Chapter 1: Acquiring Financial Data

```
Downloaded 2769 rows of data.
```

Date	Open	High	Low	Close	Adj Close	Volume
2010-12-31	11.533929	11.552857	11.475357	11.520000	9.864279	193508000
2011-01-03	11.630000	11.795000	11.601429	11.770357	10.078650	445138400
2011-01-04	11.872857	11.875000	11.719643	11.831786	10.131254	309080800
2011-01-05	11.769643	11.940714	11.767857	11.928571	10.214125	255519600
2011-01-06	11.954286	11.973214	11.889286	11.918929	10.205874	300428800
...	...	...	...	...	...	...
2021-12-23	175.850006	176.850006	175.270004	176.279999	176.055695	68356600
2021-12-27	177.089996	180.419998	177.070007	180.330002	180.100540	74919600
2021-12-28	180.160004	181.330002	178.529999	179.289993	179.061859	79144300
2021-12-29	179.330002	180.630005	178.139999	179.380005	179.151749	62348900
2021-12-30	179.470001	180.570007	178.089996	178.199997	177.973251	59773000

```
Downloaded 1818 rows of data.
```

Date	Open	High	Low	Close	Volume	Ex-Dividend	Split Ratio	Adj. Open	Adj. High	Adj. Low	Adj. Close	Adj. Volume
2011-01-03	325.6400	330.26	324.8365	329.57	15897800.0	0.0	1.0	41.849279	42.443013	41.746018	42.354338	111284600.0
2011-01-04	332.4400	332.50	328.1500	331.29	11038600.0	0.0	1.0	42.723173	42.730884	42.171849	42.575382	77270200.0
2011-01-05	329.5500	334.34	329.5000	334.00	9125700.0	0.0	1.0	42.351768	42.967350	42.345342	42.923655	63879900.0
2011-01-06	334.7194	335.25	332.9000	333.73	10729600.0	0.0	1.0	43.016108	43.084298	42.782290	42.888956	75107200.0
2011-01-07	333.9900	336.35	331.9000	336.12	11140400.0	0.0	1.0	42.922370	43.225663	42.653776	43.196105	77982800.0

None	ticker	date	adj_close
0	MSFT	2018-03-27	89.47
1	MSFT	2018-03-26	93.78
2	MSFT	2018-03-23	87.18
3	MSFT	2018-03-22	89.79
4	MSFT	2018-03-21	92.48

	adj_close		
ticker	AAPL	INTC	MSFT
date			
2011-01-03	42.354338	16.488706	23.211568
2011-01-04	42.575382	16.725954	23.300747
2011-01-05	42.923655	16.559880	23.228159
2011-01-06	42.888956	16.425440	23.908412
2011-01-07	43.196105	16.338449	23.725905

```
Downloaded 2675 rows of data.
```

date	intraperiod	frequency	open	high	low	close	volume	adj_open	adj_high	adj_low	adj_close	adj_volume
2011-01-03	False	daily	325.90	330.26	324.8365	329.57	15897201.0	9.993683	10.127381	9.961070	10.106223	445121628.0
2011-01-04	False	daily	332.50	332.50	328.1500	331.29	11048143.0	10.196071	10.196071	10.062679	10.158966	309348004.0
2011-01-05	False	daily	329.55	334.34	329.5000	334.00	9125599.0	10.105609	10.252494	10.104076	10.242068	255516772.0
2011-01-06	False	daily	335.00	335.25	332.9000	333.73	10729518.0	10.272733	10.280399	10.208337	10.233789	300426504.0
2011-01-07	False	daily	334.12	336.35	331.9000	336.12	11140316.0	10.245748	10.314130	10.177672	10.307078	311928848.0

	id	title	publication_date	url	summary
0	nws_1ExBnx	12 Best Blue-Chip Stocks Right Now	2021-08-09 20:27:39+00:00	https://finance.yahoo.com/news/12-best-blue-ch...	In this article, we will look at the 12 best b...
1	nws_JbL8mV	The Coca-Cola Company (NYSE:KO) Yields 3% With...	2021-08-09 09:26:07+00:00	https://finance.yahoo.com/news/coca-cola-compa...	The Coca-Cola Company NYSE:KO) is a staple sto...
2	nws_DkAPKO	10 High Yield Monthly Dividend Stocks to Buy i...	2021-08-07 13:57:00+00:00	https://finance.yahoo.com/news/10-high-yield-m...	In this article, we will be looking at 10 high...
3	nws_pRYkD9	10 Best Dividend Paying Stocks to Buy Now	2021-08-04 14:32:49+00:00	https://finance.yahoo.com/news/10-best-dividen...	In this article, we will be looking at the 10 ...
4	nws_kpVJDP	PepsiCo (PEP) Agrees to Offload Its Juice Bran...	2021-08-04 13:21:01+00:00	https://finance.yahoo.com/news/pepsico-pep-agr...	PepsiCo (PEP) unveils plans to offload juice b...

	id	ticker	name	lei	cik
0	com_gPQrmX	I	Intelsat SA	None	0001525773
1	com_yRZOxy	IHSI	Intelligent Highway Solutions Inc	None	0001549719
2	com_gQQr4g	INTB	Intelligent Buying, Inc.	None	0001358633
3	com_gwk3Qg	SVFC	Intellicell Biosciences Inc	None	0001125280
4	com_NgYGzd	INTC	Intel Corp	KNX4USFCNGPY45LOCE31	0000050863
5	com_gYnr4X	None	Inteliquent Inc	549300K8G7V0F3VFUL90	0001292653
6	com_ybNLQy	ILNS	Intellect Neurosciences Inc	None	0001337905
7	com_y1jq9g	ITTI	INTELLECTUAL TECHNOLOGY INC	None	0000859914
8	com_XGb25g	DTFSF	Intelimax Media Inc.	None	0001434598
9	com_ybNdby	ILIV	Intelligent Living America Inc	None	0001141673

	time	last_price	ask_price	ask_size	bid_price	bid_size	volume	source
0	2021-01-04 20:59:58+00:00	52.755	55.00	100.0	52.30	234.0	0.0	None
1	2021-01-04 20:59:57+00:00	52.745	55.00	100.0	52.74	200.0	870885.0	None
2	2021-01-04 20:59:54+00:00	52.745	55.00	100.0	52.30	234.0	870641.0	None
3	2021-01-04 20:59:51+00:00	52.740	55.00	100.0	52.30	234.0	870341.0	None
4	2021-01-04 20:59:49+00:00	52.725	52.73	600.0	52.71	300.0	868833.0	None
...	...	...	...	...	...	...	...	...
995	2021-01-04 19:01:07+00:00	52.490	52.50	100.0	52.48	200.0	582993.0	None
996	2021-01-04 19:01:03+00:00	52.510	52.50	200.0	52.49	200.0	582493.0	None
997	2021-01-04 19:01:02+00:00	52.495	52.51	200.0	52.49	200.0	582093.0	None
998	2021-01-04 19:00:59+00:00	52.510	52.51	200.0	52.50	200.0	580893.0	None
999	2021-01-04 19:00:51+00:00	52.505	52.51	200.0	52.50	100.0	580793.0	None

```
{'board_of_directors_meeting_date': None,
 'board_of_directors_meeting_type': None,
 'broadcast_url': 'http://mmm.wallstreethorizon.com/u.asp?u=347366',
 'company_website': 'http://mmm.wallstreethorizon.com/u.asp?u=14711',
 'conference_call_date': datetime.date(2020, 10, 22),
 'conference_call_passcode': None,
 'conference_call_phone_number': None,
 'conference_call_time': '8:30 AM',
 'last_confirmation_date': datetime.date(2020, 9, 23),
 'next_earnings_date': datetime.date(2020, 10, 22),
 'next_earnings_fiscal_year': 2020,
 'next_earnings_quarter': 'Q3',
 'preliminary_earnings_date': None,
 'q1_date': datetime.date(2020, 4, 21),
 'q2_date': datetime.date(2020, 7, 21),
 'q3_date': datetime.date(2020, 10, 22),
 'q4_date': datetime.date(2020, 1, 30),
 'quarter': 'Q3',
 'security': {'code': 'EQS',
              'company_id': 'com_VXWJgv',
              'composite_figi': 'BBG000BMX289',
              'composite_ticker': 'KO:US',
              'currency': 'USD',
              'figi': 'BBG000BMX4N8',
              'id': 'sec_X7m9Zy',
...
 'time_of_day': 'Before Market',
 'transcript_fiscal_year': None,
 'transcript_quarter': None,
 'transcript_url': None,
 'type': 'V'}
```

date	1a. open (EUR)	1b. open (USD)	2a. high (EUR)	2b. high (USD)	3a. low (EUR)	3b. low (USD)	4a. close (EUR)	4b. close (USD)	5. volume	6. market cap (USD)
2022-02-05	36283.779760	41571.70	36480.927824	41797.58	36084.152944	41342.98	36411.034000	41717.50	2595.290800	2595.290800
2022-02-04	32565.896144	37311.98	36458.889624	41772.33	32316.929944	37026.73	36286.005400	41574.25	64703.958740	64703.958740
2022-02-03	32203.151736	36896.37	32631.373600	37387.00	31639.000000	36250.00	32565.573208	37311.61	32081.109990	32081.109990
2022-02-02	33772.638152	38694.59	33913.446976	38855.92	31933.089960	36586.95	32203.143008	36896.36	35794.681300	35794.681300
2022-02-01	33573.910320	38466.90	34270.666560	39265.20	33166.400000	38000.00	33772.638152	38694.59	34574.446630	34574.446630
...	...	...	...	...	...	...	...	...	...	...
2019-05-17	6867.775176	7868.67	6916.940000	7925.00	6033.666400	6913.00	6419.670928	7355.26	88752.008159	88752.008159
2019-05-16	7129.973024	8169.08	7261.696000	8320.00	6724.924000	7705.00	6865.959752	7866.59	69630.513996	69630.513996
2019-05-15	6934.622928	7945.26	7199.727200	8249.00	6851.480000	7850.00	7130.662536	8169.87	37884.327211	37884.327211
2019-05-14	6804.017136	7795.62	7301.844800	8366.00	6632.895968	7599.56	6936.630368	7947.56	76583.722603	76583.722603
2019-05-13	6081.879872	6968.24	7069.680000	8100.00	5996.136000	6870.00	6799.731688	7790.71	85804.735333	85804.735333

Realtime Currency Exchange Rate	
1. From_Currency Code	BTC
2. From_Currency Name	Bitcoin
3. To_Currency Code	USD
4. To_Currency Name	United States Dollar
5. Exchange Rate	41487.32000000
6. Last Refreshed	2022-02-05 10:51:02
7. Time Zone	UTC
8. Bid Price	41487.32000000
9. Ask Price	41487.33000000

	1. open	2. high	3. low	4. close	5. volume
2022-02-05 10:30:00	3013.70000	3023.98000	3012.70000	3020.27000	2699
2022-02-05 10:00:00	3027.75000	3035.69000	3007.00000	3013.69000	7016
2022-02-05 09:30:00	3018.65000	3033.00000	3002.27000	3027.75000	12938
2022-02-05 09:00:00	3007.94000	3023.68000	3003.17000	3018.64000	4540
2022-02-05 08:30:00	3007.14000	3018.54000	2988.07000	3007.93000	7162
...	...	...	...	...	...
2022-01-15 17:00:00	3358.60000	3361.57000	3346.76000	3353.08000	3772
2022-01-15 16:30:00	3357.25000	3365.01000	3356.39000	3358.60000	3042
2022-01-15 16:00:00	3361.97000	3371.64000	3353.00000	3357.24000	7244
2022-01-15 15:30:00	3342.60000	3369.94000	3340.93000	3361.97000	17695
2022-01-15 15:00:00	3338.71000	3347.53000	3332.51000	3342.59000	4291

	symbol	name	reportDate	fiscalDateEnding	estimate	currency
0	A	Agilent Technologies Inc	2022-02-22	2022-01-31	1.18	USD
1	AA	Alcoa Corp	2022-04-13	2022-03-31	2.35	USD
2	AACG	ATA Creativity Global	2022-03-28	2021-12-31	-0.27	USD
3	AADI	Aadi Bioscience Inc	2022-03-09	2021-12-31	-0.98	USD
4	AAIC	Arlington Asset Investment Corp - Class A	2022-02-14	2021-12-31	0.06	USD
...	...	...	...	...	...	...
7154	ZYME	Zymeworks Inc	2022-02-22	2021-12-31	-1.17	USD
7155	ZYME	Zymeworks Inc	2022-05-03	2022-03-31	NaN	USD
7156	ZYNE	Zynerba Pharmaceuticals Inc	2022-03-08	2021-12-31	-0.26	USD
7157	ZYXI	Zynex Inc	2022-02-23	2021-12-31	0.20	USD
7158	ZYXI	Zynex Inc	2022-04-27	2022-03-31	NaN	USD

	date	open	high	low	close
0	2022-01-22 12:00:00	35631.29	35631.29	35631.29	35631.29
1	2022-01-22 16:00:00	35423.73	35952.33	35193.74	35193.74
2	2022-01-22 20:00:00	34991.02	35109.66	34527.65	34527.65
3	2022-01-23 00:00:00	34602.79	35630.21	34602.79	34935.31
4	2022-01-23 04:00:00	35180.44	35448.61	35044.59	35044.59
...	...	...	...	...	...
80	2022-02-04 20:00:00	39570.01	40557.17	39570.01	40495.25
81	2022-02-05 00:00:00	40781.16	40781.16	40573.23	40717.53
82	2022-02-05 04:00:00	41673.84	41673.84	41315.19	41454.15
83	2022-02-05 08:00:00	41492.85	41617.27	41492.85	41589.31
84	2022-02-05 12:00:00	41450.77	41554.04	41450.77	41554.04

	id	coin_id	name	symbol	market_cap_rank	slug	price_btc	score
0	dogecoin	5	Dogecoin	DOGE	10	dogecoin	0.000004	0
1	civilization	17626	Civilization	CIV	674	civilization	0.000003	1
2	apecoin	24383	ApeCoin	APE	31	apecoin	0.000443	2
3	oasis-network	13162	Oasis Network	ROSE	110	oasis-network	0.000006	3
4	stepn	23597	STEPN	GMT	61	stepn	0.000081	4
5	unicrypt-2	12871	UniCrypt	UNCX	927	unicrypt	0.011535	5
6	xcad-network	15857	XCAD Network	XCAD	399	xcad-network	0.000107	6

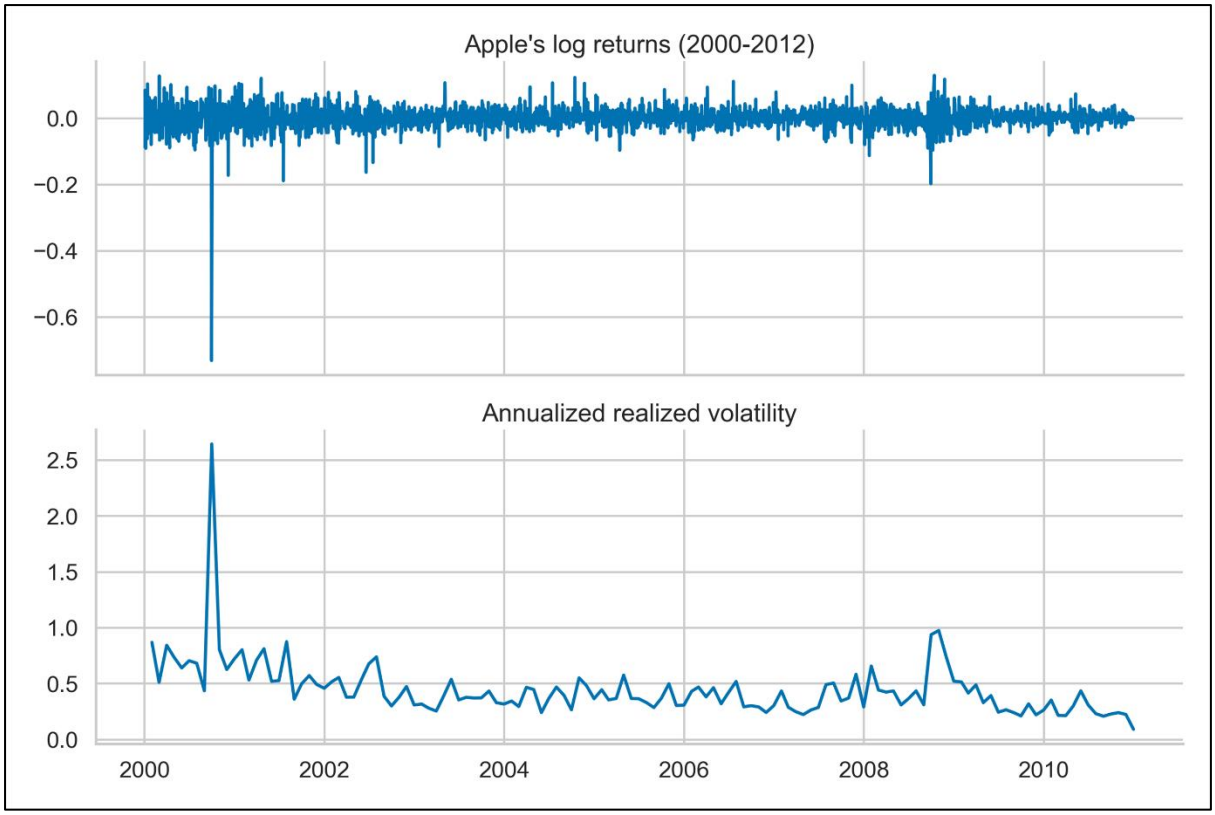
Chapter 2: Data Preprocessing

Date	Adj Close	simple_rtn	log_rtn
2009-12-31	6.444379	NaN	NaN
2010-01-04	6.544686	0.015565	0.015445
2010-01-05	6.556003	0.001729	0.001728
2010-01-06	6.451722	-0.015906	-0.016034
2010-01-07	6.439794	-0.001849	-0.001851

