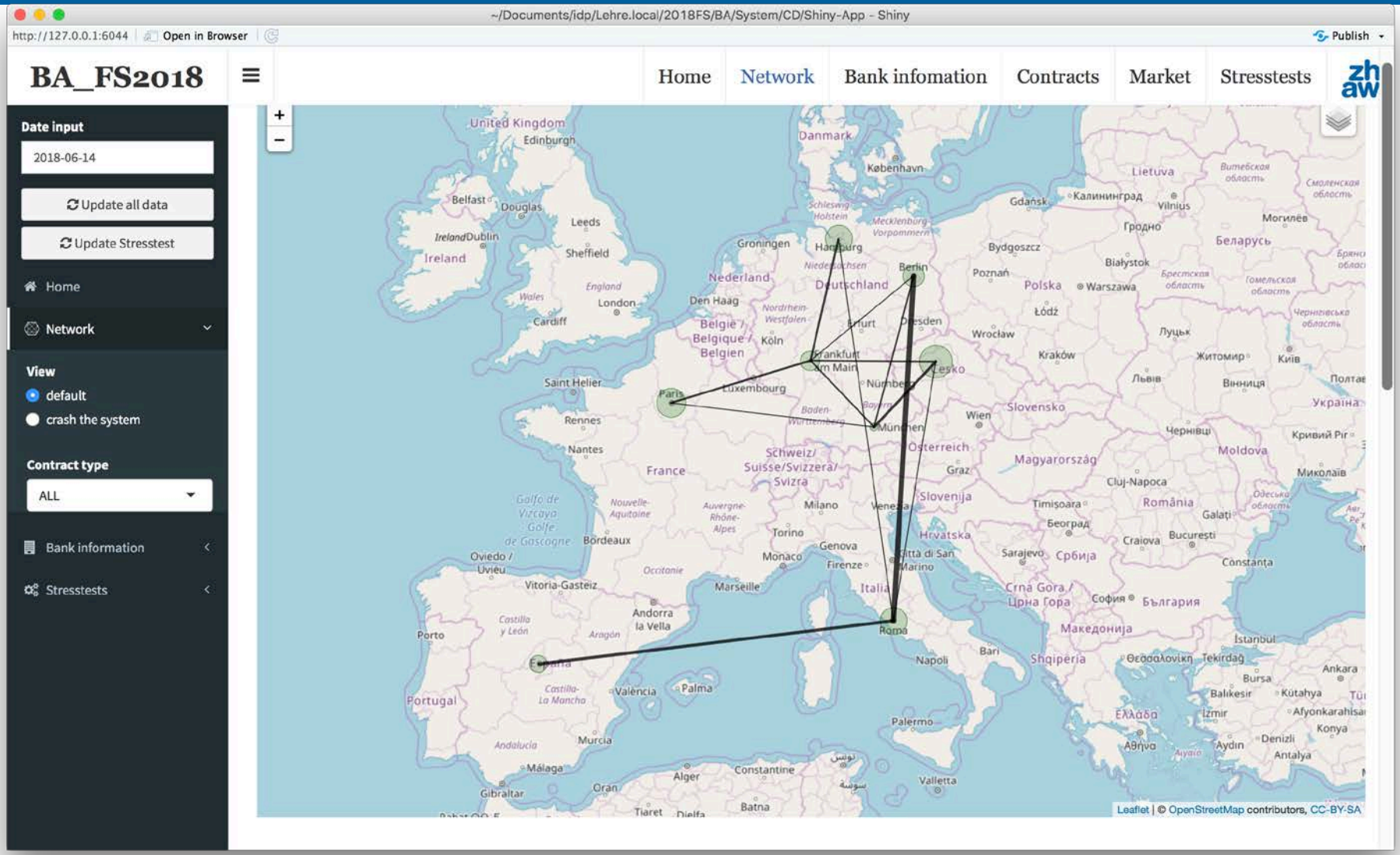

Financial Risk Demonstrator: Screenshots

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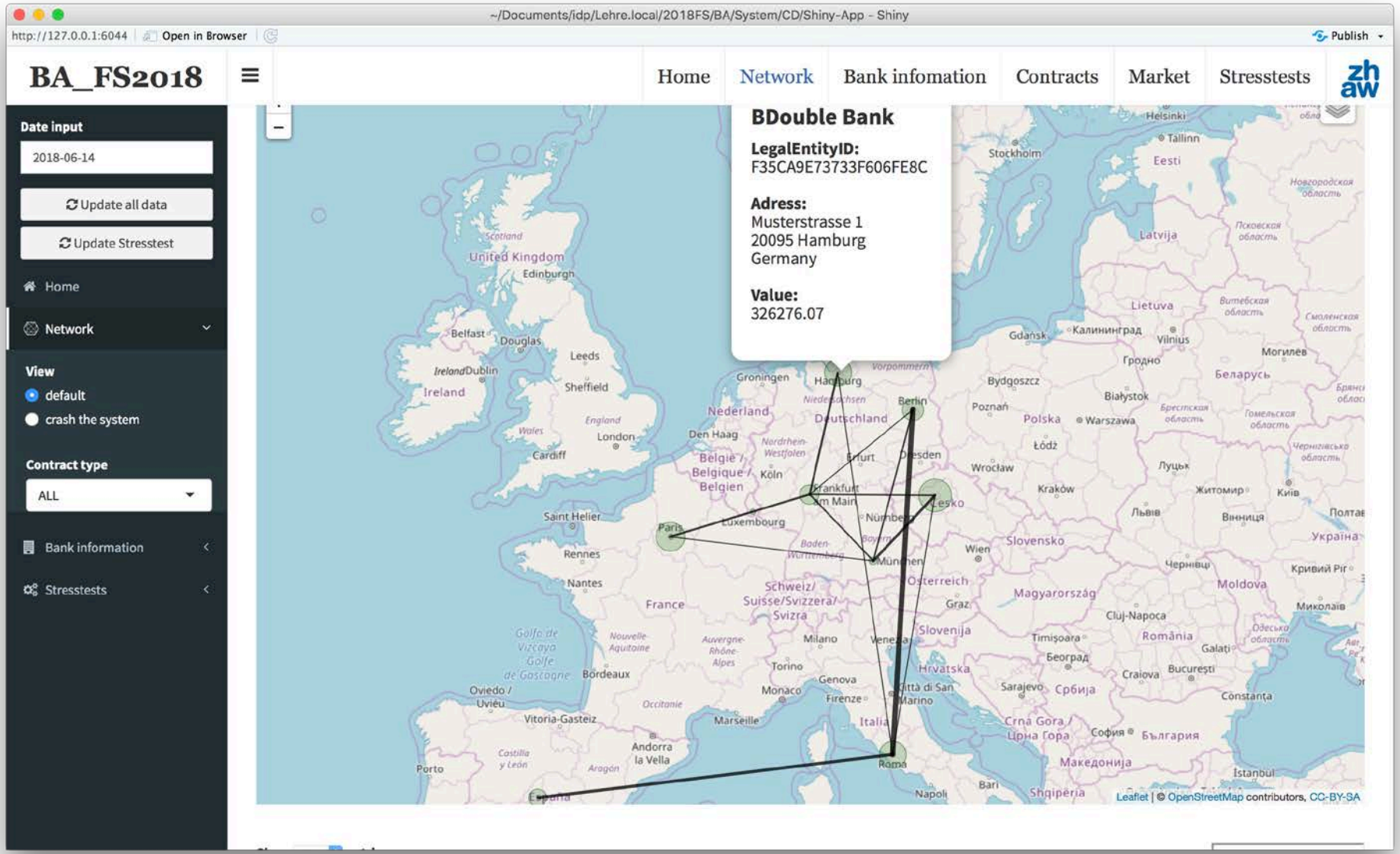

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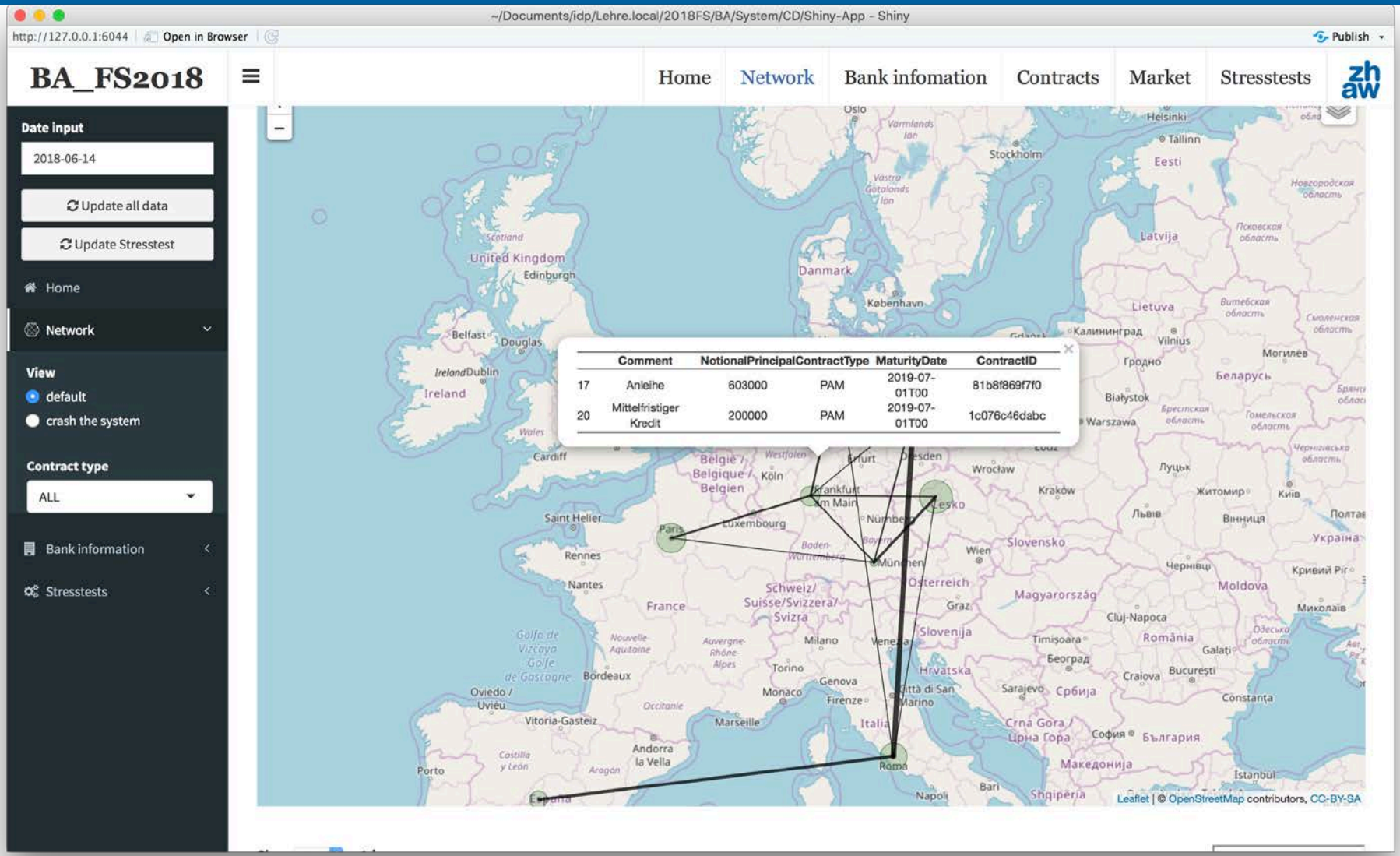

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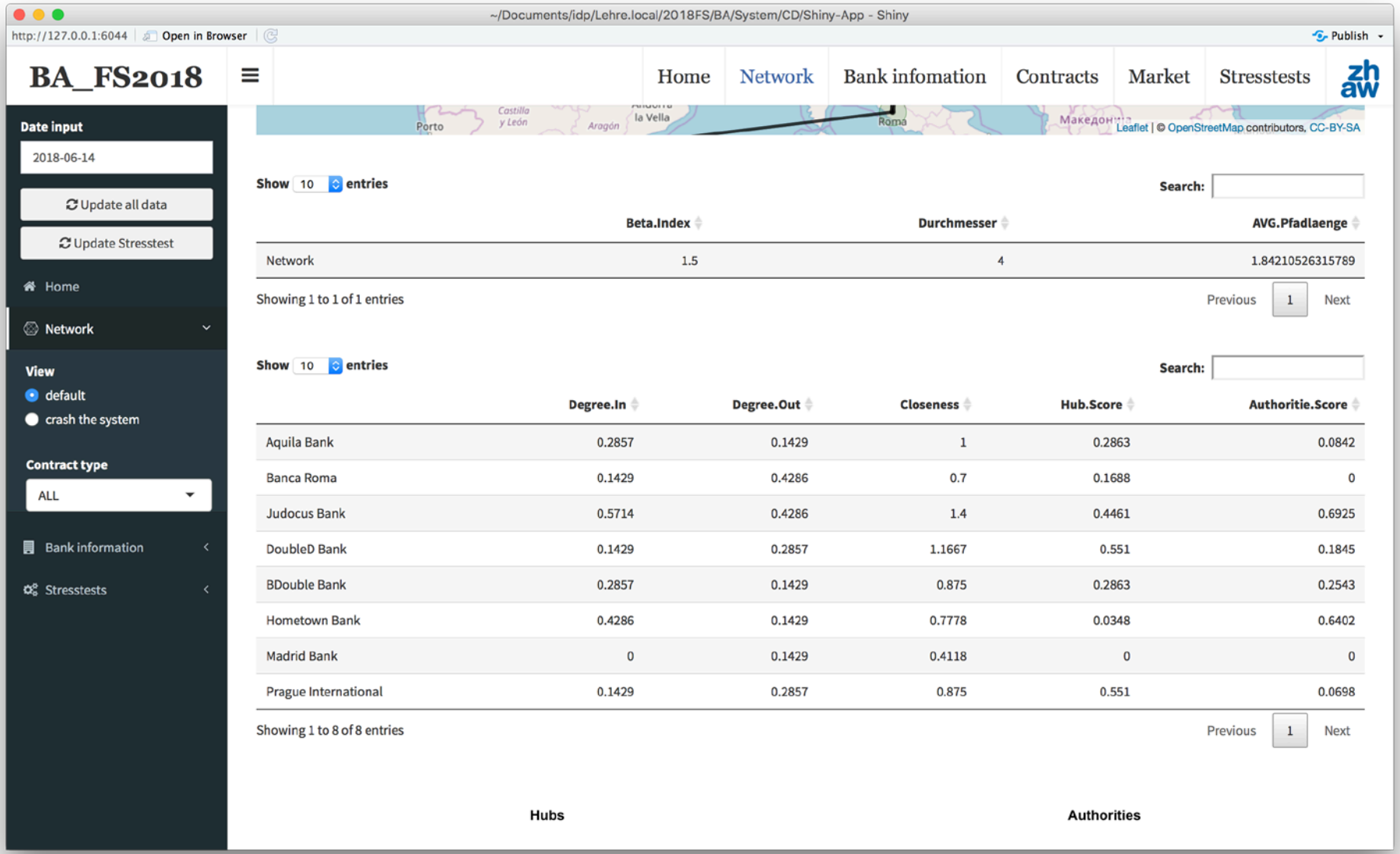

