notebook-experiment-liquidation-ratio

February 10, 2021

1 Experiment Analysis: The effect of liquidation ratio and price rescaling

Analyse the effect of setting the parameters `rescale_target_price` and `arbitrageur_considers_liquidation_ratio` to false.

- See `experiments/system_model_v3/experiment_liquidation_ratio.py`

2 Setup and Dependencies

[1]:
```
# Set project root folder, to enable importing project files from subdirectories
from pathlib import Path
import os

path = Path().resolve()
root_path = str(path).split('notebooks')[0]
os.chdir(root_path)

# Force reload of project modules, sometimes necessary for Jupyter kernel
%load_ext autoreload
%autoreload 2

# Display framework versions for easy debugging
%pip show cadCAD
%pip show radcad
```

```
Name: cadCAD
Version: 0.4.23
Summary: cadCAD: a differential games based simulation software package for
research, validation, and         Computer Aided Design of economic systems
Home-page: https://github.com/cadCAD-org/cadCAD
Author: Joshua E. Jodesty
Author-email: joshua@block.science
License: LICENSE.txt
Location: /home/bscholtz/workspace/reflexer/venv/lib/python3.8/site-packages
Requires: fn, funcy, pandas, pathos
Required-by:
```

```
Note: you may need to restart the kernel to use updated packages.
Name: radcad
Version: 0.5.4
Summary: A cadCAD implementation, for dynamical systems modelling & simulation
Home-page: None
Author: Benjamin Scholtz
Author-email: ben@bitsofether.com
License: None
Location: /home/bscholtz/workspace/reflexer/venv/lib/python3.8/site-packages
Requires: pathos, ray, pandas, boto3, tables
Required-by:
Note: you may need to restart the kernel to use updated packages.
```

[2]:
```
# Import all shared dependencies and setup
from shared import *

import plotly.express as px
import plotly.graph_objects as go
from plotly.subplots import make_subplots
# import plotly.io as pio
# pio.renderers.default = "png"
from pprint import pprint
```

[3]:
```
# Update dataframe display settings
pd.set_option('display.max_columns', 100)
pd.set_option('display.max_rows', 50)
```

3 Load Results

Using the experiment logs, select the experiment of interest from the specific HDF5 store file (these datasets are very large, and won't be committed to repo):

[4]:
```
# experiment_results = 'experiments/system_model_v3/experiment_controller_sweep/
 ↪experiment_results.hdf5'
experiment_results = 'experiments/system_model_v3/experiment_liquidation_ratio/
 ↪experiment_results.hdf5'
```

[5]:
```
experiment_results_keys = []
with pd.HDFStore(experiment_results) as store:
    experiment_results_keys = list(filter(lambda x: "results" in x, store.
 ↪keys()))
    exceptions_keys = list(filter(lambda x: "exceptions" in x, store.keys()))
```

[6]:
```
# A list of all experiment result keys
experiment_results_keys
```

[6]:
```
['/results_2021-02-09T22:02:18.259338', '/results_2021-02-09T23:51:42.952840']
```

[7]:
```
# A list of all experiment result exception keys
exceptions_keys
```

[7]:
```
['/exceptions_2021-02-09T22:02:18.259338',
 '/exceptions_2021-02-09T23:51:42.952840']
```

[8]:
```
# Copy a results_ key from the above keys to select the experiment
experiment_results_key = 'results_2021-02-09T23:51:42.952840' # Or select last␣
↪result: experiment_results_keys[-1]
experiment_timestamp = experiment_results_key.strip('results_')
exceptions_key = 'exceptions_' + experiment_timestamp
experiment_timestamp
```

[8]:
```
'2021-02-09T23:51:42.952840'
```

[9]:
```
df_raw = pd.read_hdf(experiment_results, experiment_results_key)
df_raw.tail()
```

[9]:

	cdp_metrics	optimal_values	sim_metrics	timedelta	cumulative_time	timestamp	blockheight
3732619	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…	{}	{}	3600	5184000	2017-03-02	0
3732620	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…	{}	{}	3600	5184000	2017-03-02	0
3732621	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…	{}	{}	3600	5184000	2017-03-02	0
3732622	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…	{}	{}	3600	5184000	2017-03-02	0
3732623	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…	{}	{}	3600	5184000	2017-03-02	0

	eth_price	liquidity_demand	liquidity_demand_mean	cdps	eth_collateral
3732619	300.0	-0.0	0.0	open time locked drawn …	69768.4181
3732620	300.0	-0.0	0.0	open time locked drawn …	69768.4181
3732621	300.0	-0.0	0.0	open time locked drawn …	69768.4181
3732622	300.0	-0.0	0.0	open time locked drawn …	69768.4181
3732623	300.0	-0.0	0.0	open time locked drawn …	69768.4181

	eth_locked	eth_freed	eth_bitten	principal_debt

```
3732619  154827.528922  85059.110822         0.0    2.238129e+07
3732620  154827.528922  85059.110822         0.0    2.238129e+07
3732621  154827.528922  85059.110822         0.0    2.238129e+07
3732622  154827.528922  85059.110822         0.0    2.238129e+07
3732623  154827.528922  85059.110822         0.0    2.238129e+07

           rai_drawn     rai_wiped  rai_bitten  accrued_interest  \
3732619  3.769353e+07  1.531225e+07         0.0      16159.356162
3732620  3.769354e+07  1.531225e+07         0.0      16159.356162
3732621  3.769354e+07  1.531225e+07         0.0      16159.356162
3732622  3.769354e+07  1.531225e+07         0.0      16159.356162
3732623  3.769354e+07  1.531225e+07         0.0      16159.356162

         interest_dripped  interest_wiped  interest_bitten       w_1  w_2  \
3732619                 0               0                0  0.000002  0.0
3732620                 0               0                0  0.000002  0.0
3732621                 0               0                0  0.000002  0.0
3732622                 0               0                0  0.000002  0.0
3732623                 0               0                0  0.000002  0.0

         w_3  system_revenue  stability_fee  market_price  market_price_twap  \
3732619  0.0             0.0   1.585490e-10       0.64498           0.644982
3732620  0.0             0.0   1.585490e-10       0.64498           0.644982
3732621  0.0             0.0   1.585490e-10       0.64498           0.644982
3732622  0.0             0.0   1.585490e-10       0.64498           0.644982
3732623  0.0             0.0   1.585490e-10       0.64498           0.644982

         target_price   target_rate  eth_return  eth_gross_return  \
3732619      0.644951 -5.013736e-11         0.0               1.0
3732620      0.644951 -5.013736e-11         0.0               1.0
3732621      0.644951 -5.013736e-11         0.0               1.0
3732622      0.644951 -5.013736e-11         0.0               1.0
3732623      0.644951 -5.013736e-11         0.0               1.0

         expected_market_price  expected_debt_price  error_star  \
3732619                0.66378                 3.14    -0.00003
3732620                0.66378                 3.14    -0.00003
3732621                0.66378                 3.14    -0.00003
3732622                0.66378                 3.14    -0.00003
3732623                0.66378                 3.14    -0.00003

         error_star_integral  market_slippage   RAI_balance   ETH_balance  \
3732619          -5449.108542     3.648923e-07  2.238129e+07  48118.243496
3732620          -5449.108542     3.648923e-07  2.238129e+07  48118.243496
3732621          -5449.108542     3.648923e-07  2.238129e+07  48118.243496
3732622          -5449.108542     3.648923e-07  2.238129e+07  48118.243496
3732623          -5449.108542     3.648923e-07  2.238129e+07  48118.243496
```

```
         UNI_supply                                        uniswap_oracle  \
3732619  10000000.0  <models.system_model_v3.model.parts.uniswap_or…
3732620  10000000.0  <models.system_model_v3.model.parts.uniswap_or…
3732621  10000000.0  <models.system_model_v3.model.parts.uniswap_or…
3732622  10000000.0  <models.system_model_v3.model.parts.uniswap_or…
3732623  10000000.0  <models.system_model_v3.model.parts.uniswap_or…

         simulation  subset  run  substep  timestep  events
3732619           0      35    4       14      1440     NaN
3732620           0      35    4       15      1440     NaN
3732621           0      35    4       16      1440     NaN
3732622           0      35    4       17      1440     NaN
3732623           0      35    4       18      1440     NaN
```