Date	cpi
2009-12-31	215.949
2010-01-31	216.687
2010-02-28	216.741
2010-03-31	217.631
2010-04-30	218.009
...	...
2020-08-31	259.918
2020-09-30	260.280
2020-10-31	260.388
2020-11-30	260.229
2020-12-31	260.474

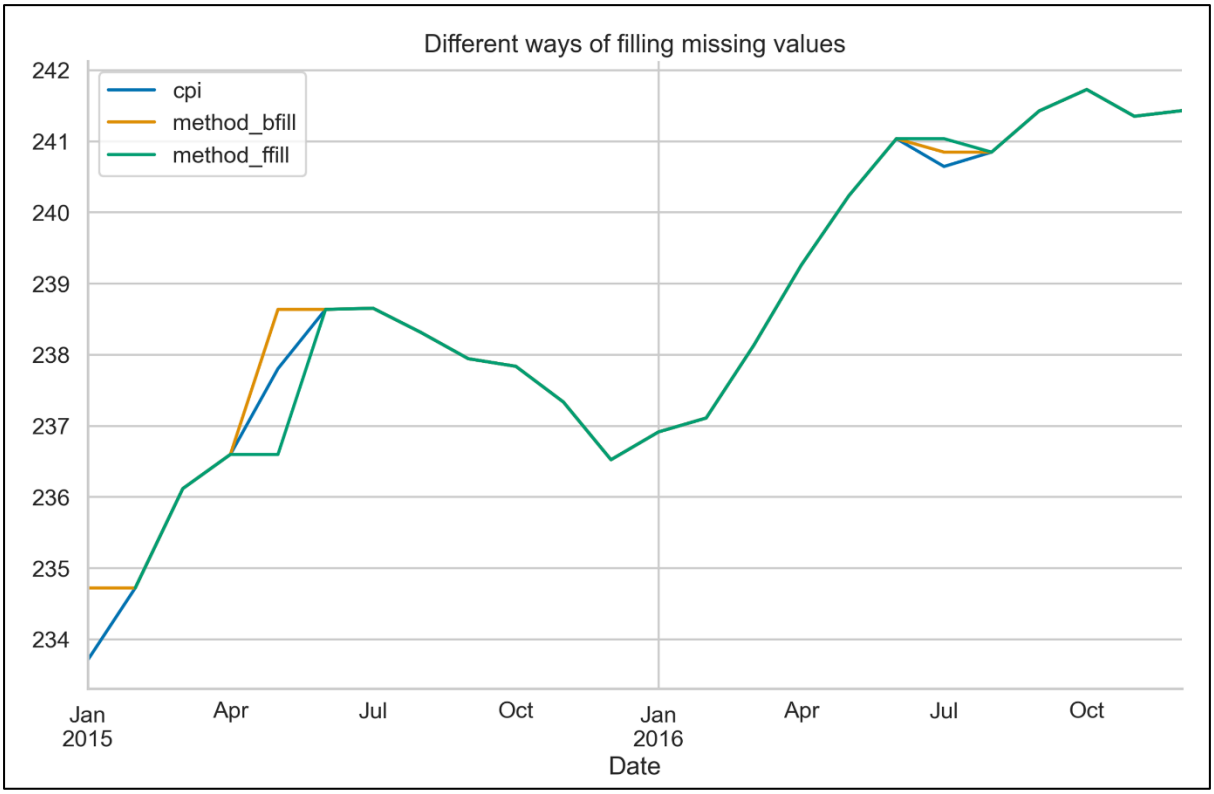
Date	Adj Close	cpi	simple_rtn	inflation_rate	real_rtn
2009-12-31	6.444379	215.949	NaN	NaN	NaN
2010-01-31	5.873430	216.687	-0.088597	0.003417	-0.091701
2010-02-28	6.257530	216.741	0.065396	0.000249	0.065131
2010-03-31	7.186588	217.631	0.148470	0.004106	0.143774
2010-04-30	7.984450	218.009	0.111021	0.001737	0.109095

date	value
2010-01-01	216.687
2010-02-01	216.741
2010-03-01	217.631
2010-04-01	218.009
2010-05-01	218.178
2010-06-01	217.965
2010-07-01	218.011
2010-08-01	218.312
2010-09-01	218.439
2010-10-01	218.711
2010-11-01	218.803
2010-12-01	219.179

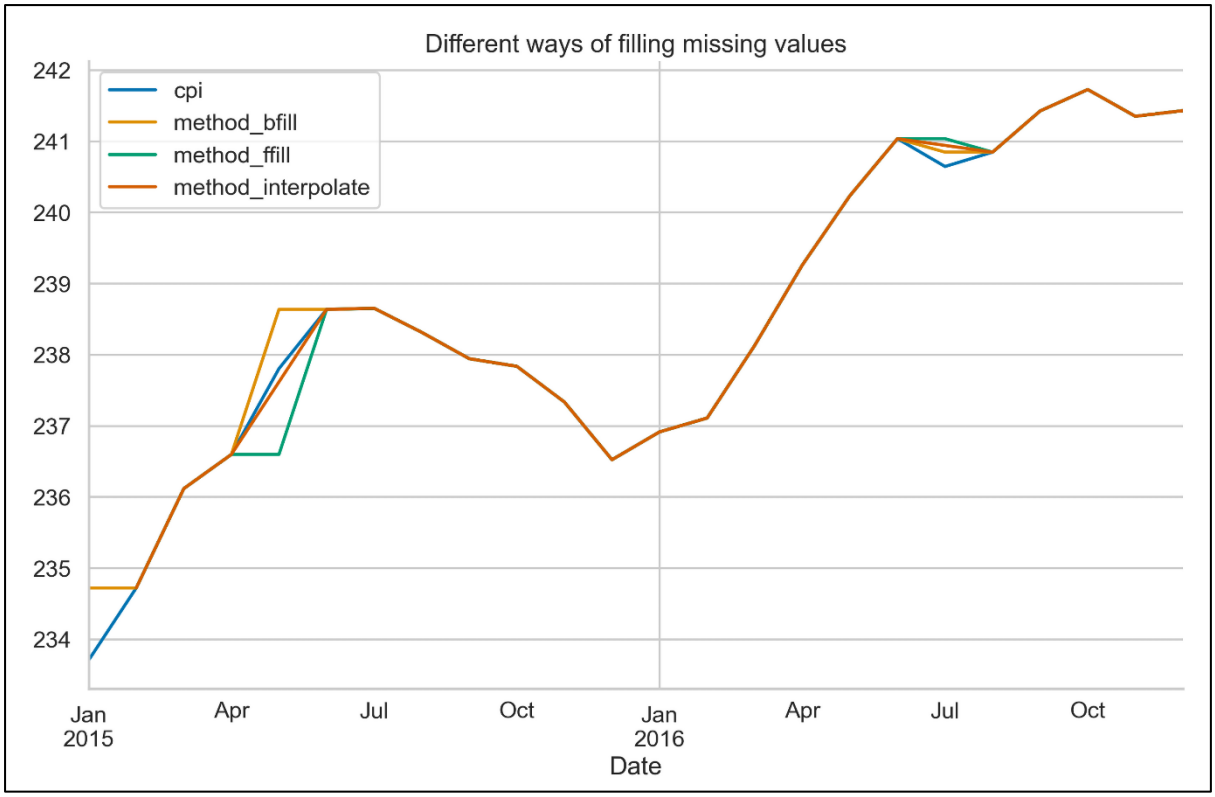


Date	cpi	cpi_missing
2015-01-31	233.707	NaN
2015-02-28	234.722	234.722
2015-03-31	236.119	236.119
2015-04-30	236.599	236.599
2015-05-31	237.805	NaN

Date	cpi	cpi_missing	method_bfill	method_ffill
2015-01-31	233.707	NaN	234.722	NaN
2015-05-31	237.805	NaN	238.638	236.599
2016-07-31	240.647	NaN	240.849	241.038
2017-05-31	244.733	NaN	244.955	244.524
2020-03-31	258.115	NaN	256.389	258.678



Date	cpi	cpi_missing	method_bfill	method_ffill	method_interpolate
2015-01-31	233.707	NaN	234.722	NaN	NaN
2015-05-31	237.805	NaN	238.638	236.599	237.6185
2016-07-31	240.647	NaN	240.849	241.038	240.9435
2017-05-31	244.733	NaN	244.955	244.524	244.7395
2020-03-31	258.115	NaN	256.389	258.678	257.5335



Date	Open	High	Low	Close	usd_eur	Open_EUR	High_EUR	Low_EUR	Close_EUR
2019-12-31	72.482	73.420	72.380	73.412	0.890	64.521	65.355	64.429	65.348
2020-01-02	74.060	75.150	73.798	75.088	0.893	66.166	67.140	65.932	67.084
2020-01-03	74.287	75.145	74.125	74.357	0.897	66.643	67.413	66.498	66.706
2020-01-06	73.448	74.990	73.188	74.950	0.893	65.613	66.991	65.381	66.956
2020-01-07	74.960	75.225	74.370	74.598	0.895	67.096	67.334	66.568	66.772

Date	Open	High	Low	Close	Adj Close	Volume
2003-12-01	0.83098	0.83724	0.83056	0.83577	0.83577	0
2003-12-02	0.83605	0.83710	0.82583	0.82720	0.82720	0
2003-12-03	0.82713	0.82802	0.82440	0.82488	0.82488	0
2003-12-04	0.82508	0.83029	0.82345	0.82775	0.82775	0
2003-12-05	0.82795	0.82878	0.82028	0.82055	0.82055	0

	id	price	qty	quoteQty	time
0	77999355	33285.50	0.00288	95.862240	2022-02-23 19:41:15.896
1	77999356	33286.84	0.00336	111.843782	2022-02-23 19:41:15.896
2	77999357	33275.29	0.00813	270.528108	2022-02-23 19:41:15.941
3	77999358	33277.44	0.01001	333.107174	2022-02-23 19:41:17.896
4	77999359	33275.29	0.01001	333.085653	2022-02-23 19:41:17.900
...	...	...	...	...	...
495	77999850	33268.98	0.00067	22.290217	2022-02-23 19:50:56.806
496	77999851	33268.49	0.00249	82.838540	2022-02-23 19:50:56.806
497	77999852	33268.98	0.02126	707.298515	2022-02-23 19:50:58.903
498	77999853	33268.00	0.00596	198.277280	2022-02-23 19:50:58.903
499	77999854	33268.52	0.00150	49.902780	2022-02-23 19:50:59.291

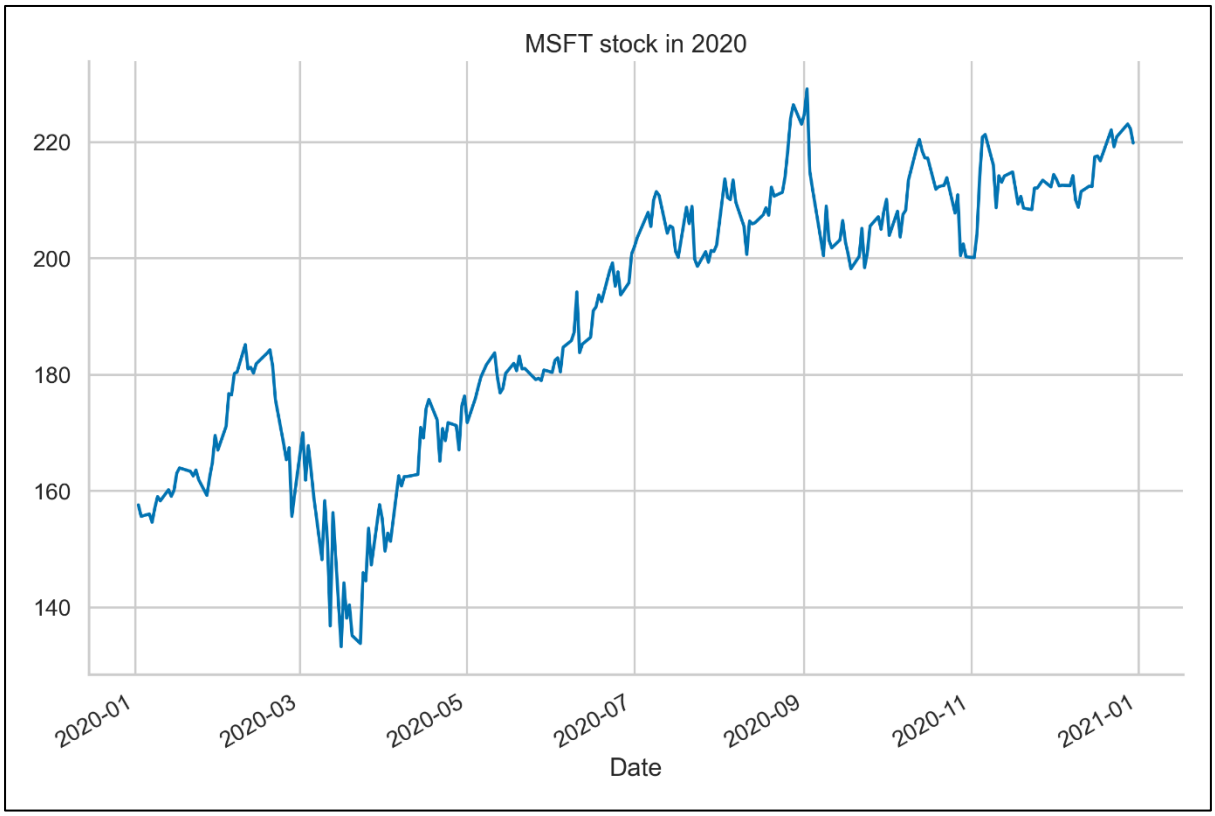
time	open	high	low	close	vwap	vol	cnt
2022-02-23 19:41:00	33285.50	33286.84	33254.00	33269.47	33269.239073	0.71050	52
2022-02-23 19:42:00	33265.24	33265.63	33226.18	33231.76	33237.848521	2.26604	110
2022-02-23 19:43:00	33234.74	33250.30	33215.73	33240.09	33231.975184	0.70111	73
2022-02-23 19:44:00	33240.10	33240.10	33216.23	33231.33	33234.523449	0.81760	21
2022-02-23 19:45:00	33227.68	33286.04	33226.31	33279.94	33245.756842	3.39557	89
2022-02-23 19:46:00	33270.23	33305.45	33266.54	33279.62	33284.459090	0.46893	31
2022-02-23 19:47:00	33283.24	33328.46	33273.90	33322.05	33295.109170	0.30348	32
2022-02-23 19:48:00	33308.50	33333.98	33297.37	33315.46	33315.803656	0.58047	37
2022-02-23 19:49:00	33310.42	33322.00	33281.73	33294.93	33309.609233	0.22579	21
2022-02-23 19:50:00	33283.21	33294.20	33268.00	33268.52	33281.789160	0.73358	34