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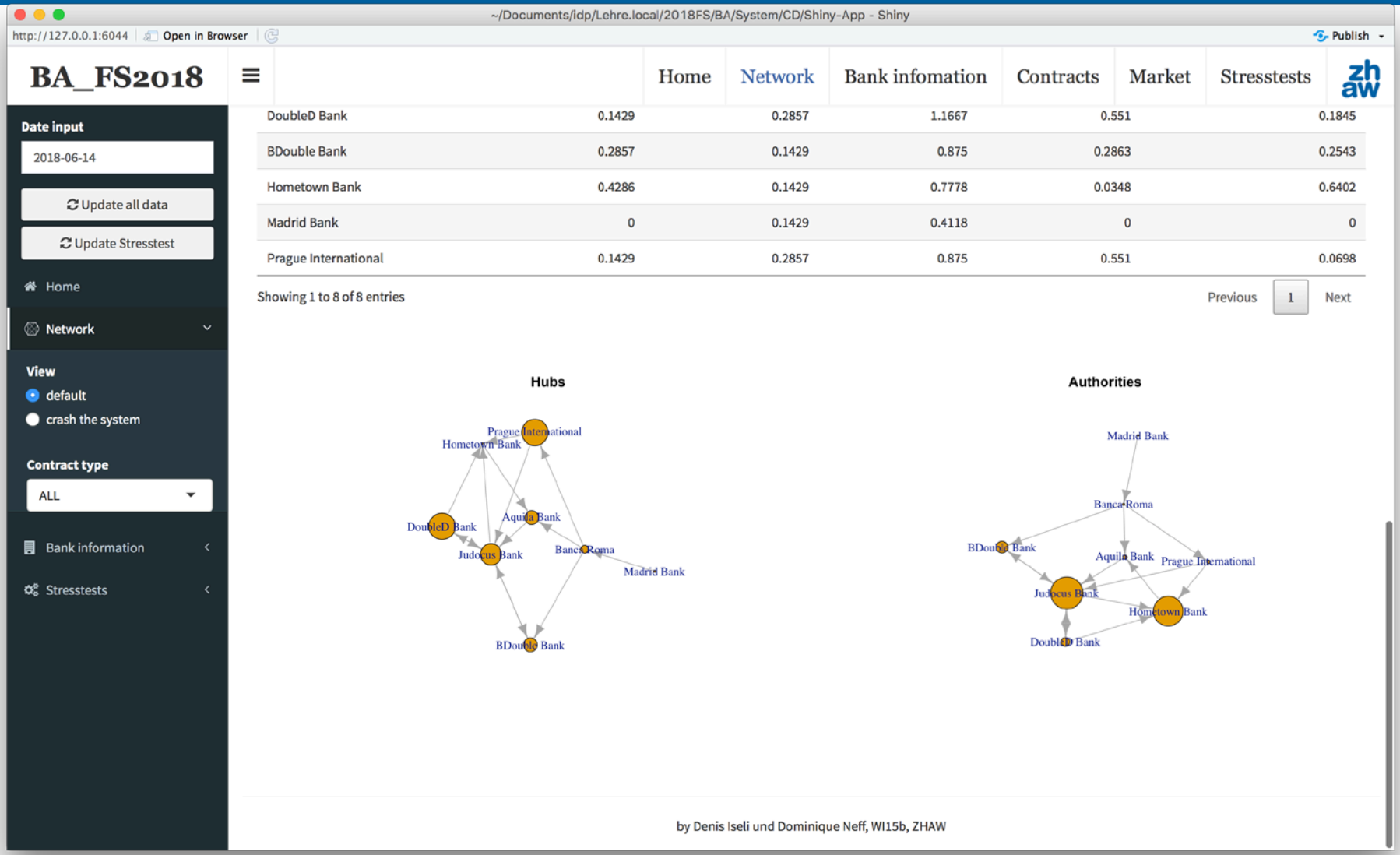

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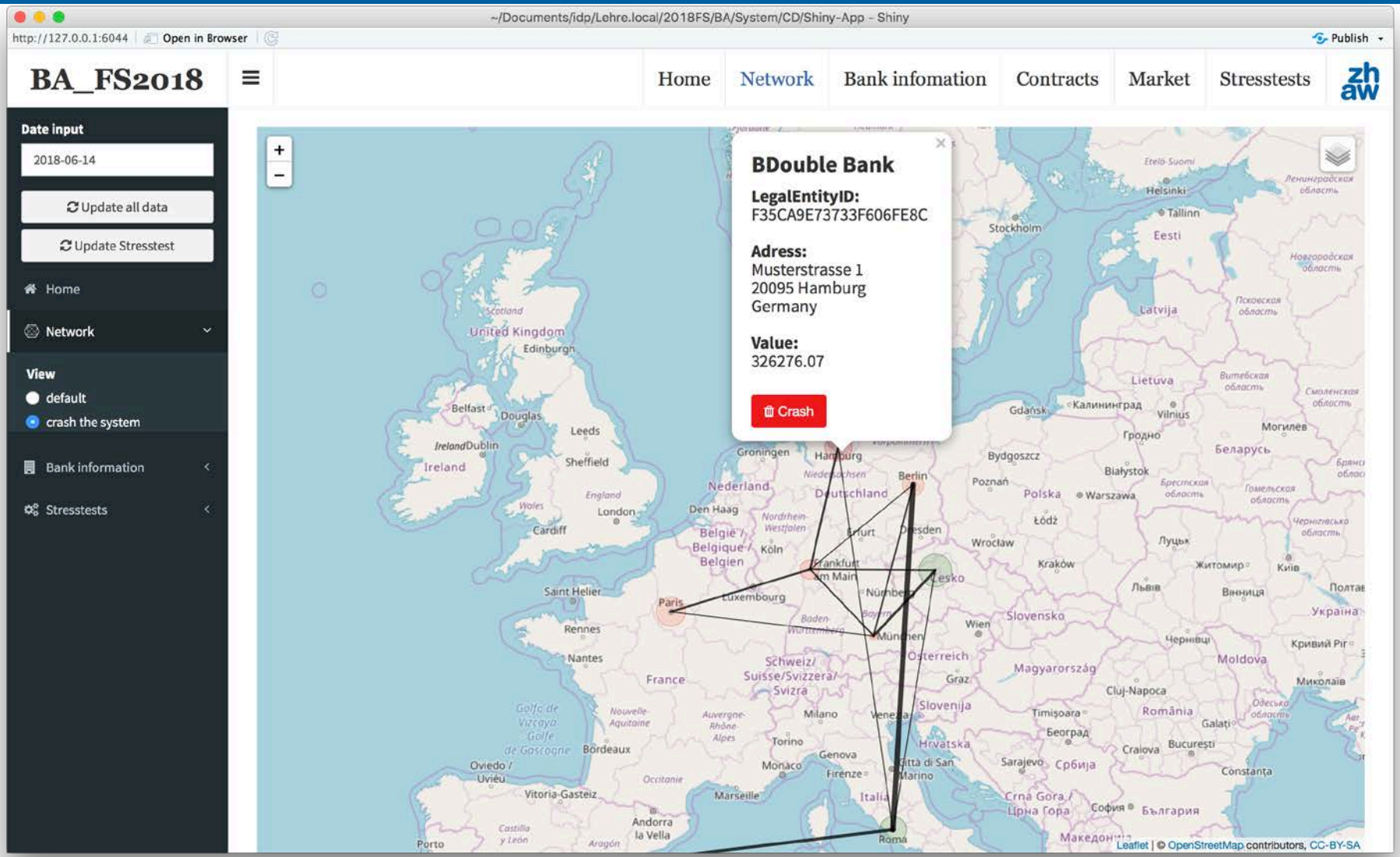

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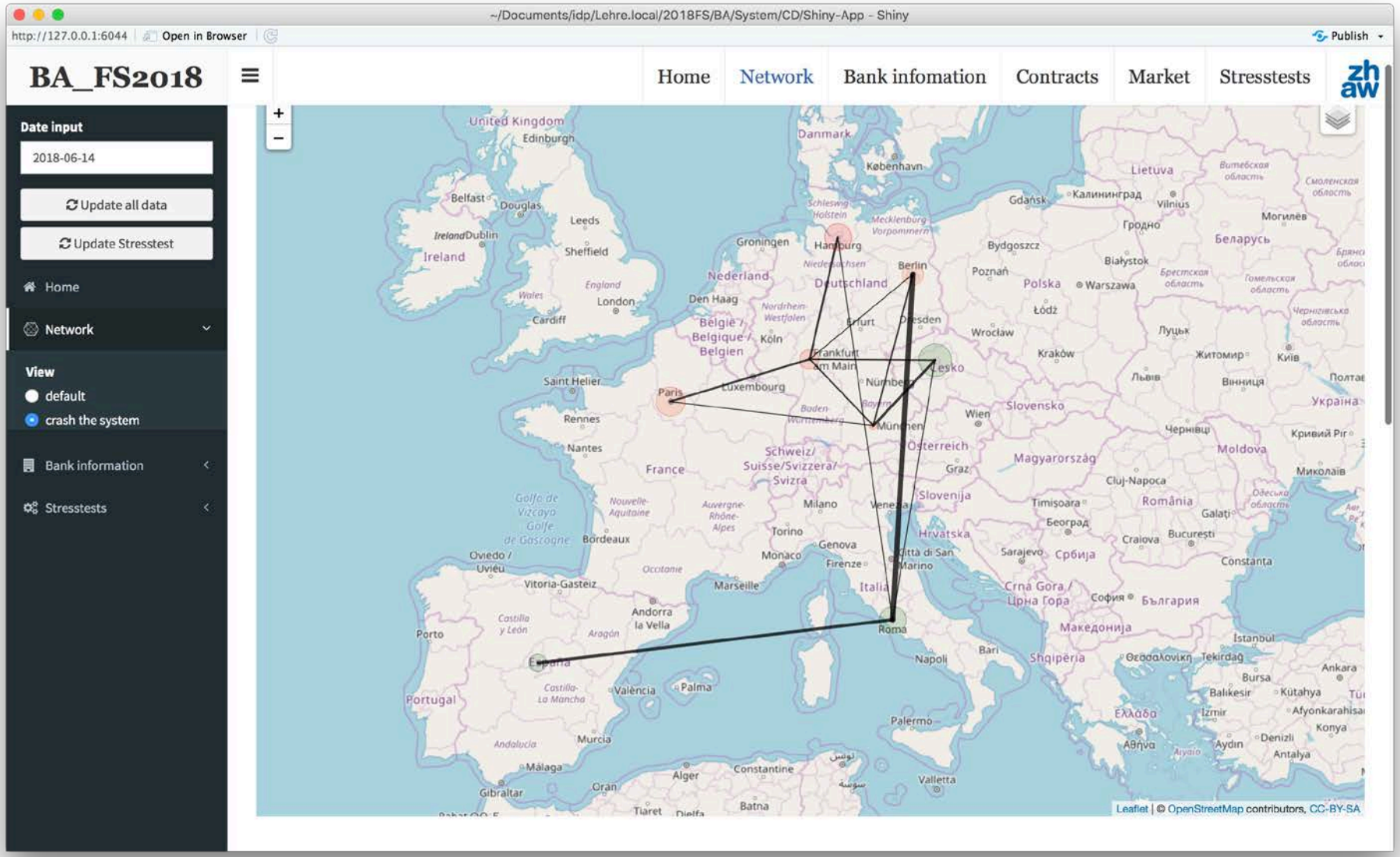