Get experiment exceptions, tracebacks, and simulation metadata for further analysis:

[10]:
```
exceptions_df = pd.read_hdf(experiment_results, exceptions_key)
exceptions_df.head()
```

[10]:
```
  exception traceback  simulation  run  subset  timesteps  \
0      None      None           0    0       0       1440
1      None      None           0    0       1       1440
2      None      None           0    0       2       1440
3      None      None           0    0       3       1440
4      None      None           0    0       4       1440

                                          parameters  \
0  {"0":{"debug":false,"raise_on_assert":true,"fr…
1  {"0":{"debug":false,"raise_on_assert":true,"fr…
2  {"0":{"debug":false,"raise_on_assert":true,"fr…
3  {"0":{"debug":false,"raise_on_assert":true,"fr…
4  {"0":{"debug":false,"raise_on_assert":true,"fr…

                                       initial_state
0  {'cdp_metrics': {}, 'optimal_values': {}, 'sim…
1  {'cdp_metrics': {}, 'optimal_values': {}, 'sim…
2  {'cdp_metrics': {}, 'optimal_values': {}, 'sim…
3  {'cdp_metrics': {}, 'optimal_values': {}, 'sim…
4  {'cdp_metrics': {}, 'optimal_values': {}, 'sim…
```

[11]:
```
# Print the first 5 exceptions - indicating failed simulations
pprint(list(exceptions_df['exception'])[:5])
```

```
[None, None, None, None, None]
```

4 Post Process Results

[12]:
```
from experiments.system_model_v3.post_process import post_process_results
from experiments.system_model_v3.experiment_liquidation_ratio import params,␣
↪SIMULATION_TIMESTEPS
```

```
* Number of timesteps: 1440 / 60.0 days
* Number of MC runs: 4
* Timestep duration: 0.004 seconds
* Control parameters: ['kp', 'ki', 'rescale_target_price',
'arbitrageur_considers_liquidation_ratio']
* Number of parameter combinations: 36
* Expected experiment duration: 13.824000000000002 minutes / 0.23040000000000002
hours
```

Remove substeps, add `set_params` to dataframe, and add post-processing columns:

[13]:
```
df = post_process_results(df_raw, params, set_params=['ki', 'kp',␣
↪'liquidation_ratio', 'rescale_target_price',␣
↪'arbitrageur_considers_liquidation_ratio'])
df
```

[13]:

	index	cdp_metrics	…	optimal_values	sim_metrics	timedelta	cumulative_time
0	0	{}		{}	{}	0	0
1	18	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	3600
2	36	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	7200
3	54	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	10800
4	72	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	14400
…	…	…	…	…	…	…	…
207499	3732551	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	5169600
207500	3732569	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	5173200
207501	3732587	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	5176800
207502	3732605	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…		{}	{}	3600	5180400
207503	3732623	{'cdp_count': 1, 'open_cdp_count': 1, 'closed_…					

```
207503             {}          {}       3600          5184000

                timestamp  blockheight   eth_price  liquidity_demand  \
0      2017-01-01 00:00:00            0  294.069151               1.0
1      2017-01-01 01:00:00            0  300.000000               0.0
2      2017-01-01 02:00:00            0  300.000000              -0.0
3      2017-01-01 03:00:00            0  300.000000               0.0
4      2017-01-01 04:00:00            0  300.000000              -0.0
…                      …          …         …               …
207499 2017-03-01 20:00:00            0  300.000000               0.0
207500 2017-03-01 21:00:00            0  300.000000               0.0
207501 2017-03-01 22:00:00            0  300.000000              -0.0
207502 2017-03-01 23:00:00            0  300.000000               0.0
207503 2017-03-02 00:00:00            0  300.000000              -0.0

        liquidity_demand_mean  \
0                      1.0000
1                      0.5000
2                      0.2500
3                      0.1250
4                      0.0625
…                       …
207499                 0.0000
207500                 0.0000
207501                 0.0000
207502                 0.0000
207503                 0.0000

                                                    cdps  eth_collateral  \
0                                                   None   154827.528922
1                                                   None   154827.528922
2                                                   None   105925.122117
3                                                   None   105925.122117
4                                                   None   105925.122117
…                                                    …              …
207499                                              None    69768.418100
207500                                              None    69768.418100
207501                                              None    69768.418100
207502     open  time         locked         drawn    …    69768.418100
207503     open  time         locked         drawn    …    69768.418100

           eth_locked     eth_freed  eth_bitten  principal_debt     rai_drawn  \
0       154827.528922      0.000000         0.0    1.000000e+07  1.000000e+07
1       154827.528922      0.000000         0.0    1.450000e+07  1.450000e+07
2       154827.528922  48902.406805         0.0    1.012023e+07  1.450000e+07
3       154827.528922  48902.406805         0.0    1.012023e+07  1.450000e+07
4       154827.528922  48902.406805         0.0    1.012023e+07  1.450000e+07
```

```
…                …            …          …                …             …
207499  154827.528922  85059.110822        0.0    2.238127e+07  3.769352e+07
207500  154827.528922  85059.110822        0.0    2.238128e+07  3.769352e+07
207501  154827.528922  85059.110822        0.0    2.238128e+07  3.769353e+07
207502  154827.528922  85059.110822        0.0    2.238129e+07  3.769353e+07
207503  154827.528922  85059.110822        0.0    2.238129e+07  3.769354e+07

           rai_wiped  rai_bitten  accrued_interest  interest_dripped  \
0       0.000000e+00         0.0          0.000000                 0
1       0.000000e+00         0.0          5.707764                 0
2       4.379765e+06         0.0         11.484158                 0
3       4.379765e+06         0.0         17.260556                 0
4       4.379765e+06         0.0         23.036956                 0
…                …          …                 …                 …
207499  1.531225e+07         0.0      16108.220517                 0
207500  1.531225e+07         0.0      16121.004414                 0
207501  1.531225e+07         0.0      16133.788320                 0
207502  1.531225e+07         0.0      16146.572236                 0
207503  1.531225e+07         0.0      16159.356162                 0

        interest_wiped  interest_bitten           w_1  w_2  w_3  \
0                    0                0  0.000000e+00  0.0  0.0
1                    0                0  8.276258e+00  0.0  0.0
2                    0                0  4.723892e-06  0.0  0.0
3                    0                0  2.696510e-12  0.0  0.0
4                    0                0  0.000000e+00  0.0  0.0
…                  …                …             …  …  …
207499               0                0  2.363668e-06  0.0  0.0
207500               0                0  2.363669e-06  0.0  0.0
207501               0                0  2.334199e-06  0.0  0.0
207502               0                0  2.334199e-06  0.0  0.0
207503               0                0  2.334200e-06  0.0  0.0

        system_revenue  stability_fee  market_price  market_price_twap  \
0                  0.0   1.585490e-10      3.140000           0.000000
1                  0.0   1.585490e-10      3.140000           0.000000
2                  0.0   1.585490e-10      1.525000           0.000000
3                  0.0   1.585490e-10      3.133425           0.000000
4                  0.0   1.585490e-10      3.133425           0.000000
…                  …              …             …                  …
207499             0.0   1.585490e-10      0.644981           0.644982
207500             0.0   1.585490e-10      0.644980           0.644982
207501             0.0   1.585490e-10      0.644980           0.644982
207502             0.0   1.585490e-10      0.644980           0.644982
207503             0.0   1.585490e-10      0.644980           0.644982

        target_price   target_rate  eth_return  eth_gross_return  \
```

```
0           3.140000  0.000000e+00    0.000000              0.0
1           2.165517  0.000000e+00    0.020168              1.0
2           2.165517  0.000000e+00    0.000000              1.0
3           2.165517  0.000000e+00    0.000000              1.0
4           2.165517  0.000000e+00    0.000000              1.0
…              …           …          …                 …
207499      0.644952 -5.139649e-11    0.000000              1.0
207500      0.644952 -5.075558e-11    0.000000              1.0
207501      0.644952 -5.075558e-11    0.000000              1.0
207502      0.644951 -5.075558e-11    0.000000              1.0
207503      0.644951 -5.013736e-11    0.000000              1.0

        expected_market_price  expected_debt_price  error_star  \
0                    3.140000                 3.14    0.000000
1                    3.231683                 3.14    3.140000
2                    1.569093                 3.14    3.140000
3                    3.224303                 3.14    3.140000
4                    3.224444                 3.14    3.140000
…                       …                    …          …
207499               0.663780                 3.14   -0.000030
207500               0.663780                 3.14   -0.000031
207501               0.663780                 3.14   -0.000030
207502               0.663780                 3.14   -0.000030
207503               0.663780                 3.14   -0.000030

        error_star_integral  market_slippage   RAI_balance    ETH_balance  \
0                  0.000000     0.000000e+00  1.000000e+07  106777.606153
1               5652.000000     0.000000e+00  1.450000e+07   73708.353400
2              16932.000000     5.143311e-01  1.012023e+07  105703.331685
3              28166.000000    -1.054705e+00  1.012023e+07  105703.331685
4              39354.000000     0.000000e+00  1.012023e+07  105703.331685
…                     …              …            …             …
207499         -5541.109474     3.694992e-07  2.238127e+07   48118.278670
207500         -5518.109904     3.694992e-07  2.238128e+07   48118.269794
207501         -5495.109012     3.694992e-07  2.238128e+07   48118.261028
207502         -5472.108117     3.648923e-07  2.238129e+07   48118.252262
207503         -5449.108542     3.648923e-07  2.238129e+07   48118.243496

        UNI_supply                                        uniswap_oracle  \
0       10000000.0                                                  None
1       10000000.0                                                  None
2       10000000.0                                                  None
3       10000000.0                                                  None
4       10000000.0                                                  None
…            …                                                      …
207499  10000000.0                                                  None
207500  10000000.0                                                  None
```

```
207501  10000000.0                                                None
207502  10000000.0  <models.system_model_v3.model.parts.uniswap_or…
207503  10000000.0  <models.system_model_v3.model.parts.uniswap_or…

        simulation  subset  run  substep  timestep  events  \
0                0       0    1        0         0     NaN
1                0       0    1       18         1     NaN
2                0       0    1       18         2     NaN
3                0       0    1       18         3     NaN
4                0       0    1       18         4     NaN
…              …     …  …       …        …     …
207499           0      35    4       18      1436     NaN
207500           0      35    4       18      1437     NaN
207501           0      35    4       18      1438     NaN
207502           0      35    4       18      1439     NaN
207503           0      35    4       18      1440     NaN

        eth_collateral_value  collateralization_ratio            ki  \
0               4.553000e+07                 1.450000 -5.000000e-09
1               4.644826e+07                 1.479244 -5.000000e-09
2               3.177754e+07                 1.450000 -5.000000e-09
3               3.177754e+07                 1.450000 -5.000000e-09
4               3.177754e+07                 1.450000 -5.000000e-09
…                        …                      …          …
207499          2.093053e+07                 1.450000 -2.000000e-10
207500          2.093053e+07                 1.450000 -2.000000e-10
207501          2.093053e+07                 1.450000 -2.000000e-10
207502          2.093053e+07                 1.450000 -2.000000e-10
207503          2.093053e+07                 1.450000 -2.000000e-10

                kp  liquidation_ratio rescale_target_price  \
0       2.000000e-07               1.45                 True
1       2.000000e-07               1.45                 True
2       2.000000e-07               1.45                 True
3       2.000000e-07               1.45                 True
4       2.000000e-07               1.45                 True
…              …                 …                    …
207499  5.000000e-06               1.45                False
207500  5.000000e-06               1.45                False
207501  5.000000e-06               1.45                False
207502  5.000000e-06               1.45                False
207503  5.000000e-06               1.45                False

       arbitrageur_considers_liquidation_ratio  target_price_scaled
0                                         True             4.553000
1                                         True             3.140000
2                                         True             3.140000
```

```
3                                        True              3.140000
4                                        True              3.140000
…                                        …                  …
207499                                   False             0.935180
207500                                   False             0.935180
207501                                   False             0.935180
207502                                   False             0.935180
207503                                   False             0.935179

[207504 rows x 58 columns]
```