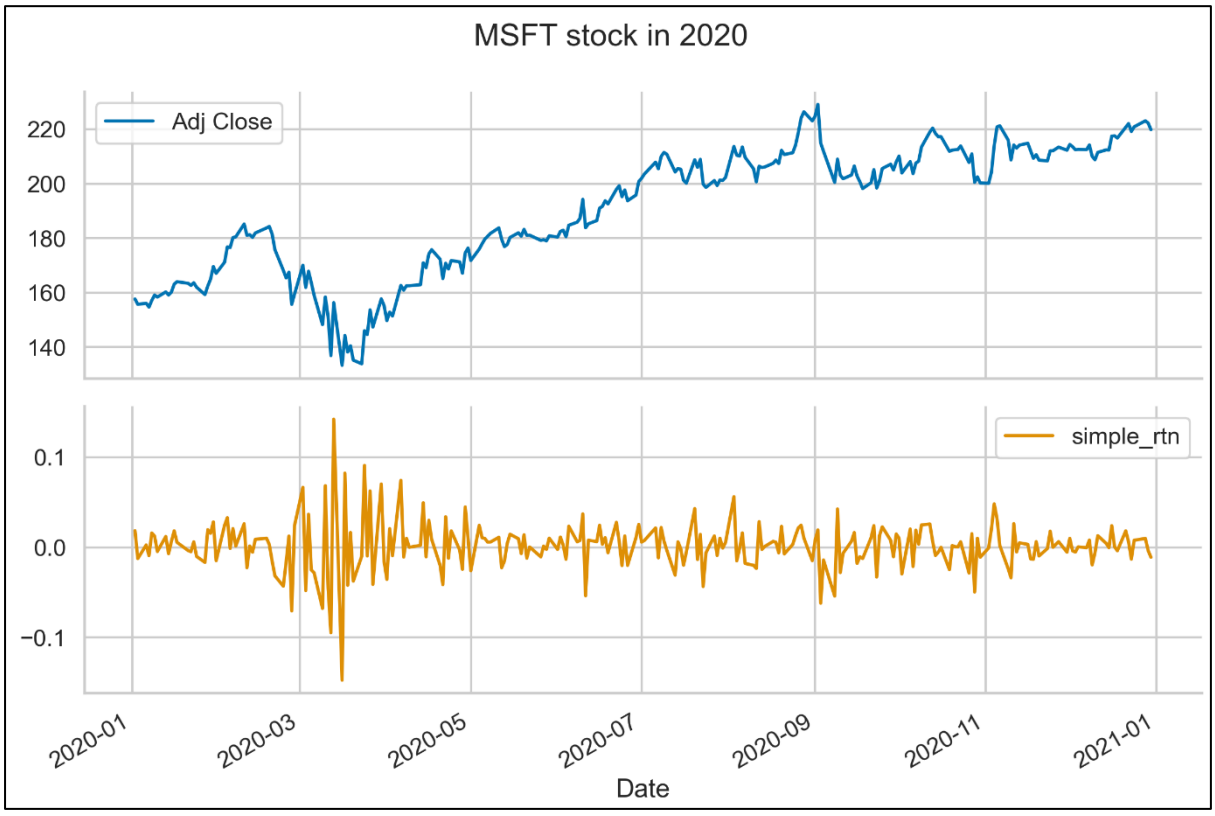
tick_group	time	open	high	low	close	vwap	vol	cnt
0	2022-02-23 19:41:57.784	33285.50	33286.84	33254.00	33270.89	33269.220356	0.65723	50
1	2022-02-23 19:42:29.168	33269.47	33269.47	33243.50	33243.50	33249.679200	0.75967	50
2	2022-02-23 19:42:43.886	33241.86	33244.71	33226.18	33230.04	33233.334328	1.45604	50
3	2022-02-23 19:43:37.837	33234.89	33244.70	33215.73	33222.93	33228.599024	0.31810	50
4	2022-02-23 19:44:28.440	33222.72	33250.30	33216.23	33216.98	33234.604510	1.26310	50
5	2022-02-23 19:45:15.153	33226.01	33258.29	33221.43	33233.13	33236.663489	1.87995	50
6	2022-02-23 19:46:02.625	33233.13	33286.04	33233.13	33284.14	33256.233756	1.56017	50
7	2022-02-23 19:47:47.964	33284.89	33305.45	33266.54	33293.35	33284.115017	0.63715	50
8	2022-02-23 19:49:05.929	33294.13	33333.98	33294.13	33314.63	33314.426886	0.78777	50
9	2022-02-23 19:50:59.291	33313.24	33322.00	33268.00	33268.52	33286.482830	0.88389	50

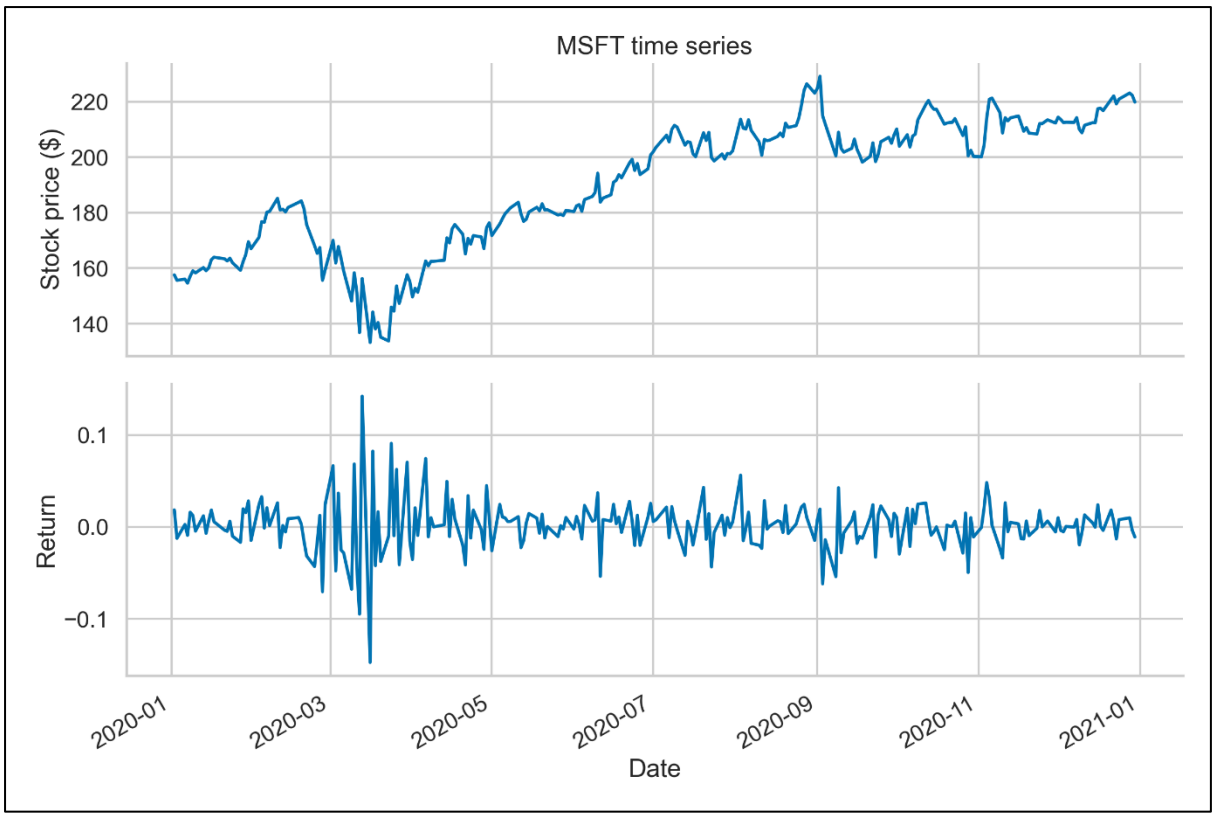
vol_group	time	open	high	low	close	vwap	vol	cnt
0	2022-02-23 19:42:19.499	33285.50	33286.84	33246.90	33250.00	33264.436711	0.99446	85
1	2022-02-23 19:42:31.215	33246.91	33253.07	33226.18	33226.87	33240.193454	0.86169	46
2	2022-02-23 19:43:04.416	33232.23	33244.71	33230.04	33239.77	33232.363594	1.12313	33
3	2022-02-23 19:44:01.139	33240.00	33250.30	33215.73	33240.10	33232.135781	0.71425	72
4	2022-02-23 19:45:12.130	33240.10	33258.29	33216.23	33241.21	33238.411739	1.25593	44
5	2022-02-23 19:45:15.146	33241.21	33241.21	33232.03	33233.13	33234.773416	0.83403	15
6	2022-02-23 19:45:21.810	33233.13	33253.41	33233.13	33248.69	33236.027748	1.21260	20
7	2022-02-23 19:46:23.762	33248.69	33286.04	33242.90	33281.10	33270.171474	0.99072	45
8	2022-02-23 19:48:32.173	33280.33	33333.98	33273.90	33301.66	33300.233202	0.98864	69
9	2022-02-23 19:50:36.613	33301.65	33322.00	33274.39	33283.79	33296.304224	0.94414	53
10	2022-02-23 19:50:59.291	33283.81	33294.20	33268.00	33268.52	33280.873796	0.28348	18

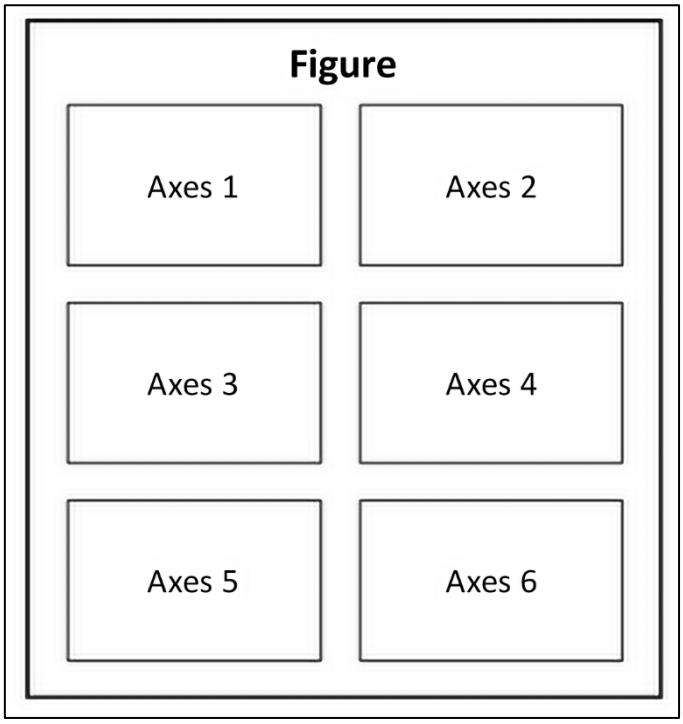
value_group	time	open	high	low	close	vwap	vol	cnt
0	2022-02-23 19:42:29.230	33285.50	33286.84	33239.96	33239.96	33258.572184	1.42997	103
1	2022-02-23 19:43:17.962	33239.96	33244.71	33226.18	33231.41	33233.221296	1.57424	66
2	2022-02-23 19:44:58.211	33231.40	33250.30	33215.73	33231.33	33233.232079	1.49104	87
3	2022-02-23 19:45:15.146	33227.68	33258.29	33226.31	33233.13	33238.544792	1.28824	39
4	2022-02-23 19:45:59.597	33233.13	33286.04	33233.13	33280.92	33243.191526	1.70740	43
5	2022-02-23 19:48:32.173	33279.94	33333.98	33266.54	33301.66	33293.331944	1.48456	91
6	2022-02-23 19:50:59.291	33301.65	33322.00	33268.00	33268.52	33292.741055	1.22762	71

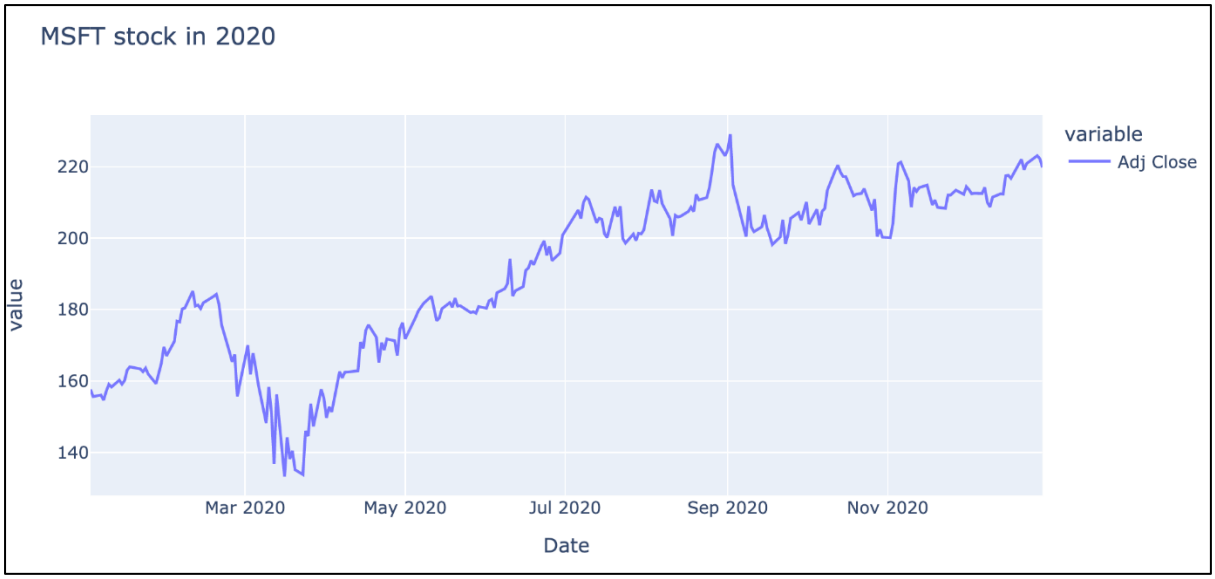
Chapter 3: Visualizing Financial Time Series