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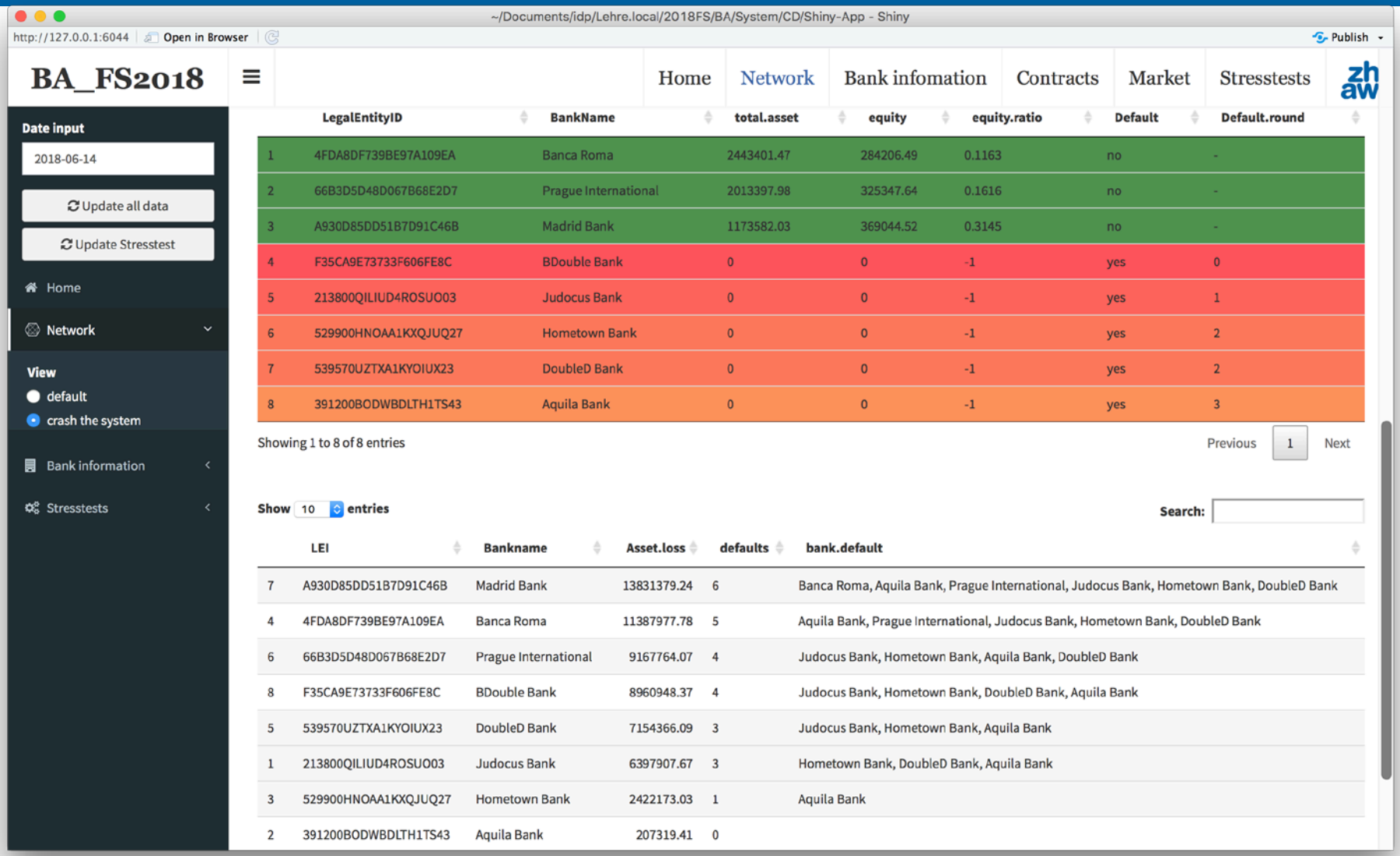

	LegalEntityID	BankName	total.asset	equity	equity.ratio	Default	Default.round
1	4FDA8DF739BE97A109EA	Banca Roma	2443401.47	284206.49	0.1163	no	-
2	66B3D5D48D067B68E2D7	Prague International	2013397.98	325347.64	0.1616	no	-
3	A930D85DD51B7D91C46B	Madrid Bank	1173582.03	369044.52	0.3145	no	-