[14]:
```
%%capture
# Save the processed results to the same HDF5 store file
df.to_hdf(experiment_results, key=f'processed_results_{experiment_timestamp}')
```

5 Control Parameters

[15]:
```
from radcad.core import generate_parameter_sweep

param_sweep = generate_parameter_sweep(params)
```

[16]:
```
df_control_parameters = df[['subset', 'kp', 'ki']]

df_control_parameters = df_control_parameters.drop_duplicates(subset=['kp',␣
↪'ki'])
df_control_parameters
```

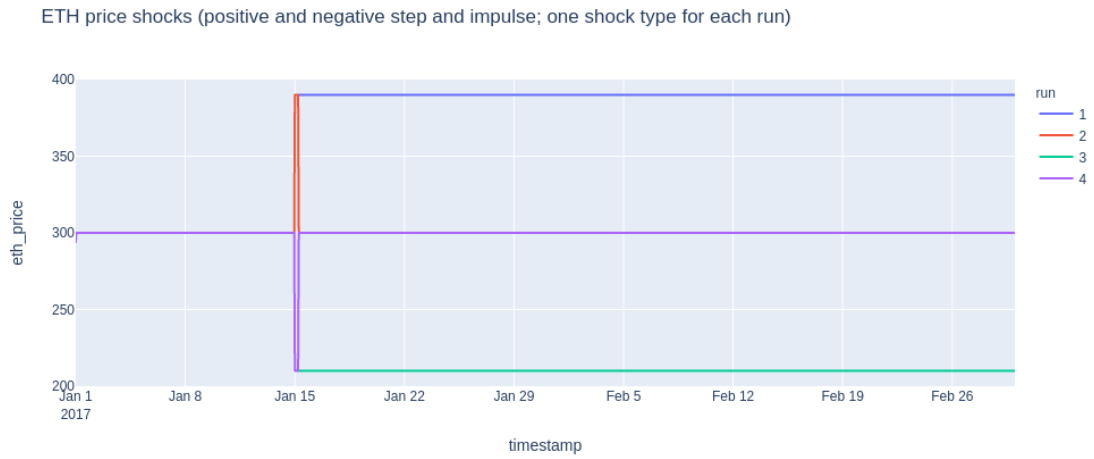
[16]:

	subset	kp	ki
0	0	2.000000e-07	-5.000000e-09
5764	4	2.000000e-07	-1.000000e-09
11528	8	2.000000e-07	-2.000000e-10
17292	12	1.000000e-06	-5.000000e-09
23056	16	1.000000e-06	-1.000000e-09
28820	20	1.000000e-06	-2.000000e-10
34584	24	5.000000e-06	-5.000000e-09
40348	28	5.000000e-06	-1.000000e-09
46112	32	5.000000e-06	-2.000000e-10

6 Simulation Analysis

[17]:
```
df.query('subset == 0')[['timestamp', 'eth_price', 'run']].plot(
    title="ETH price shocks (positive and negative step and impulse; one shock␣
↪type for each run)",
    x='timestamp',
    y='eth_price',
```

```
    color='run'
)
```



Experiment parameter subsets:

[53]:
```
df[['subset', 'kp', 'ki', 'rescale_target_price',␣
↪'arbitrageur_considers_liquidation_ratio']] \
    .drop_duplicates(subset=['kp', 'ki', 'rescale_target_price',␣
↪'arbitrageur_considers_liquidation_ratio'])
```

[53]:

	subset	kp	ki	rescale_target_price	\
0	0	2.000000e-07	-5.000000e-09	True	
1441	1	2.000000e-07	-5.000000e-09	True	
2882	2	2.000000e-07	-5.000000e-09	False	
4323	3	2.000000e-07	-5.000000e-09	False	
5764	4	2.000000e-07	-1.000000e-09	True	
7205	5	2.000000e-07	-1.000000e-09	True	
8646	6	2.000000e-07	-1.000000e-09	False	
10087	7	2.000000e-07	-1.000000e-09	False	
11528	8	2.000000e-07	-2.000000e-10	True	
12969	9	2.000000e-07	-2.000000e-10	True	
14410	10	2.000000e-07	-2.000000e-10	False	
15851	11	2.000000e-07	-2.000000e-10	False	
17292	12	1.000000e-06	-5.000000e-09	True	
18733	13	1.000000e-06	-5.000000e-09	True	
20174	14	1.000000e-06	-5.000000e-09	False	
21615	15	1.000000e-06	-5.000000e-09	False	
23056	16	1.000000e-06	-1.000000e-09	True	
24497	17	1.000000e-06	-1.000000e-09	True	
25938	18	1.000000e-06	-1.000000e-09	False	

27379	19	1.000000e-06	-1.000000e-09	False
28820	20	1.000000e-06	-2.000000e-10	True
30261	21	1.000000e-06	-2.000000e-10	True
31702	22	1.000000e-06	-2.000000e-10	False
33143	23	1.000000e-06	-2.000000e-10	False
34584	24	5.000000e-06	-5.000000e-09	True
36025	25	5.000000e-06	-5.000000e-09	True
37466	26	5.000000e-06	-5.000000e-09	False
38907	27	5.000000e-06	-5.000000e-09	False
40348	28	5.000000e-06	-1.000000e-09	True
41789	29	5.000000e-06	-1.000000e-09	True
43230	30	5.000000e-06	-1.000000e-09	False
44671	31	5.000000e-06	-1.000000e-09	False
46112	32	5.000000e-06	-2.000000e-10	True
47553	33	5.000000e-06	-2.000000e-10	True
48994	34	5.000000e-06	-2.000000e-10	False
50435	35	5.000000e-06	-2.000000e-10	False

	arbitrageur_considers_liquidation_ratio
0	True
1441	False
2882	True
4323	False
5764	True
7205	False
8646	True
10087	False
11528	True
12969	False
14410	True
15851	False
17292	True
18733	False
20174	True
21615	False
23056	True
24497	False
25938	True
27379	False
28820	True
30261	False
31702	True
33143	False
34584	True
36025	False
37466	True
38907	False

```
40348                                  True
41789                                 False
43230                                  True
44671                                 False
46112                                  True
47553                                 False
48994                                  True
50435                                 False
```