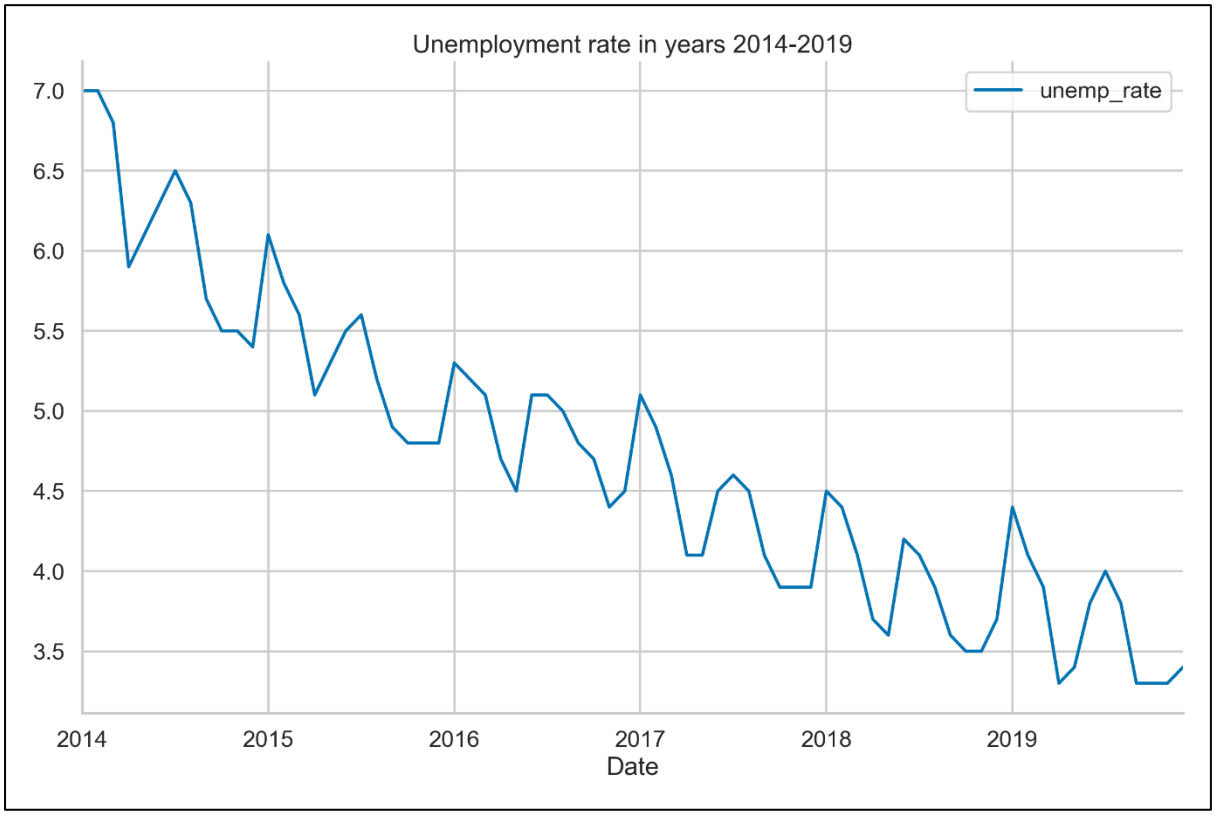


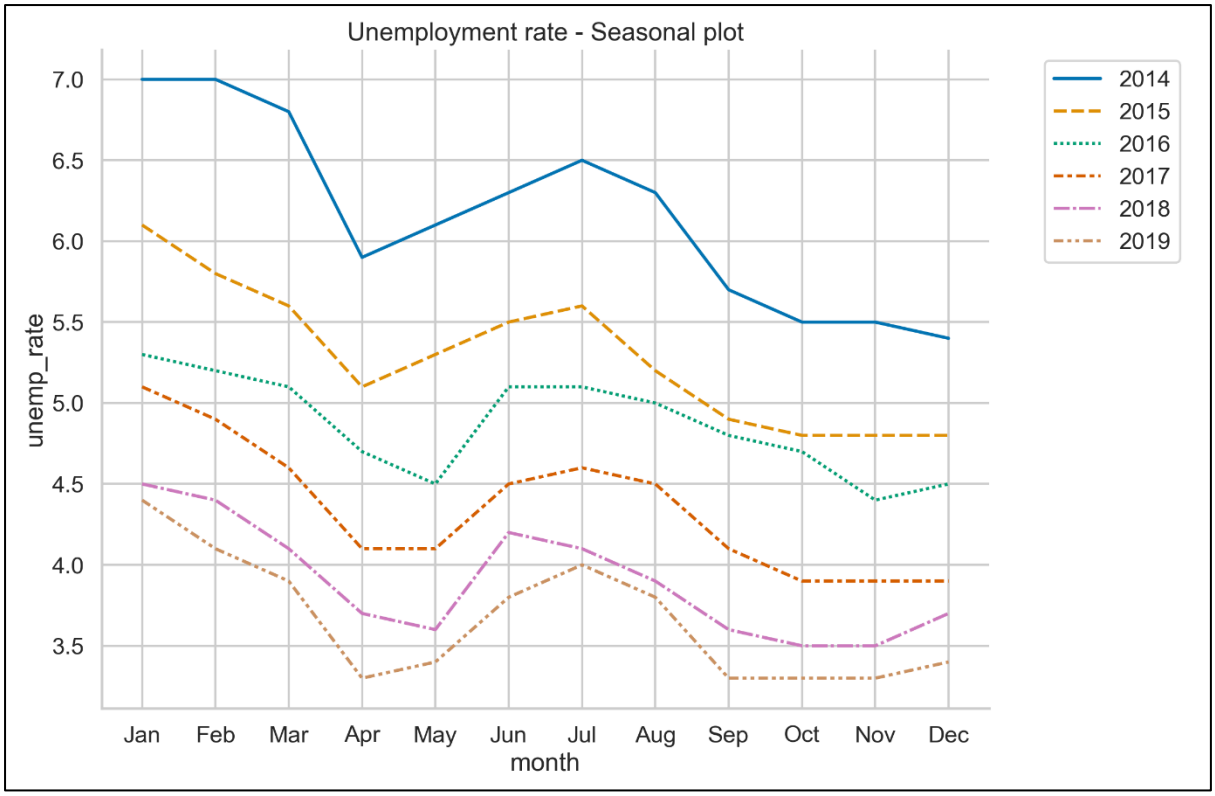


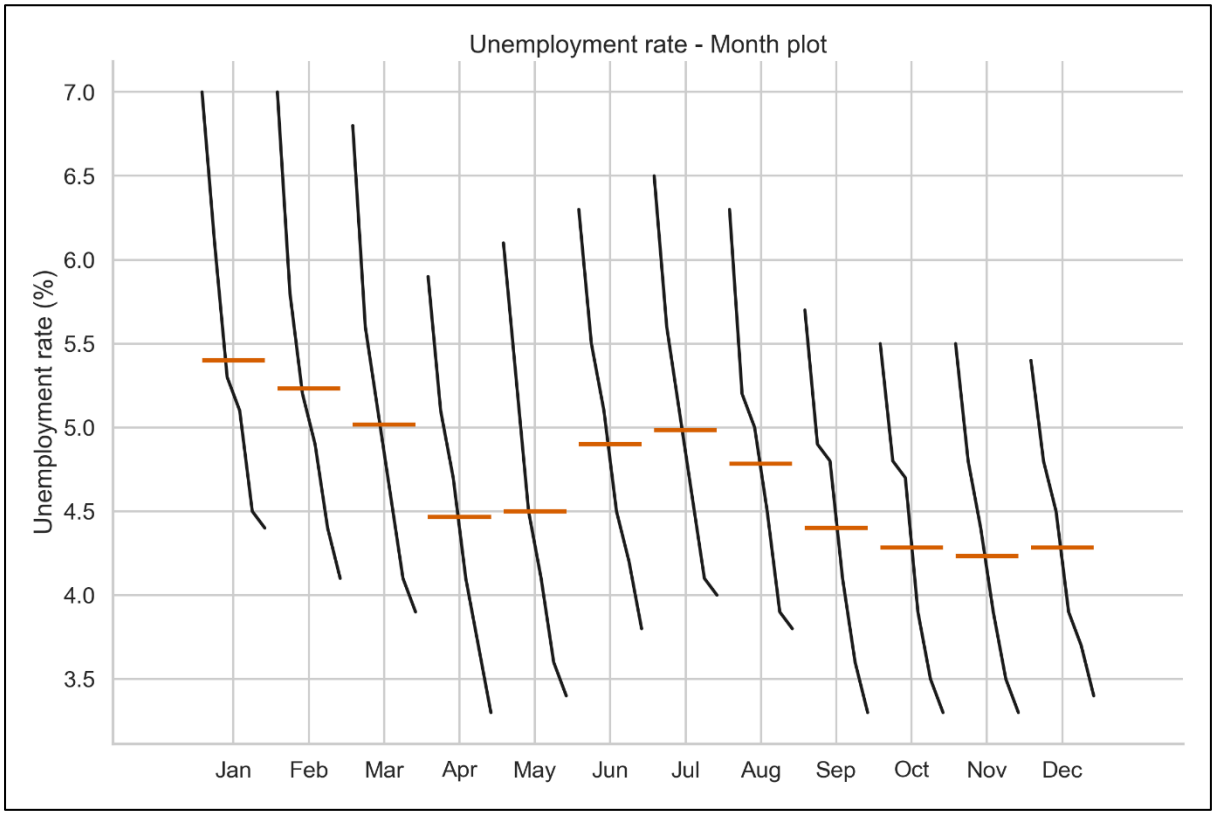

MSFT time series
Stock price ($)
220
200
180
160
140
Return
0.1
0.0
−0.1
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01
Date

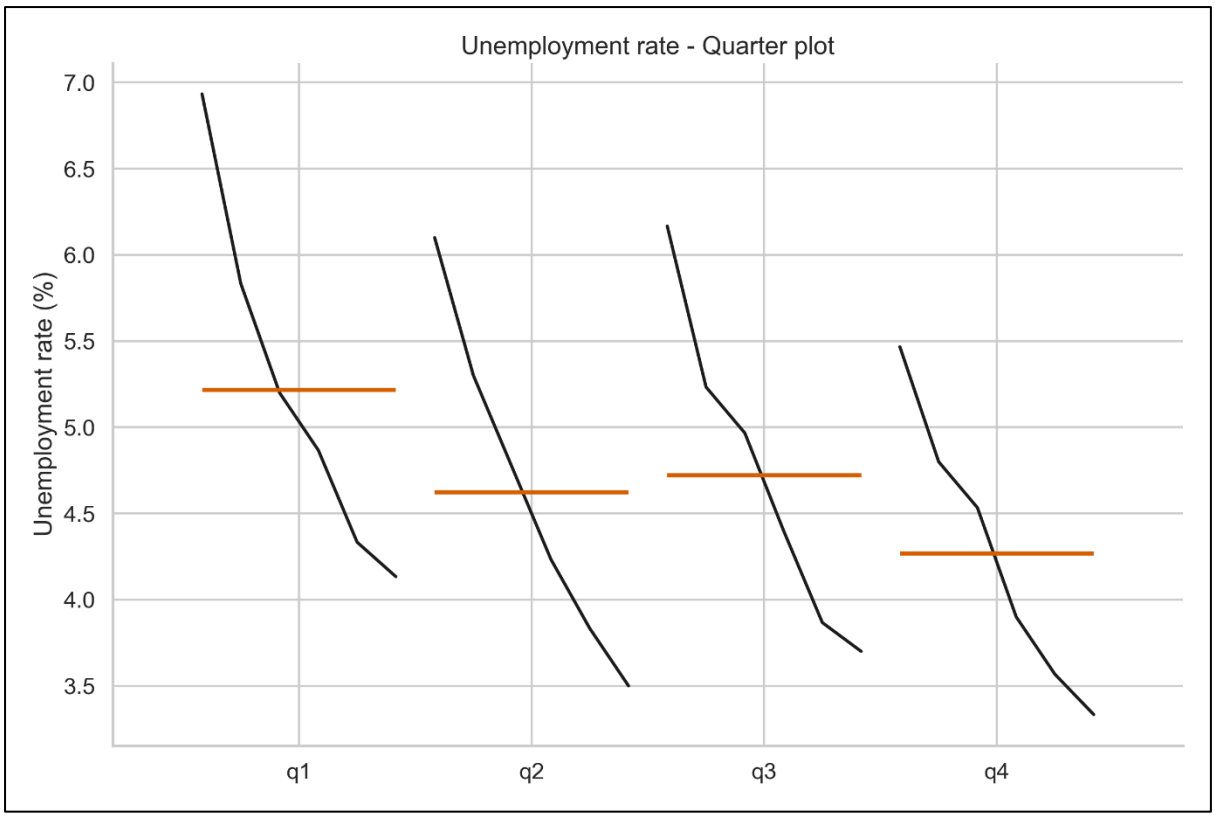

Figure
Axes 1
Axes 2
Axes 3
Axes 4
Axes 5
Axes 6

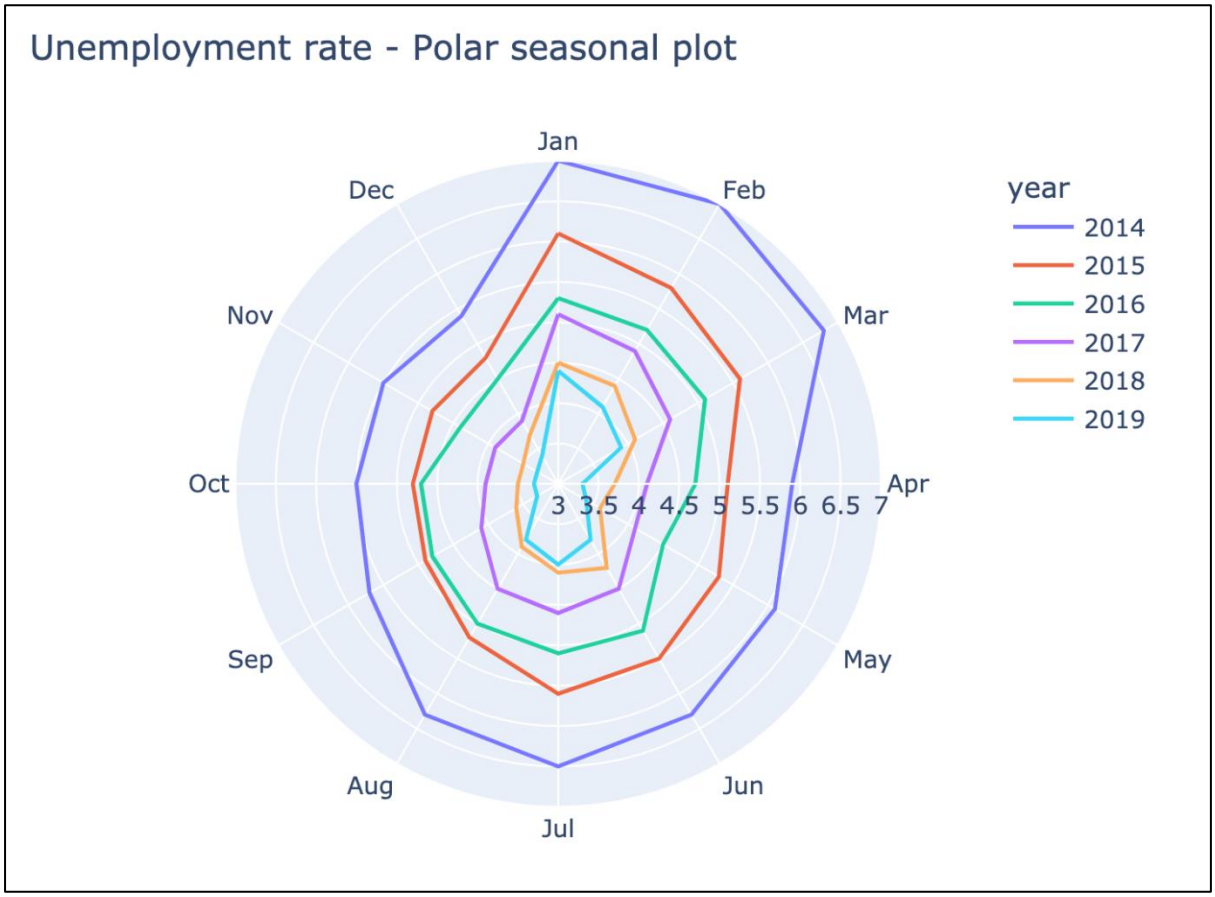

MSFT stock in 2020
variable
Adj Close
value
220
200
180
160
140
Mar 2020
May 2020
Jul 2020
Sep 2020
Nov 2020
Date

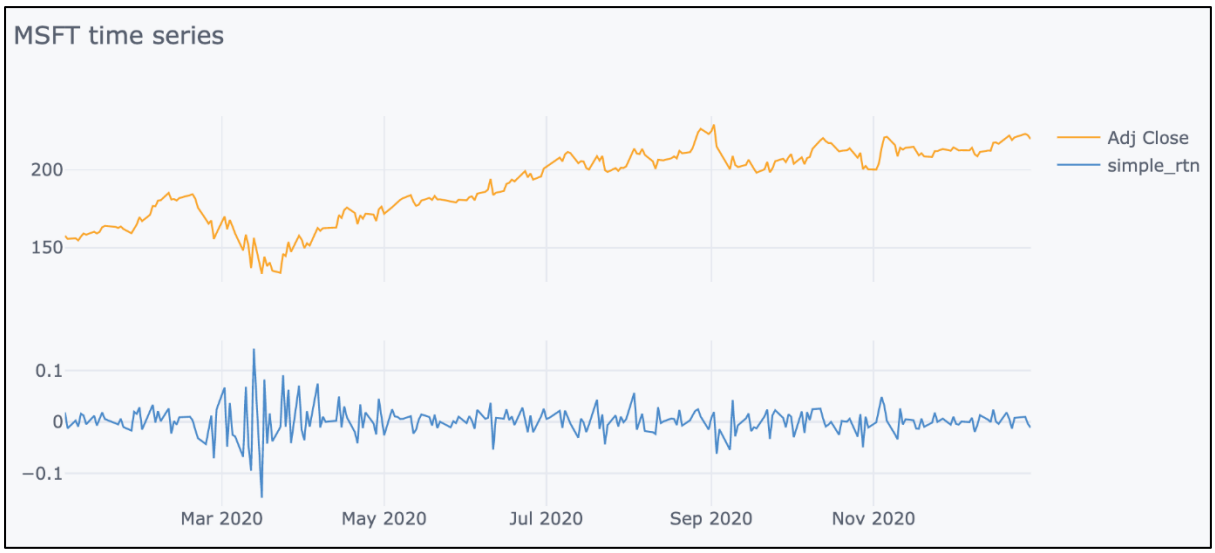

Unemployment rate in years 2014-2019
unemp_rate
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
2014
2015
2016
2017
2018
2019
Date

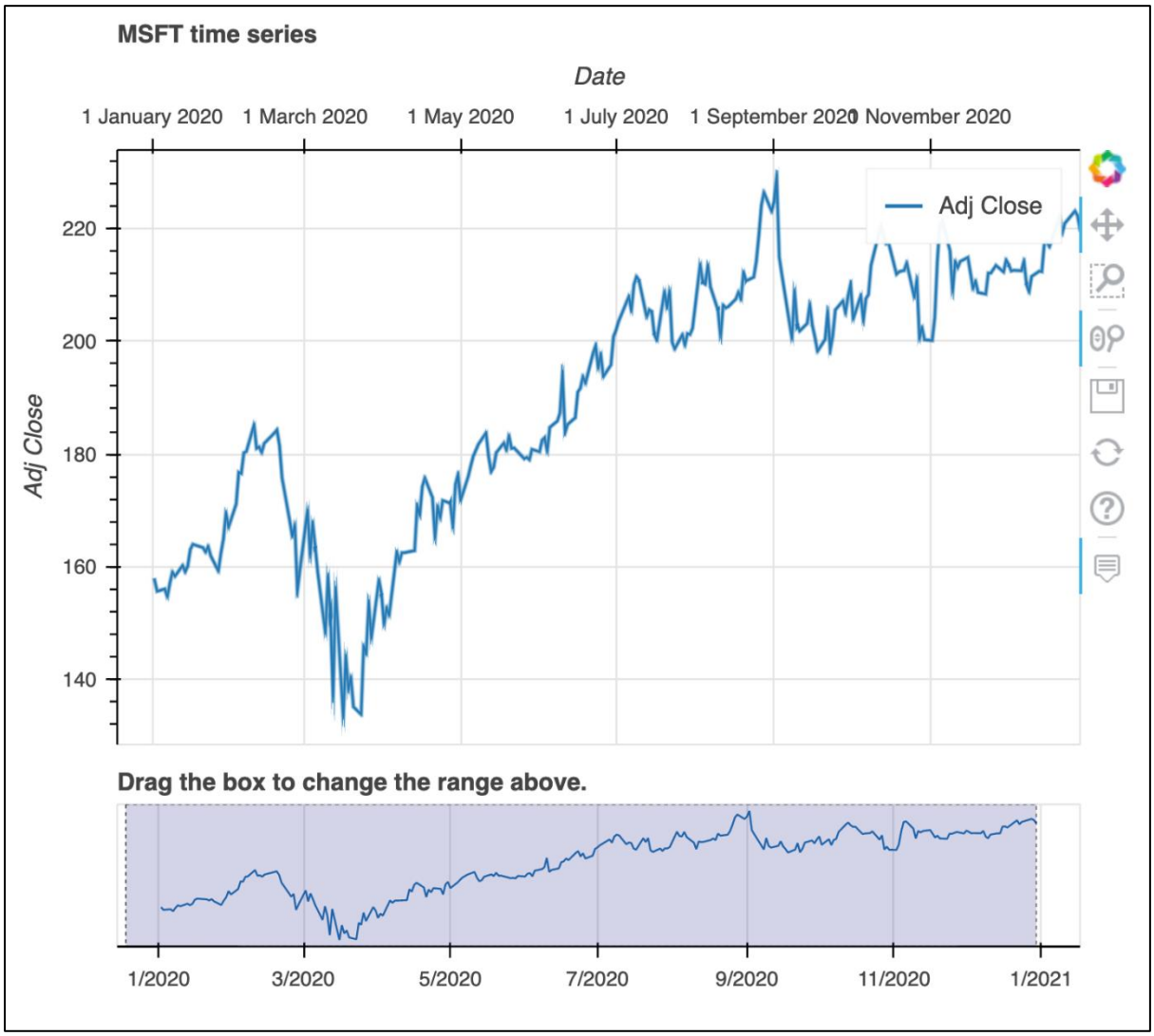

Unemployment rate - Seasonal plot
unemp_rate
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
month
2014
2015
2016
2017
2018
2019