4	F35CA9E73733F606FE8C	BDouble Bank	0	0	-1	yes	0
5	213800QILIUD4ROSUO03	Judocus Bank	0	0	-1	yes	1
6	529900HNOAA1KXQJUQ27	Hometown Bank	0	0	-1	yes	2
7	539570UZTXA1KYOIUX23	DoubleD Bank	0	0	-1	yes	2
8	391200BODWBDLTH1TS43	Aquila Bank	0	0	-1	yes	3

	LEI	Bankname	Asset.loss	defaults	bank.default
7	A930D85DD51B7D91C46B	Madrid Bank	13831379.24	6	Banca Roma, Aquila Bank, Prague International, Judocus Bank, Hometown Bank, DoubleD Bank
4	4FDA8DF739BE97A109EA	Banca Roma	11387977.78	5	Aquila Bank, Prague International, Judocus Bank, Hometown Bank, DoubleD Bank
6	66B3D5D48D067B68E2D7	Prague International	9167764.07	4	Judocus Bank, Hometown Bank, Aquila Bank, DoubleD Bank
8	F35CA9E73733F606FE8C	BDouble Bank	8960948.37	4	Judocus Bank, Hometown Bank, DoubleD Bank, Aquila Bank
5	539570UZTXA1KYOIUX23	DoubleD Bank	7154366.09	3	Judocus Bank, Hometown Bank, Aquila Bank
1	213800QILIUD4ROSUO03	Judocus Bank	6397907.67	3	Hometown Bank, DoubleD Bank, Aquila Bank
3	529900HNOAA1KXQJUQ27	Hometown Bank	2422173.03	1	Aquila Bank
2	391200BODWBDLTH1TS43	Aquila Bank	207319.41	0	

Summary – Conclusion

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- An R interface to the ACTUS library has been created that makes it possible to use ACTUS contracts in R.
- This provides a convenient means to become acquainted and experiment with the ACTUS library.
- This tool is also used in our Bachelor studies.
- A visual demonstrator has been build by two students during their Bachelor's thesis.
- This demonstrator models a system of eight simple banks and allows to carry out stress tests and simple systemic analysis.
- The demonstrator will be extended and its performance enhanced in a project for and with ECB that is about to start.
- The ACTUS website: http://actusfrf.org