[52]:
```
fig = px.line(
    df.query('run == 1'),
    title="Price response for all control parameter subsets, first run",
    x="timestamp",
    y=["market_price", "market_price_twap", "target_price"],
    facet_col="subset",
    facet_col_wrap=4,
    facet_row_spacing=0.04, # default is 0.07 when facet_col_wrap is used
    facet_col_spacing=0.04, # default is 0.03
    height=2000
)
fig.show()
```

Get the initial target price to test stability conditions:

[19]:
```
initial_target_price = df['target_price'].iloc[0]
initial_target_price
```

[19]:
```
3.14
```

Find all controller constant subsets where the price goes to zero:

[20]:
```
df_market_price_zero = df.query("market_price <= 0.1*@initial_target_price")
df_market_price_zero[['subset', 'kp', 'ki']].drop_duplicates(subset=['kp',␣
↪'ki'])
```

[20]:

	subset	kp	ki
38192	26	0.000005	-5.000000e-09
43864	30	0.000005	-1.000000e-09
49612	34	0.000005	-2.000000e-10

Find all controller constant subsets where the price goes to infinity:

[21]:
```
df_market_price_infinity = df.query("market_price > 10*@initial_target_price")
df_market_price_infinity[['subset', 'kp', 'ki']].drop_duplicates(subset=['kp',␣
↪'ki'])
```

[21]:

	subset	kp	ki
4205	2	2.000000e-07	-5.000000e-09

Create dataframe of stable simulation scenarios.

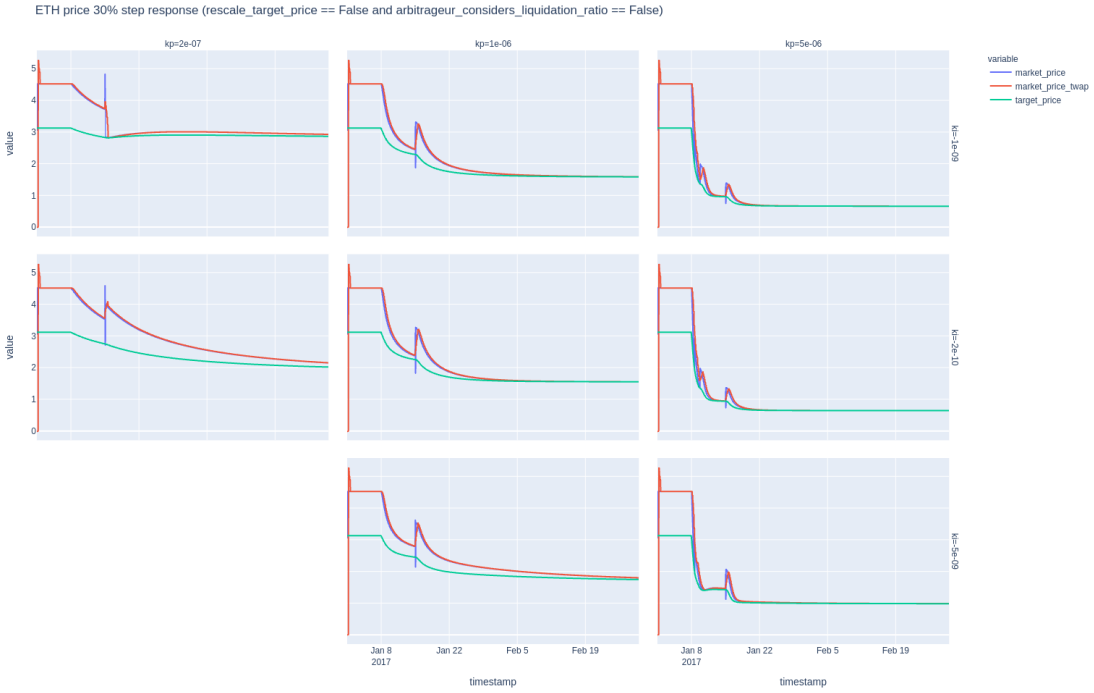
Stability is defined as: 1. The market price and scaled target price remaining within 0.1x and 10x the starting price, for all timesteps

[22]:
```
df['stable_price'] = False
df.loc[df.eval("""
0.1*@initial_target_price < market_price <= 10*@initial_target_price and 0.
↪1*@initial_target_price < target_price_scaled <= 10*@initial_target_price
"""), 'stable_price'] = True
df_stable_price = df.groupby("subset").filter(lambda x: all(x.query('timestep >␣
↪24*2')['stable_price'])) #  and x['timestep'].max() == SIMULATION_TIMESTEPS
df_stable_price['subset'].unique()
```

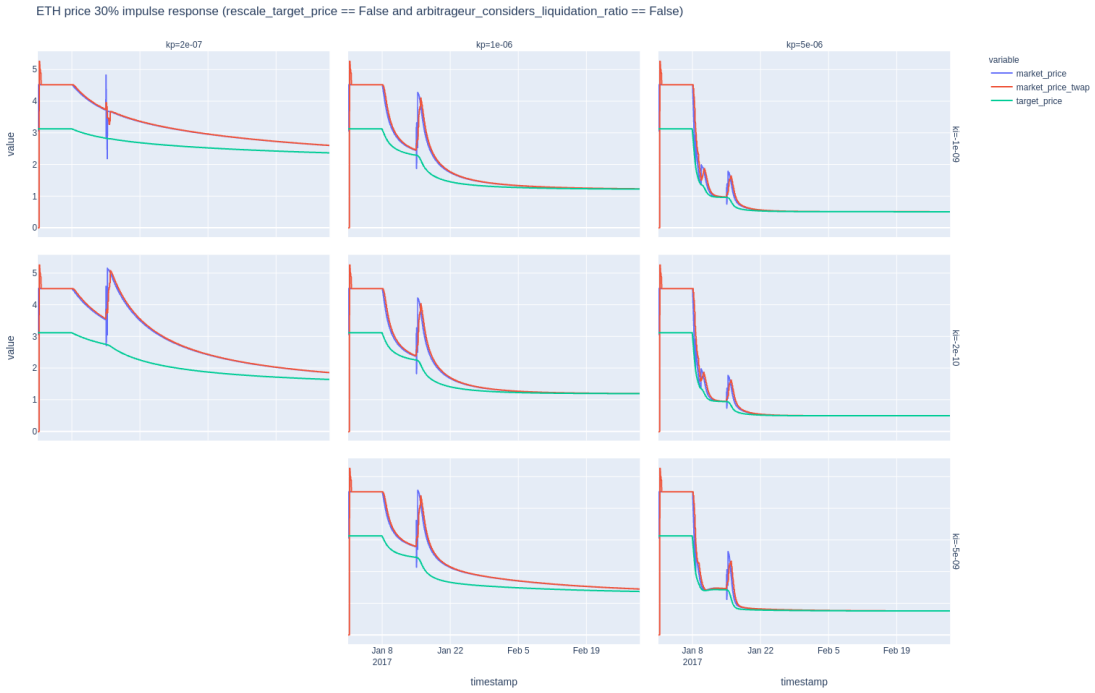
[22]:
```
array([ 0,  1,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
       19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33, 35])
```