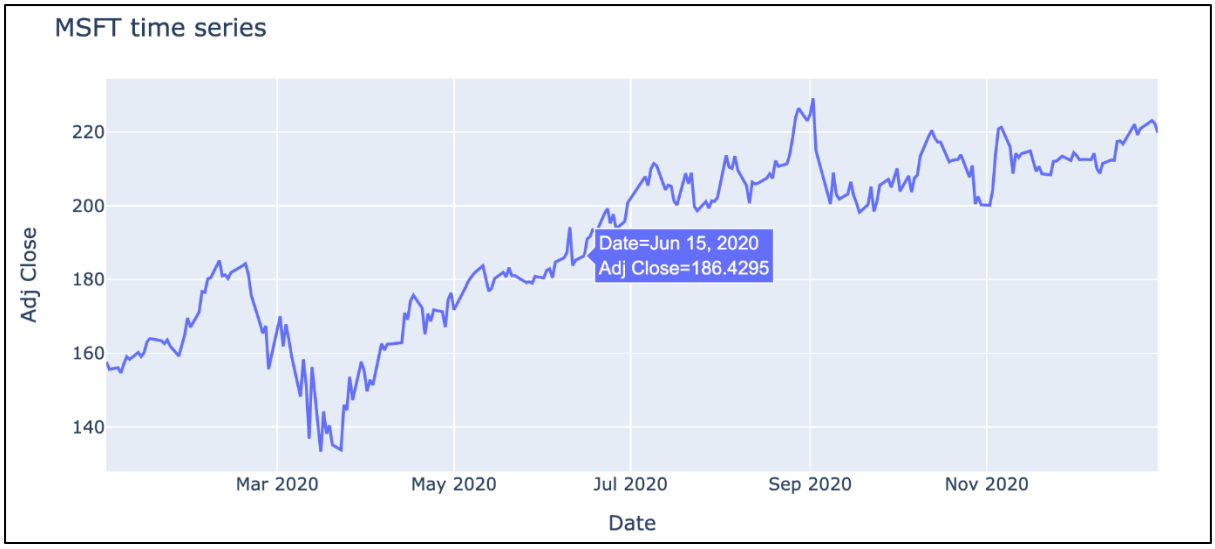

Unemployment rate - Month plot
Unemployment rate (%)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

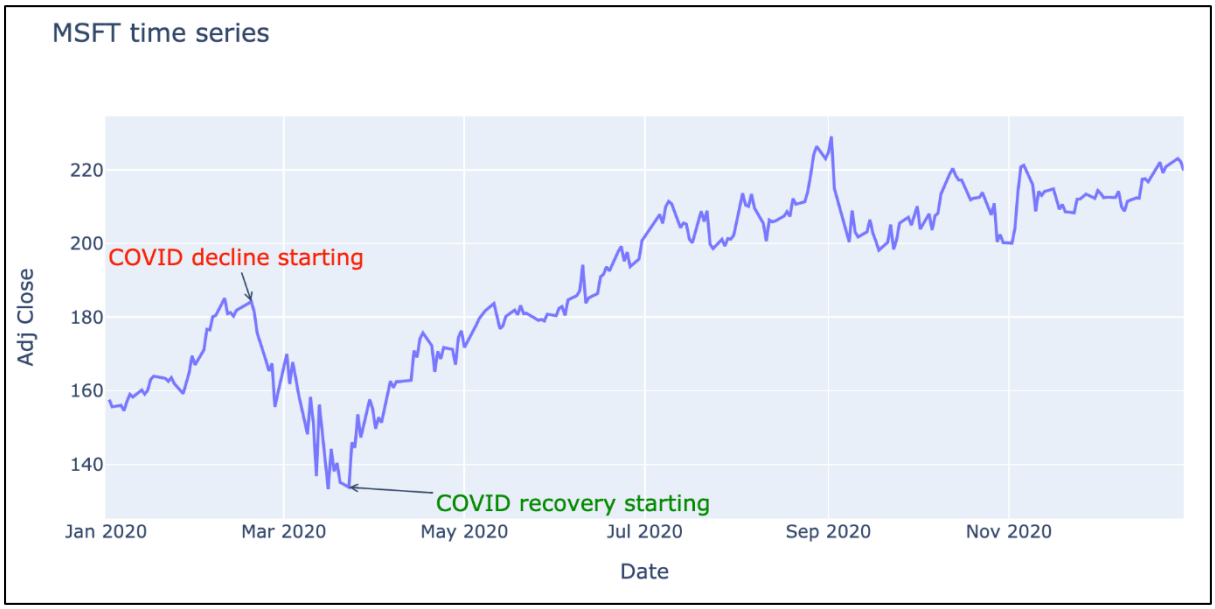

Unemployment rate - Quarter plot
Unemployment rate (%)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
q1
q2
q3
q4

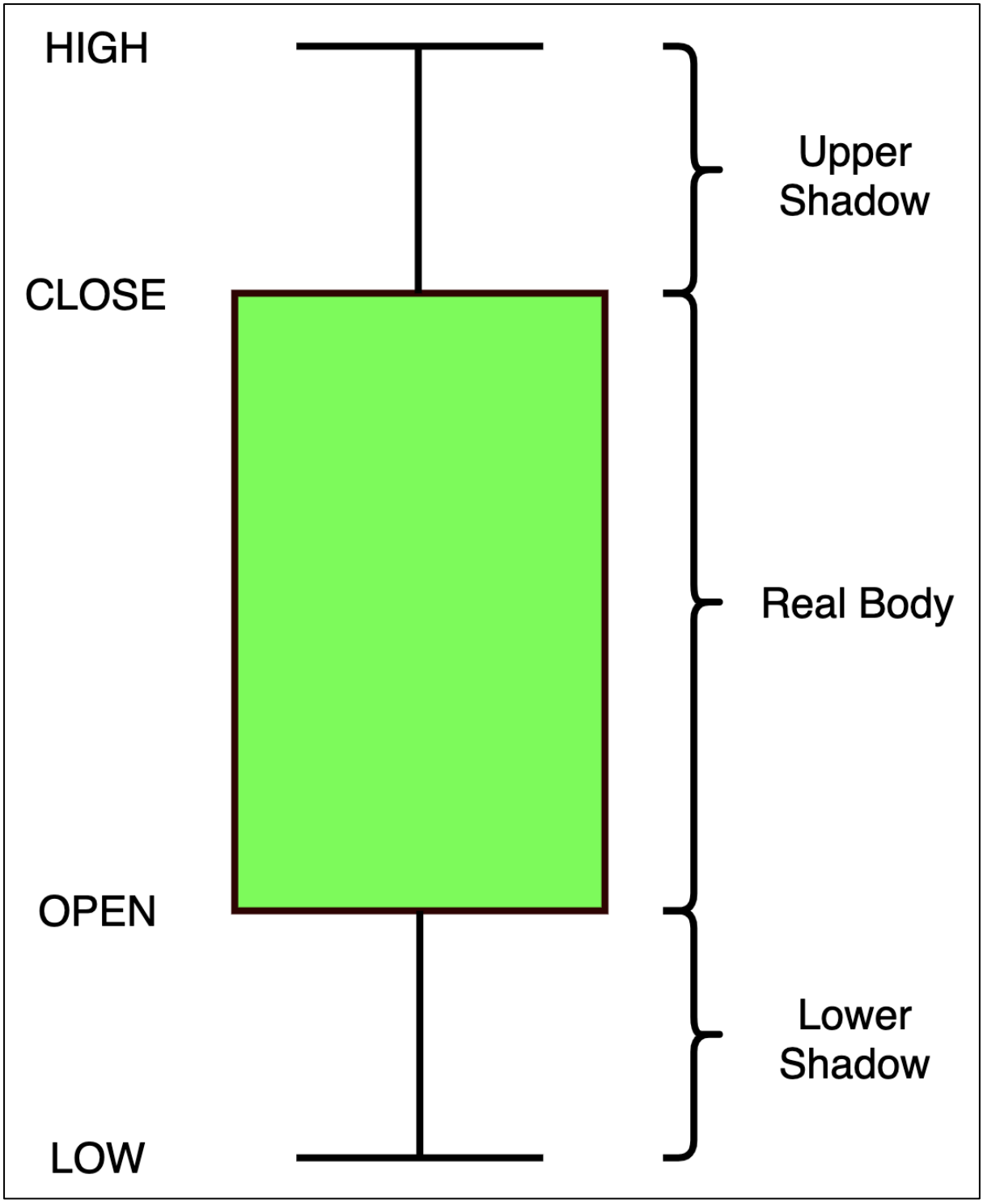

Unemployment rate - Polar seasonal plot
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
3 3.5 4 4.5 5 5.5 6 6.5 7
year
2014
2015
2016
2017
2018
2019


MSFT time series
Adj Close
simple_rtn
200
150
0.1
0
−0.1
Mar 2020
May 2020
Jul 2020
Sep 2020
Nov 2020


MSFT time series
Date
1 January 2020
1 March 2020
1 May 2020
1 July 2020
1 September 2020
1 November 2020
Adj Close
220
200
180
160
140
Drag the box to change the range above.
1/2020
3/2020
5/2020
7/2020
9/2020
11/2020
1/2021

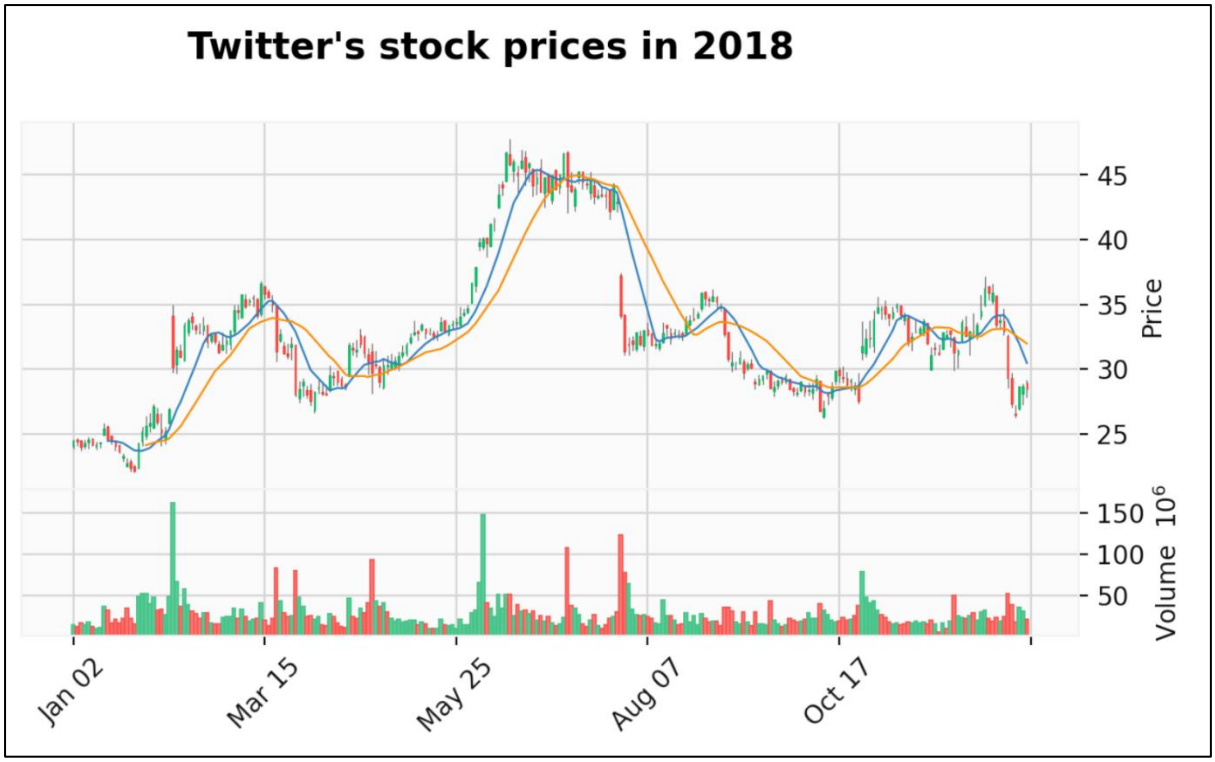

MSFT time series
Adj Close
220
200
180
160
140
Date=Jun 15, 2020
Adj Close=186.4295
Mar 2020
May 2020
Jul 2020
Sep 2020
Nov 2020
Date


MSFT time series
Adj Close
220
200
180
160
140
COVID decline starting
COVID recovery starting
Jan 2020
Mar 2020
May 2020
Jul 2020
Sep 2020
Nov 2020
Date

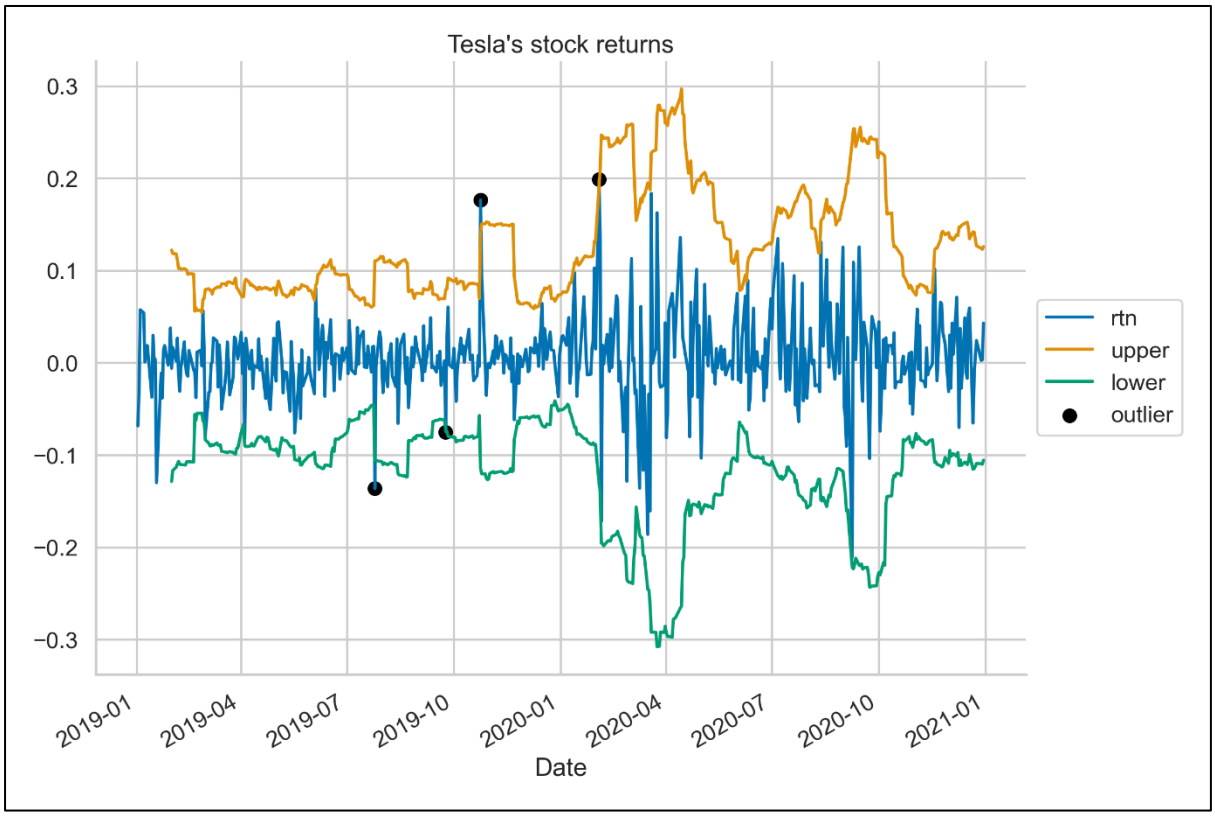

HIGH
CLOSE
OPEN
LOW
Upper Shadow
Real Body
Lower Shadow

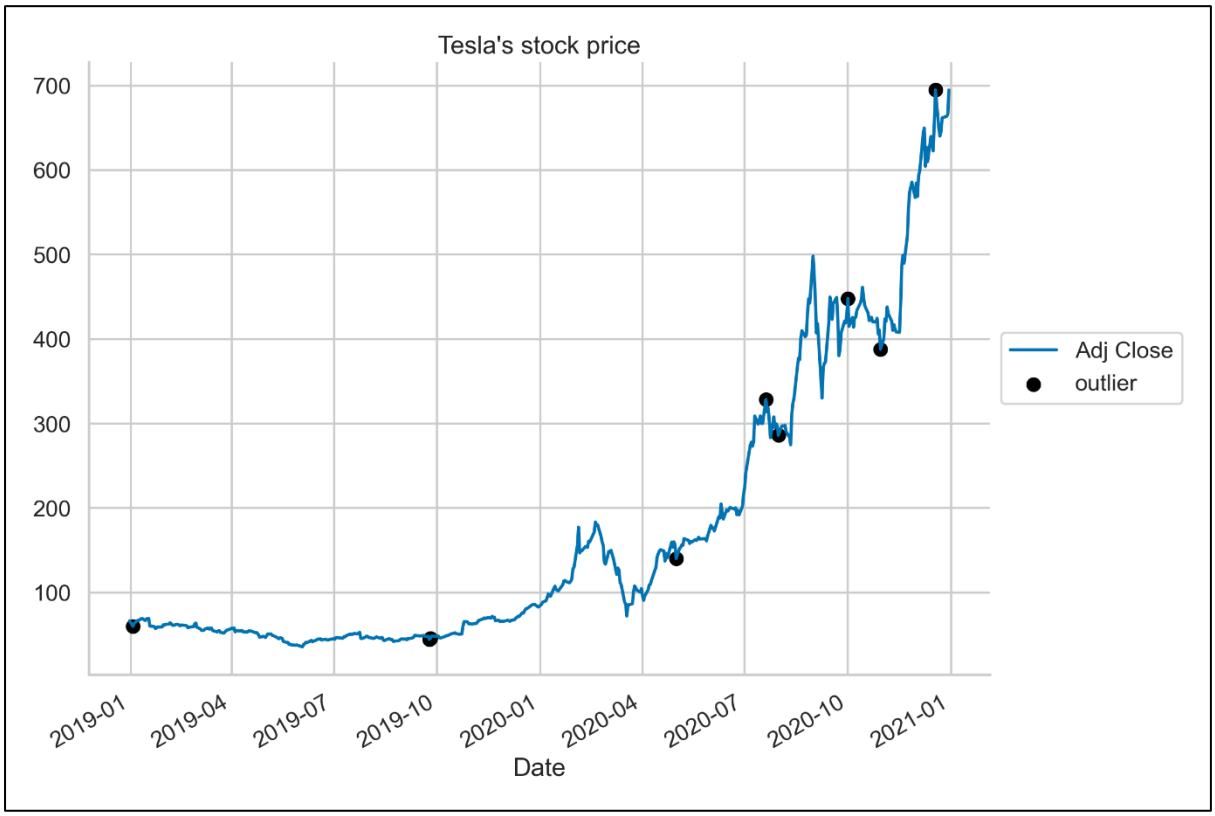

Twitter's Stock Price
Volume
SMA(20)
EMA(20)
Twitter's stock prices in 2018
45
40
35
30
25
Mar 2018
May 2018
Jul 2018
Sep 2018
Nov 2018
150M
100M
50M
0

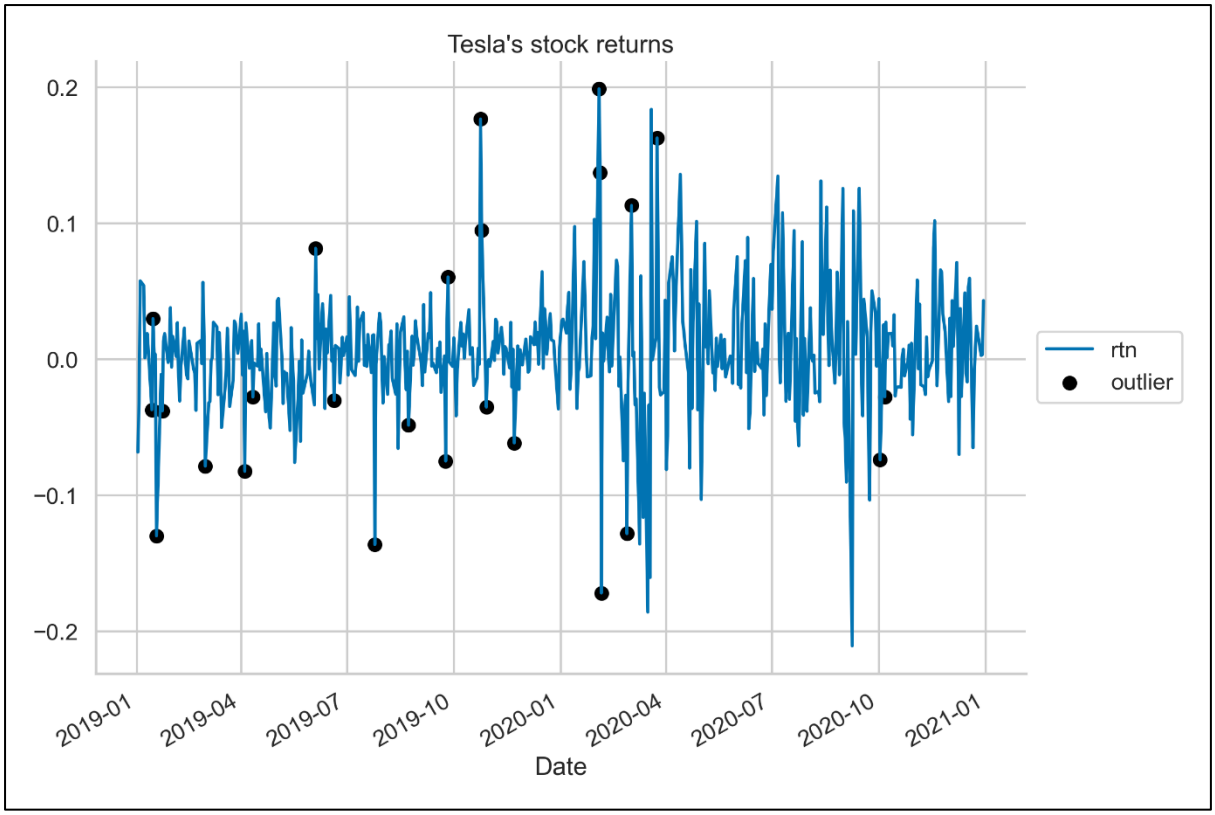

Twitter's stock prices in 2018
Price ($)
45
40
35
30
25
Mar 2018
May 2018
Jul 2018
Sep 2018
Nov 2018


Twitter's stock prices in 2018
45
40
35
30
25
Price
150
100
50
Volume 10^6
Jan 02
Mar 15
May 25
Aug 07
Oct 17

Chapter 4: Exploring Financial Time Series Data



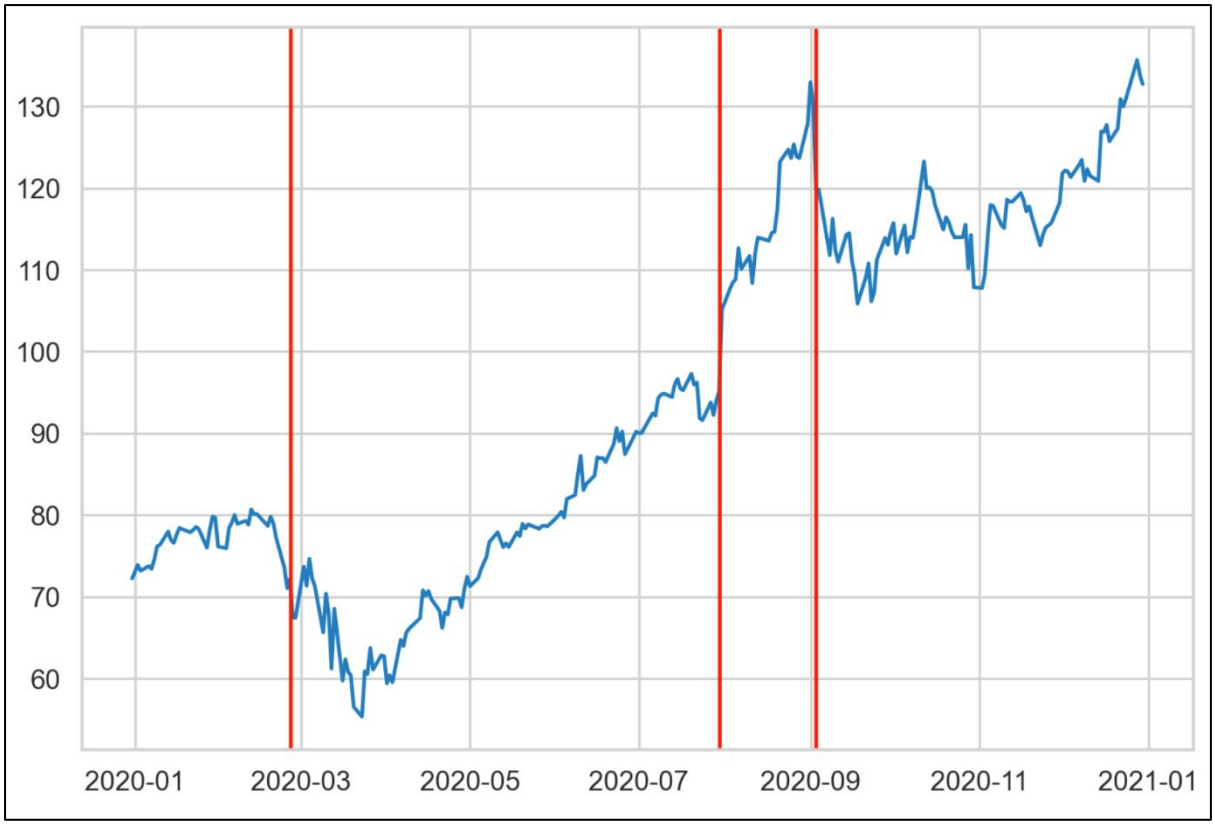


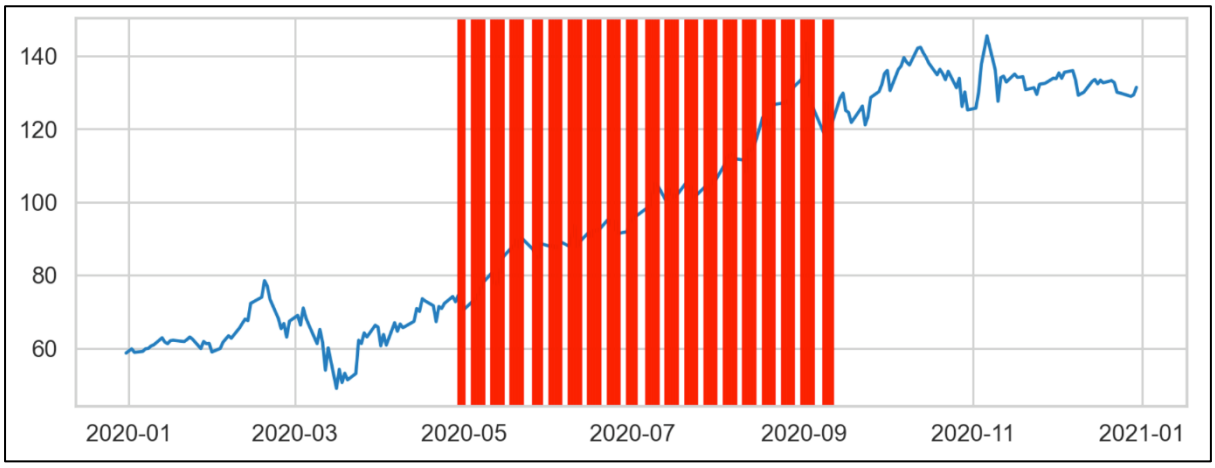


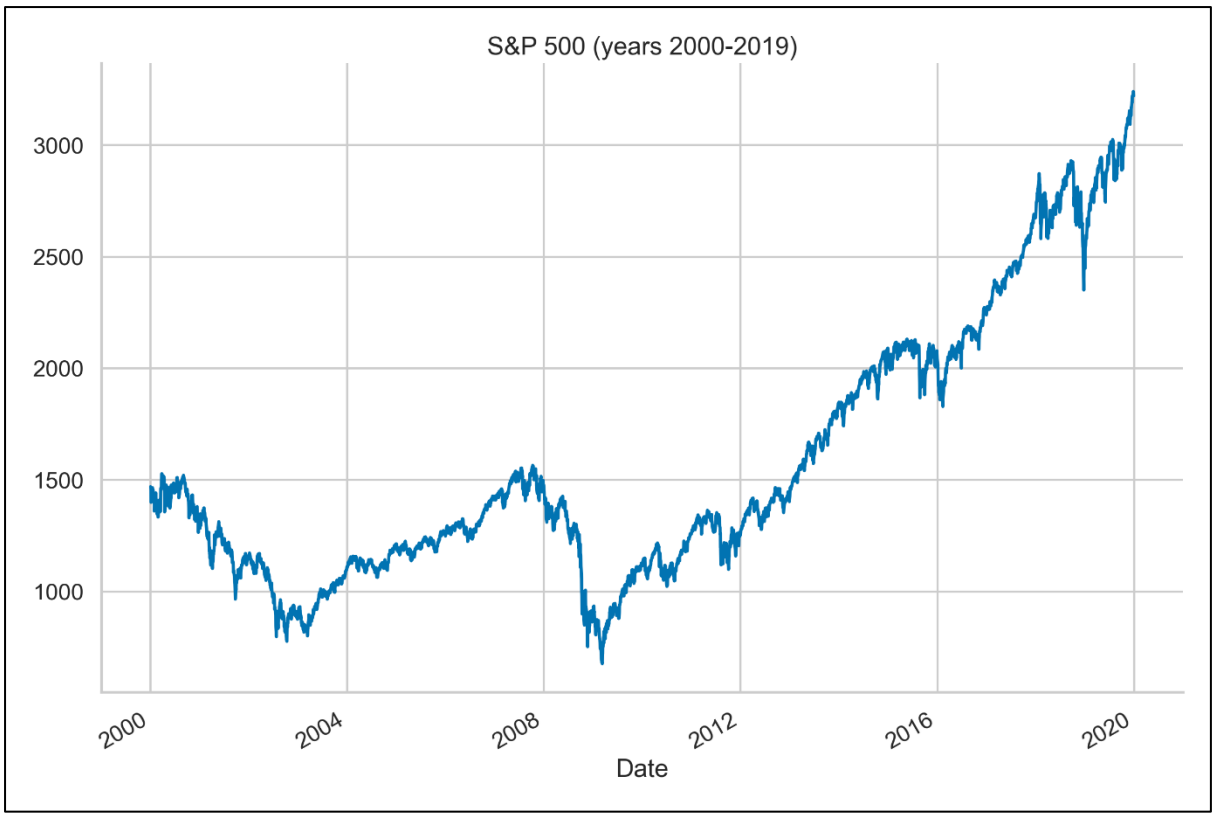
Date	Open	High	Low	Close	Adj Close	Volume	rtn	outlier	outlier_rtn
2019-09-24	48.3	48.4	44.52	44.64	44.64	64457500	-0.07	True	True

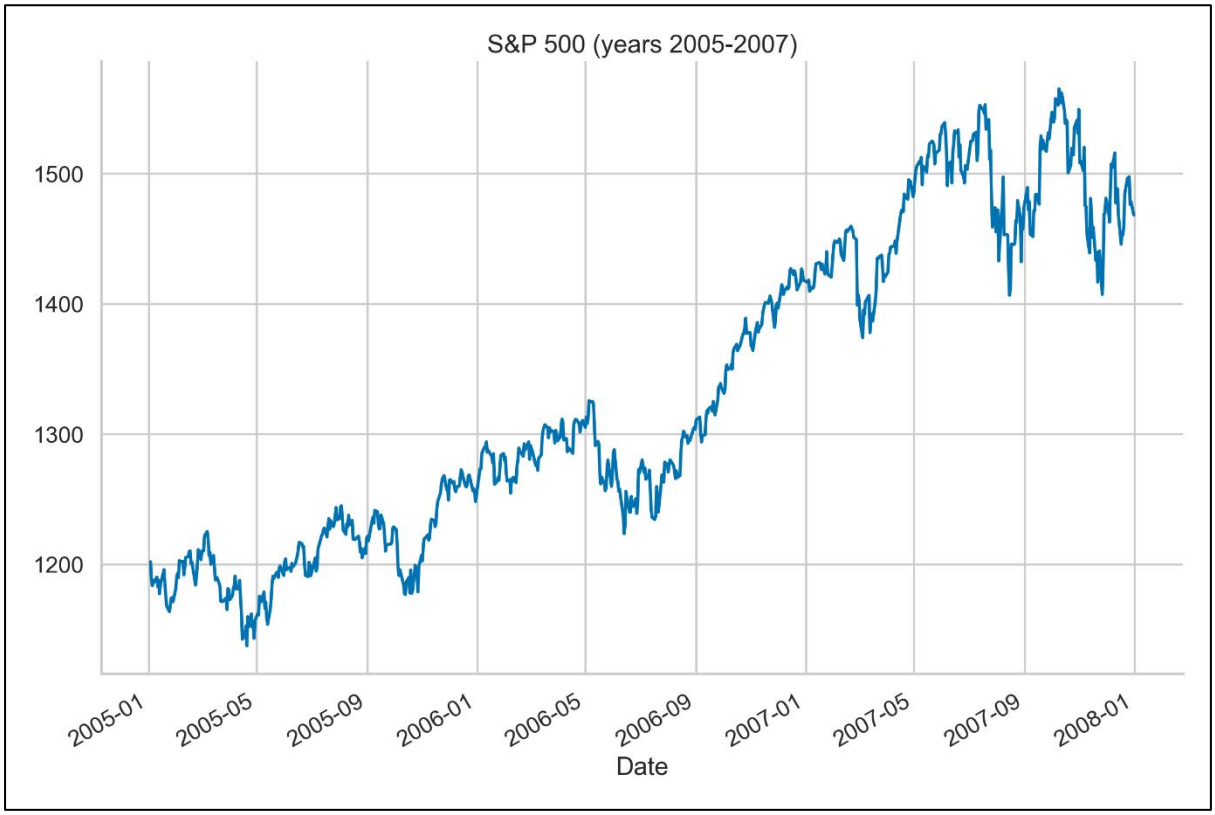

130
120
110
100
90
80
70
60
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01