[35]:
```
fig = px.line(
    df_stable_price.query('run == 1 and rescale_target_price == False and␣
↪arbitrageur_considers_liquidation_ratio == False'),
    title="ETH price 30% step response (rescale_target_price == False and␣
↪arbitrageur_considers_liquidation_ratio == False)",
    x="timestamp",
    y=["market_price", "market_price_twap", "target_price"],
    facet_col="kp",
    facet_row="ki",
```

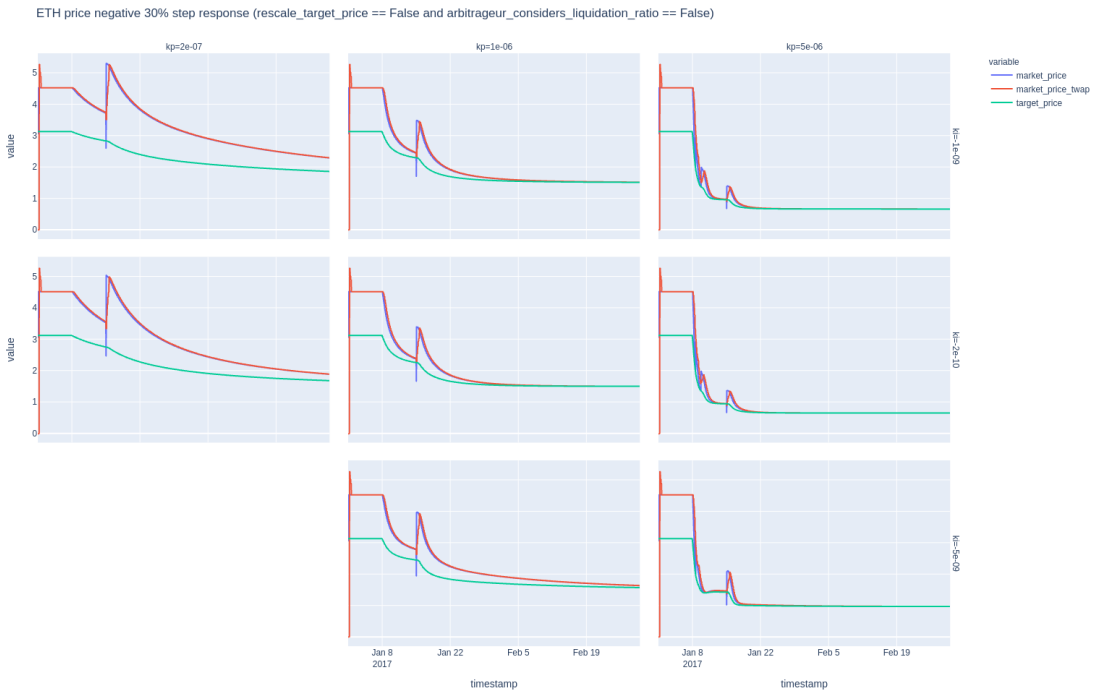
```
    facet_col_wrap=2,
    height=1000
)
fig.show()
```



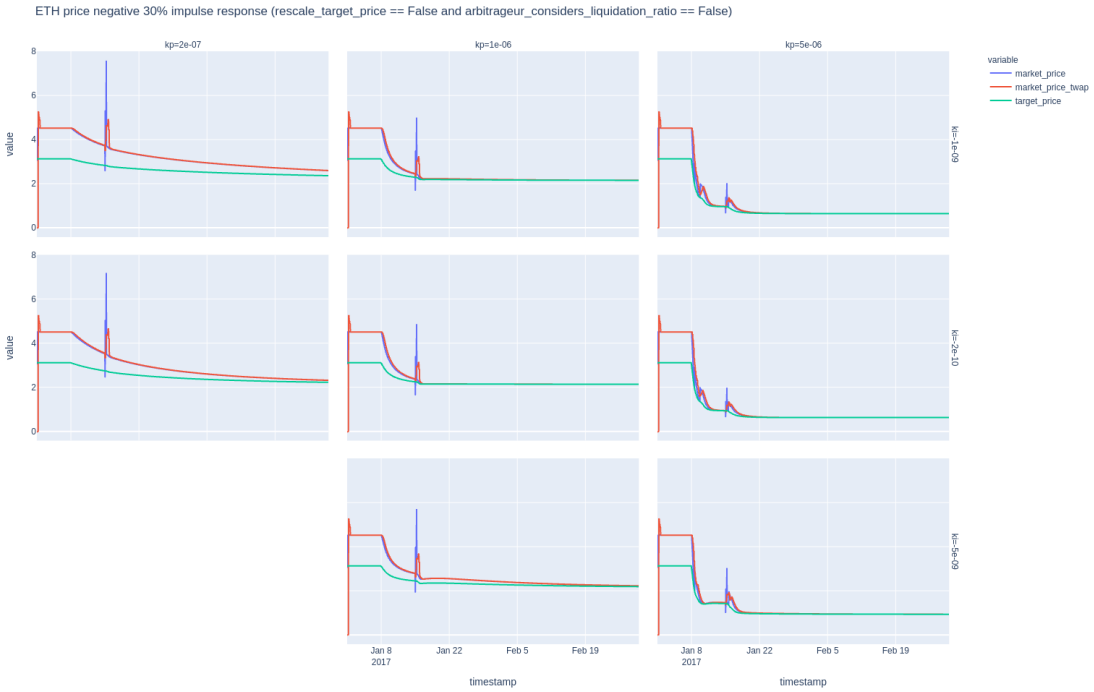
[36]:
```
fig = px.line(
    df_stable_price.query('run == 2 and rescale_target_price == False and␣
↪arbitrageur_considers_liquidation_ratio == False'),
    title="ETH price 30% impulse response (rescale_target_price == False and␣
↪arbitrageur_considers_liquidation_ratio == False)",
    x="timestamp",
    y=["market_price", "market_price_twap", "target_price"],
    facet_col="kp",
    facet_row="ki",
    facet_col_wrap=2,
    height=1000
)
fig.show()
```