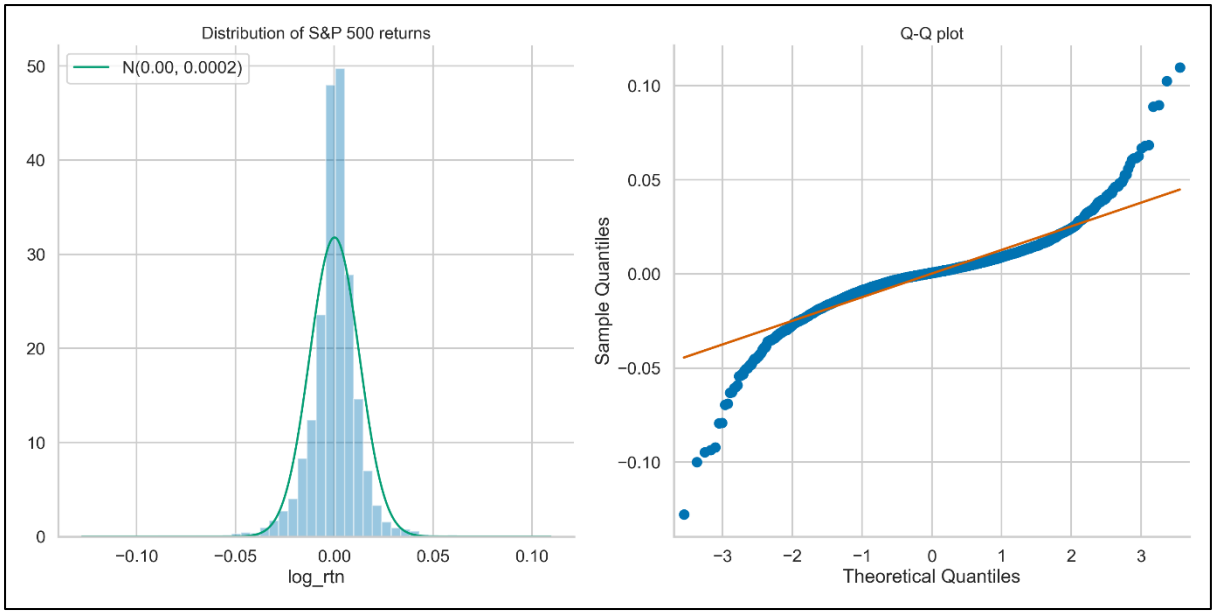

130
120
110
100
90
80
70
60
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01

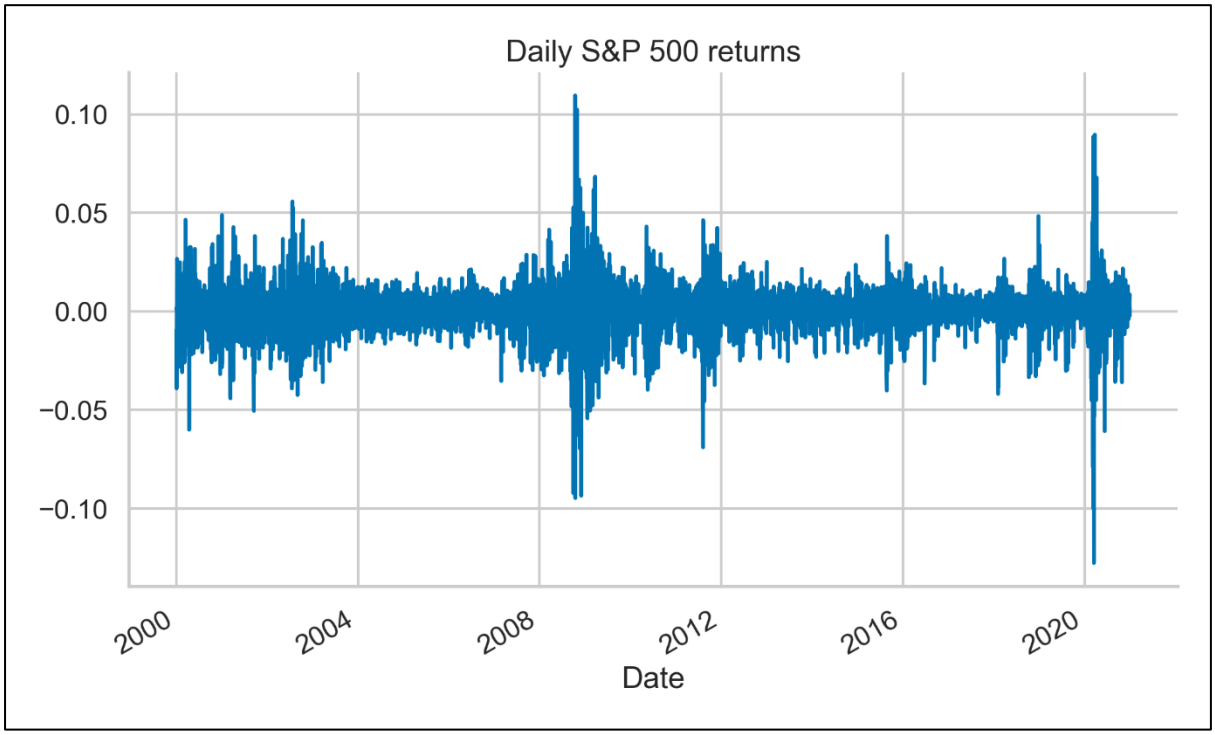

130
120
110
100
90
80
70
60
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01

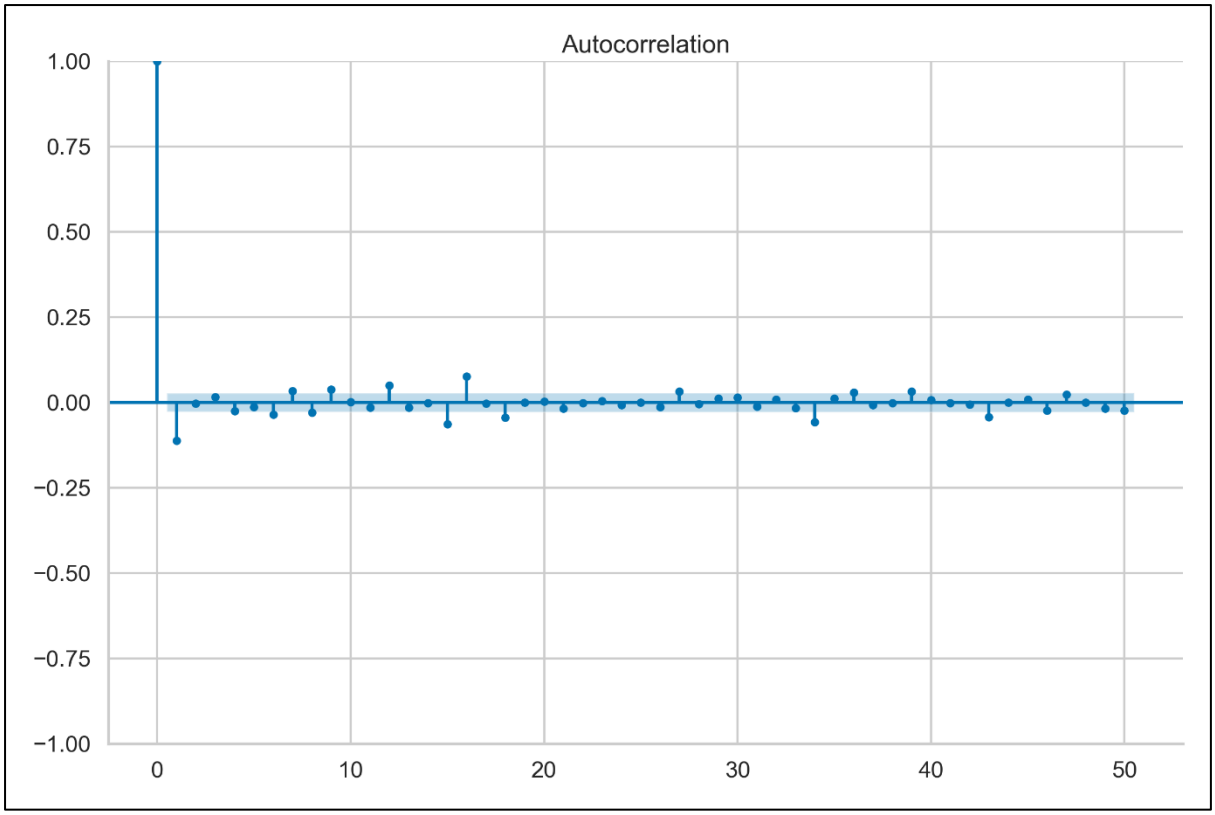

140
120
100
80
60
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01

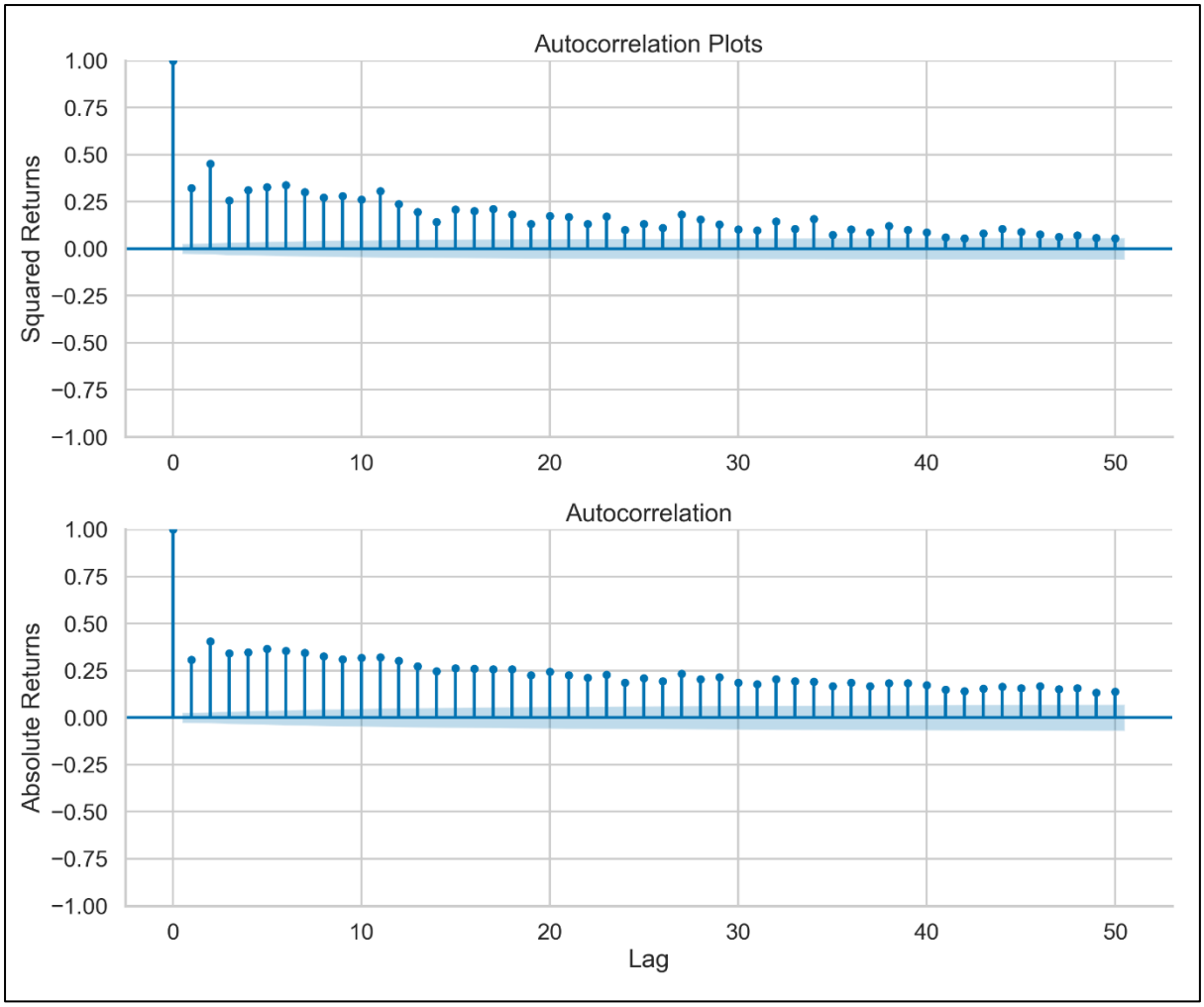

S&P 500 (years 2000-2019)
3000
2500
2000
1500
1000
2000
2004
2008
2012
2016
2020
Date

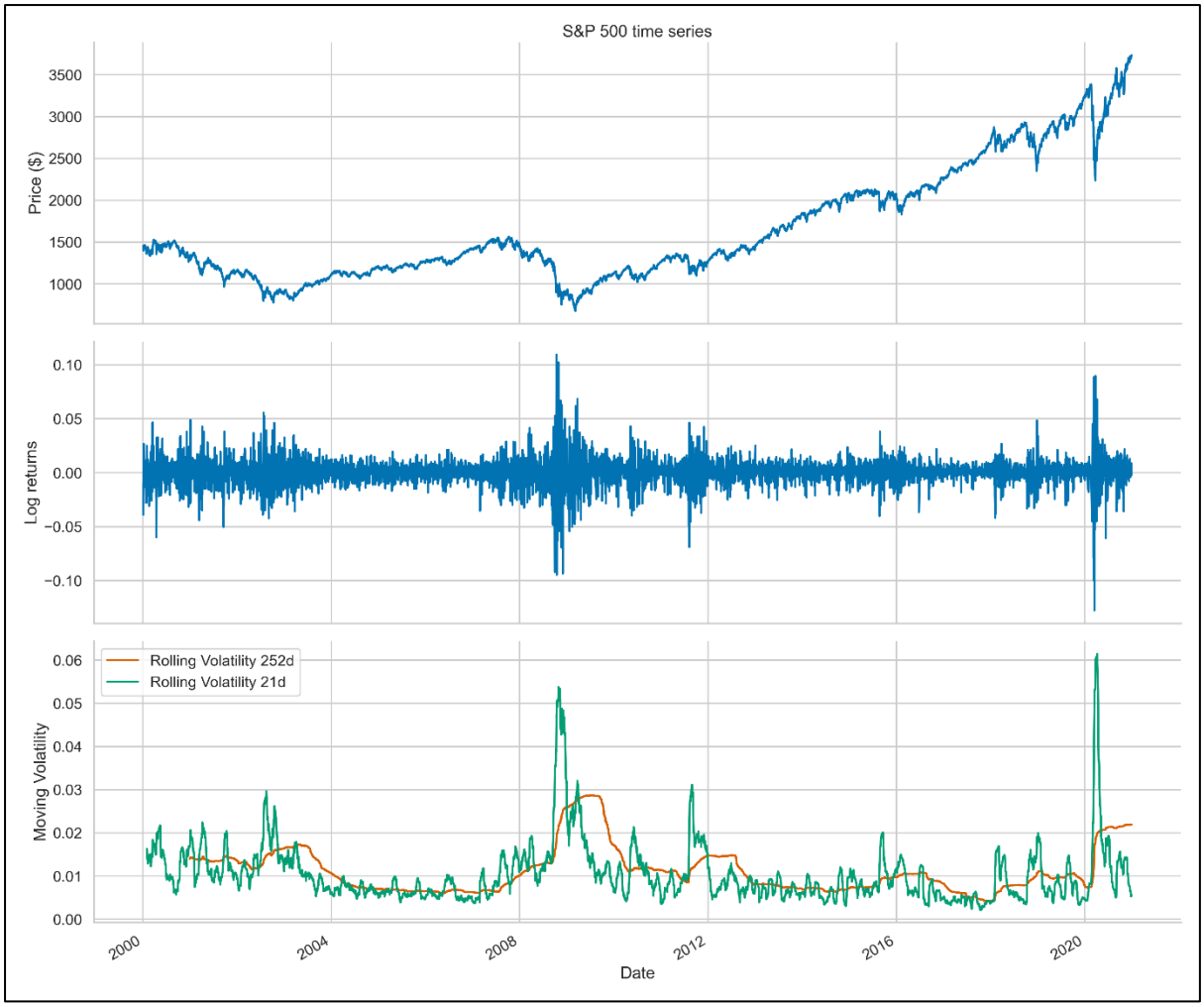

S&P 500 (years 2005-2007)
1500
1400
1300
1200
2005-01
2005-05
2005-09
2006-01
2006-05
2006-09
2007-01
2007-05
2007-09
2008-01
Date