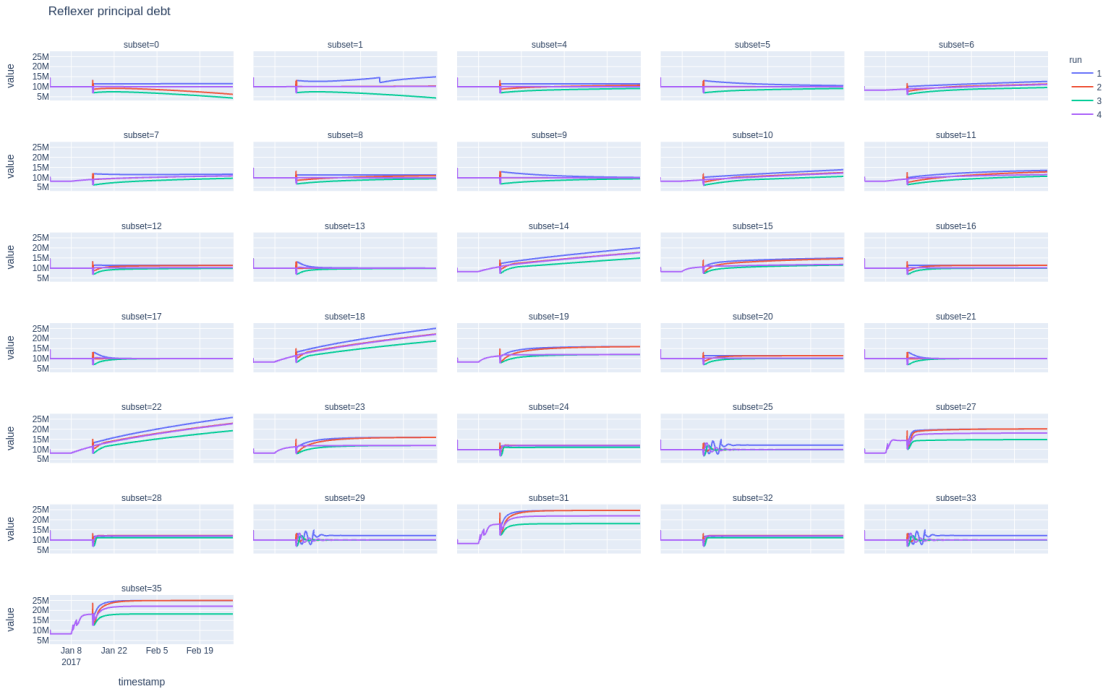
[45]:
```
fig = px.line(
    df_stable_price.query('run == 3 and rescale_target_price == False and␣
↪arbitrageur_considers_liquidation_ratio == False'),
    title="ETH price negative 30% step response (rescale_target_price == False␣
↪and arbitrageur_considers_liquidation_ratio == False)",
    x="timestamp",
    y=["market_price", "market_price_twap", "target_price"],
    facet_col="kp",
    facet_row="ki",
    facet_col_wrap=2,
    height=1000
)
fig.show()
```



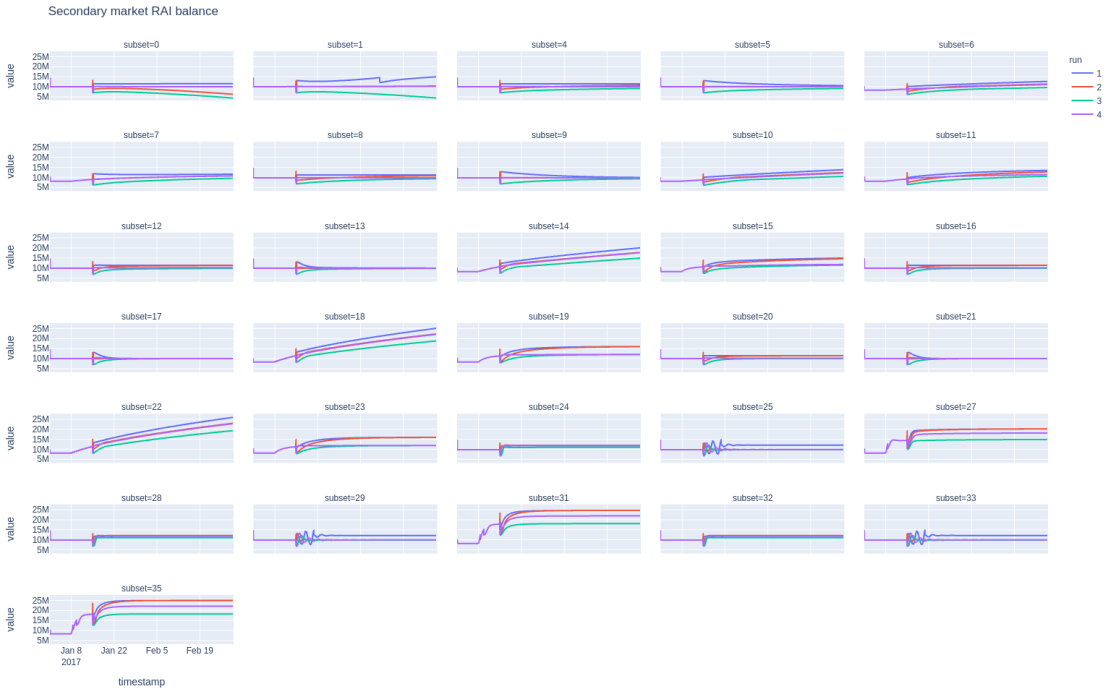
[44]:
```
fig = px.line(
    df_stable_price.query('run == 4 and rescale_target_price == False and␣
↪arbitrageur_considers_liquidation_ratio == False'),
    title="ETH price negative 30% impulse response (rescale_target_price ==␣
↪False and arbitrageur_considers_liquidation_ratio == False)",
    x="timestamp",
    y=["market_price", "market_price_twap", "target_price"],
    facet_col="kp",
    facet_row="ki",
    facet_col_wrap=2,
    height=1000
)
fig.show()
```



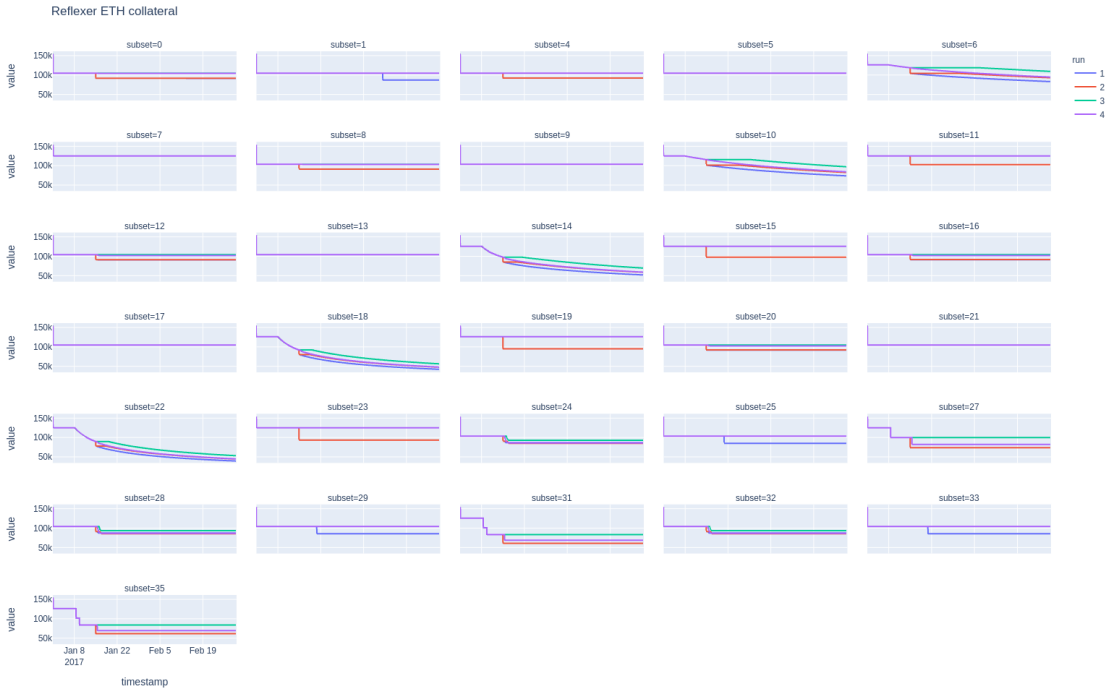
[39]:
```
fig = px.line(
    df_stable_price,
    title="Reflexer principal debt",
    x="timestamp",
    y=["principal_debt"],
    color='run',
    facet_col="subset",
    facet_col_wrap=5,
    height=1000
)
fig.show()
```



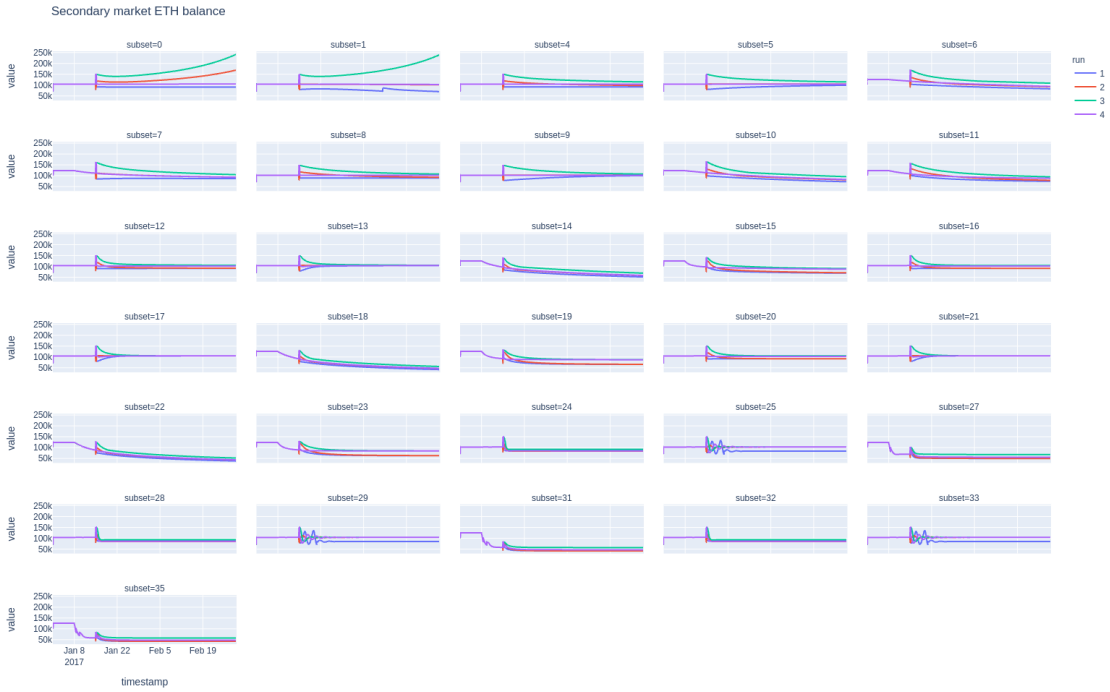
[40]:
```
fig = px.line(
    df_stable_price,
    title="Secondary market RAI balance",
    x="timestamp",
    y=["RAI_balance"],
    color='run',
    facet_col="subset",
    facet_col_wrap=5,
    height=1000
)
fig.show()
```



[41]:
```
fig = px.line(
    df_stable_price,
    title="Reflexer ETH collateral",
    x="timestamp",
    y=["eth_collateral"],
    color='run',
    facet_col="subset",
    facet_col_wrap=5,
    height=1000
)
fig.show()
```



[42]:
```
fig = px.line(
    df_stable_price,
    title="Secondary market ETH balance",
    x="timestamp",
    y=["ETH_balance"],
    color='run',
    facet_col="subset",
    facet_col_wrap=5,
    height=1000
)
fig.show()
```



[43]:
```
df_stable_price.plot(
    x='timestamp',
    y=['collateralization_ratio'],
    title='Collateralization ratio',
    facet_col="subset",
    facet_col_wrap=5,
    height=1000
)
```


Collateralization ratio
subset=0
subset=1
subset=4
subset=5
subset=6
subset=7
subset=8
subset=9
subset=10
subset=11
subset=12
subset=13
subset=14
subset=15
subset=16
subset=17
subset=18
subset=19
subset=20
subset=21
subset=22
subset=23
subset=24
subset=25
subset=27
subset=28
subset=29
subset=31
subset=32
subset=33
subset=35
value
2
1.5
1
Jan 8
2017
Jan 22
Feb 5
Feb 19
timestamp
variable
collateralization_ratio