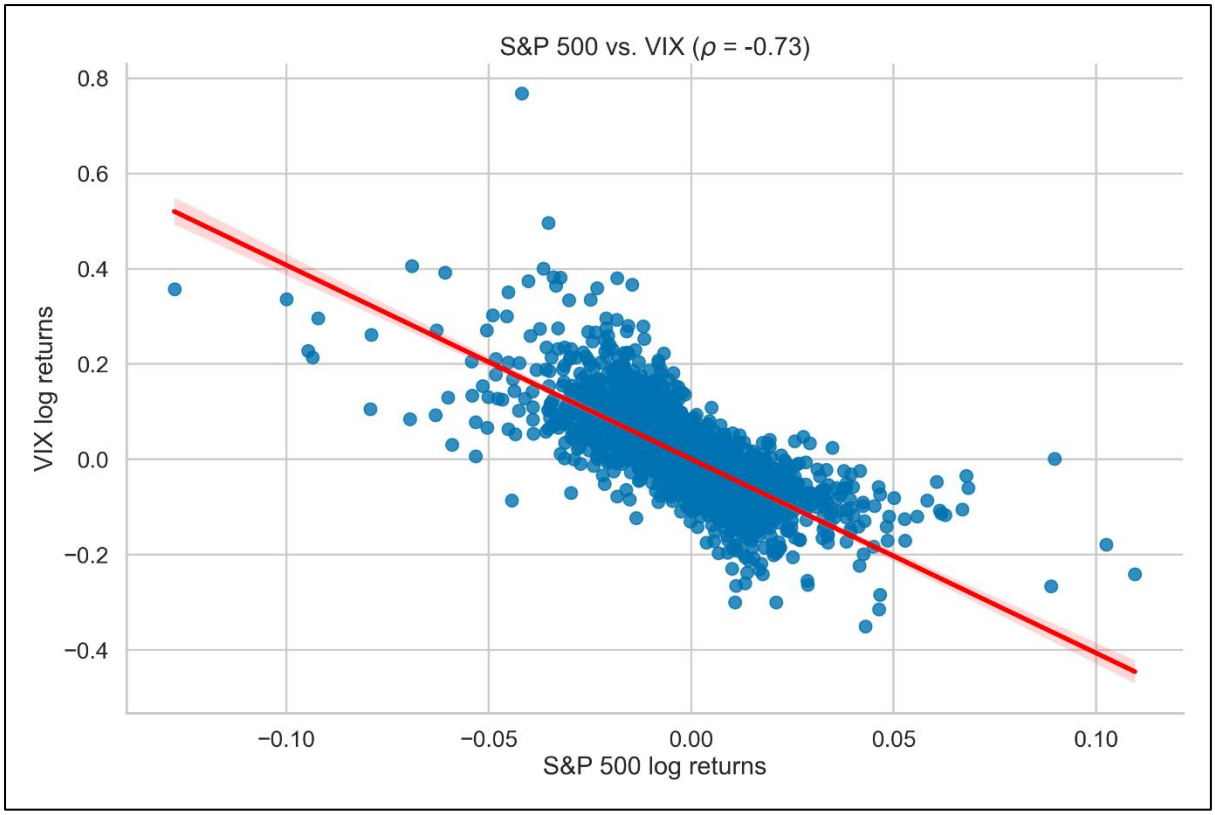

Distribution of S&P 500 returns
N(0.00, 0.0002)
log_rtn
Q-Q plot
Sample Quantiles
Theoretical Quantiles


Daily S&P 500 returns
Date

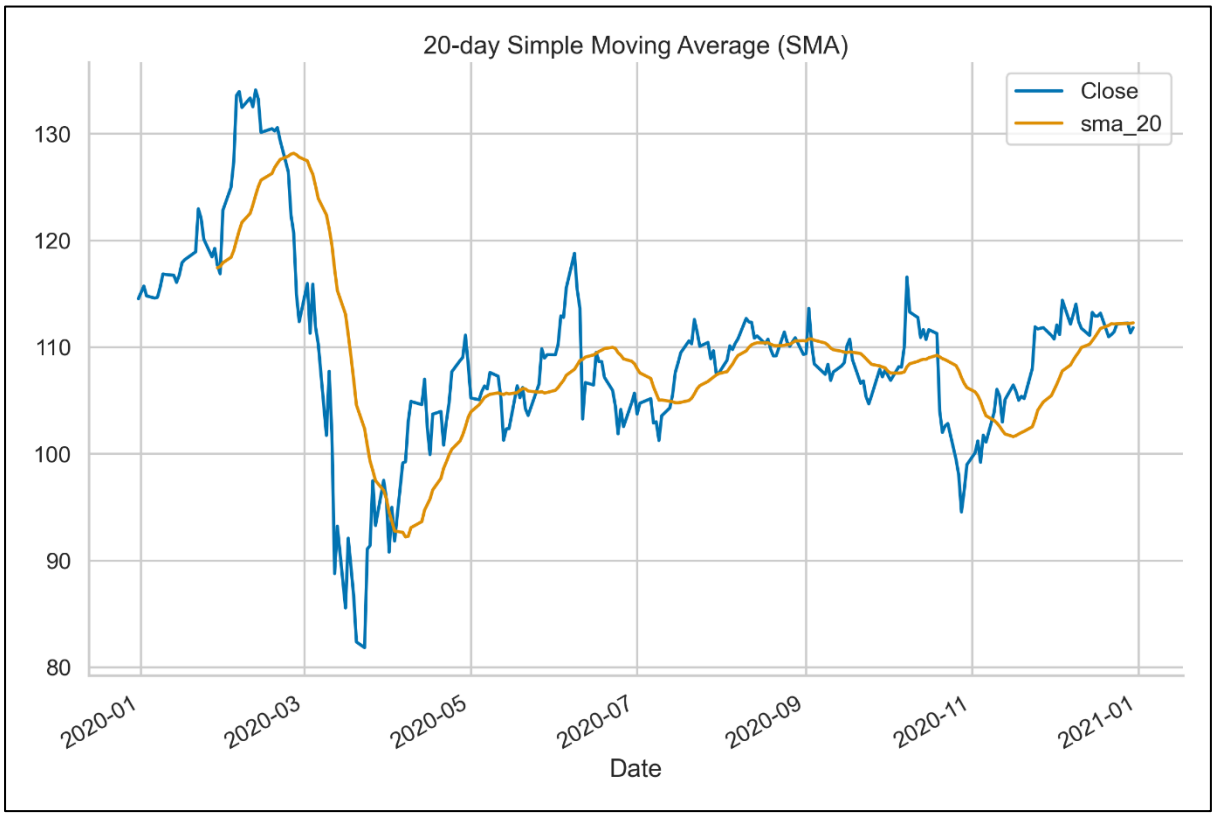

Autocorrelation
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
10
20
30
40
50

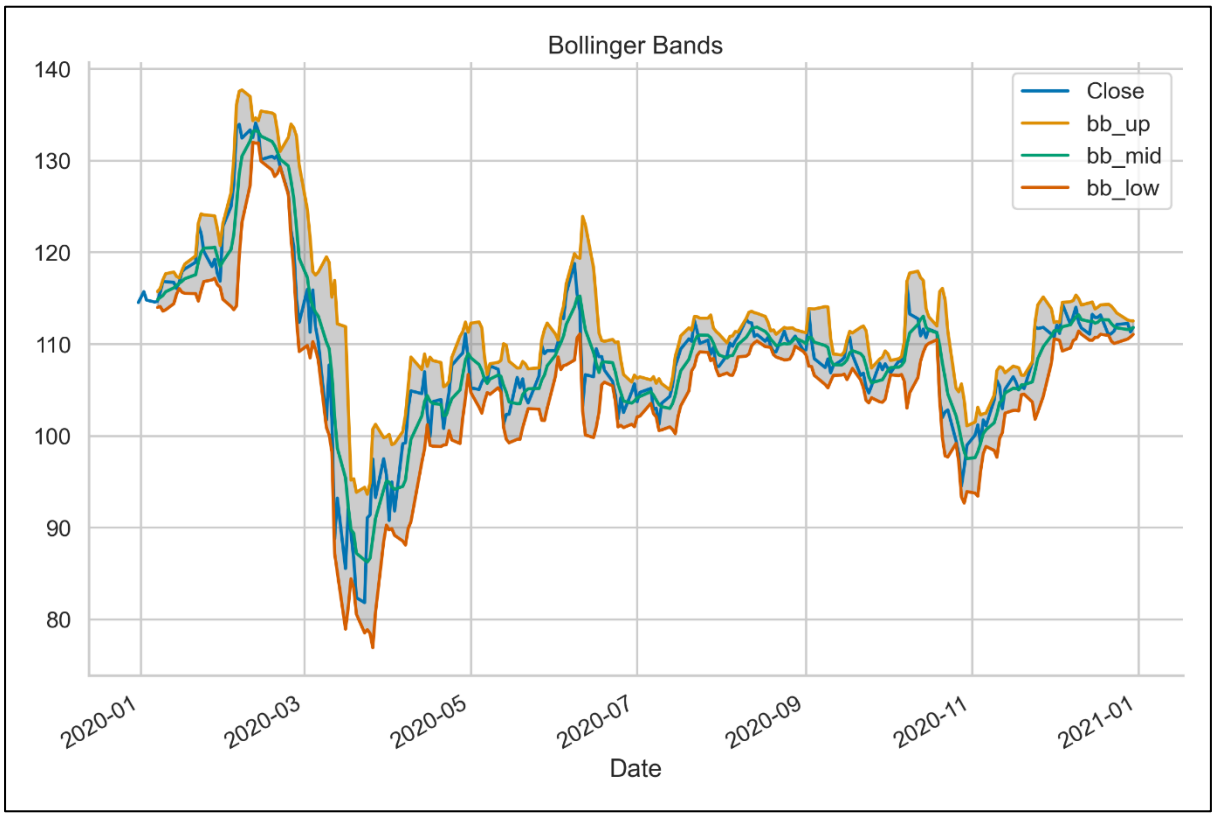

Autocorrelation Plots
Squared Returns
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
10
20
30
40
50
Autocorrelation
Absolute Returns
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
10
20
30
40
50
Lag

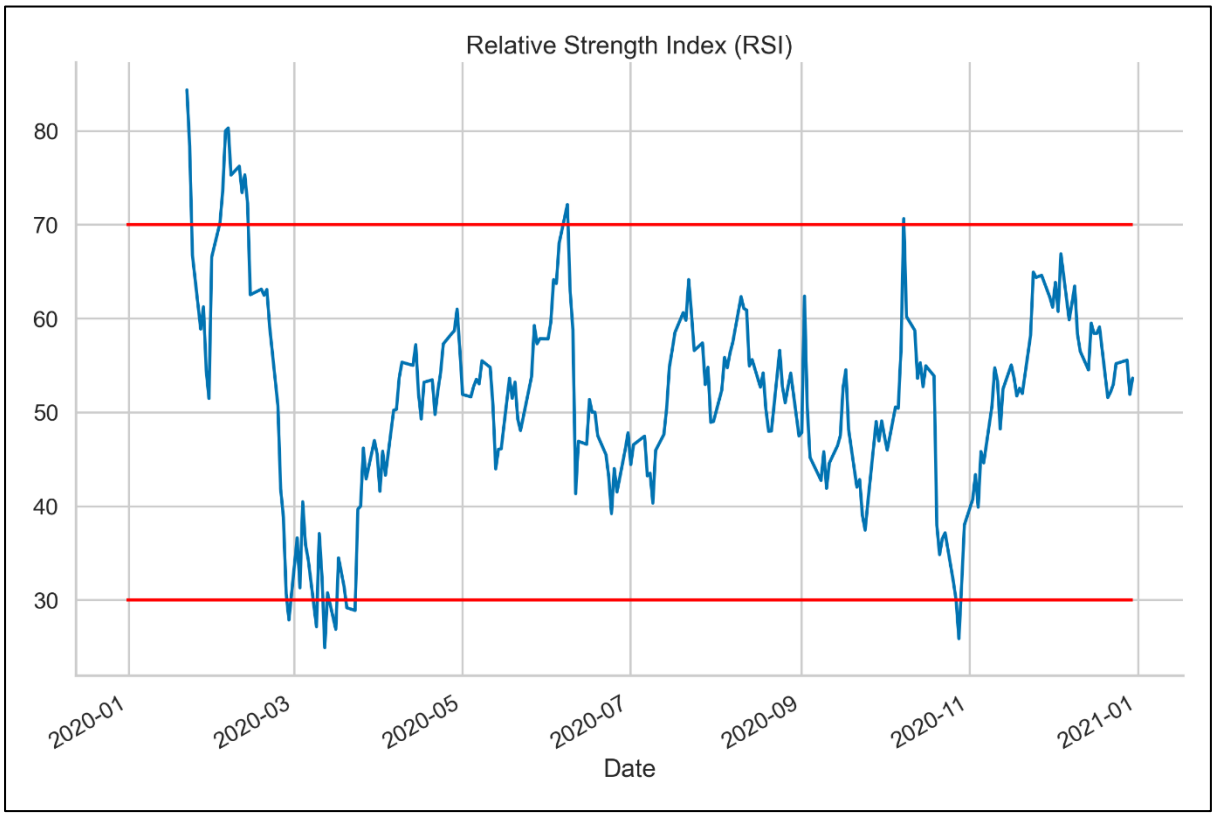

S&P 500 time series
Price ($)
3500
3000
2500
2000
1500
1000
Log returns
0.10
0.05
0.00
−0.05
−0.10
Moving Volatility
Rolling Volatility 252d
Rolling Volatility 21d
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2000
2004
2008
2012
2016
2020
Date

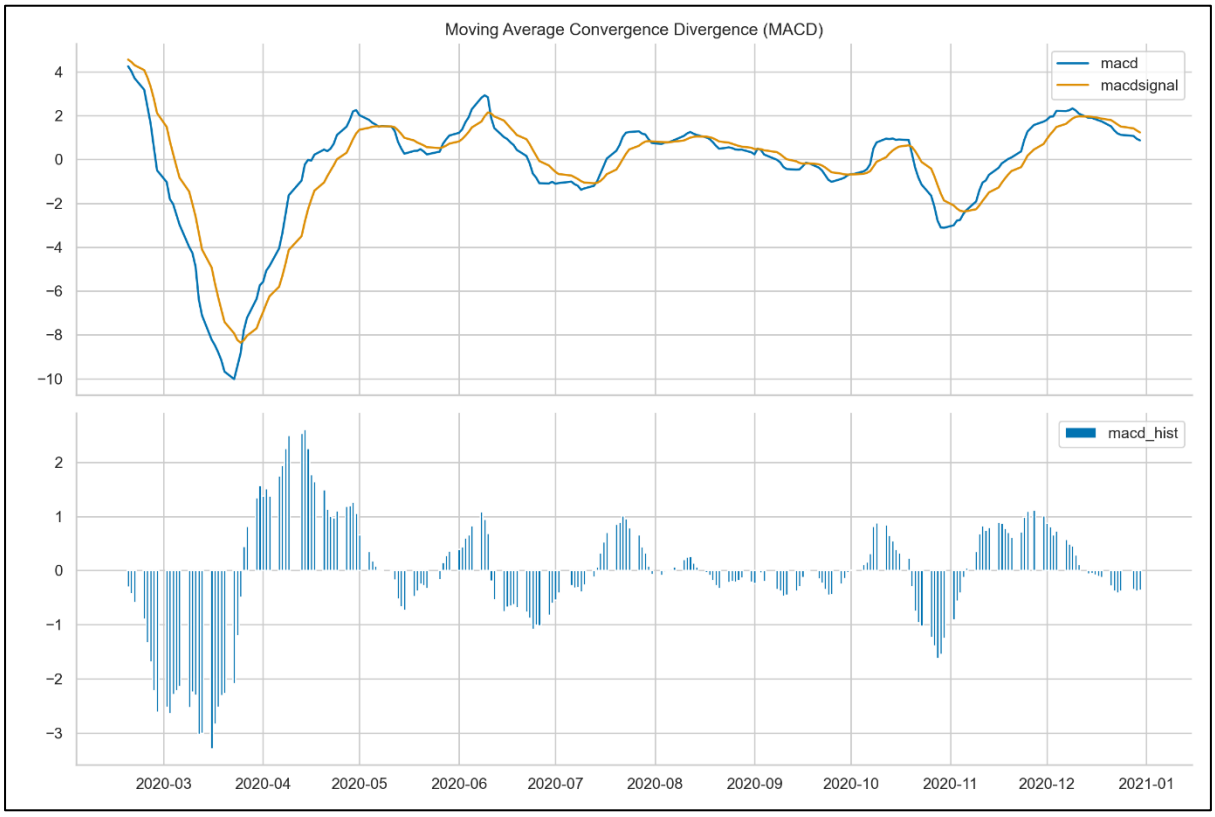

S&P 500 vs. VIX (ρ = -0.73)
VIX log returns
S&P 500 log returns
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.10
−0.05
0.00
0.05
0.10

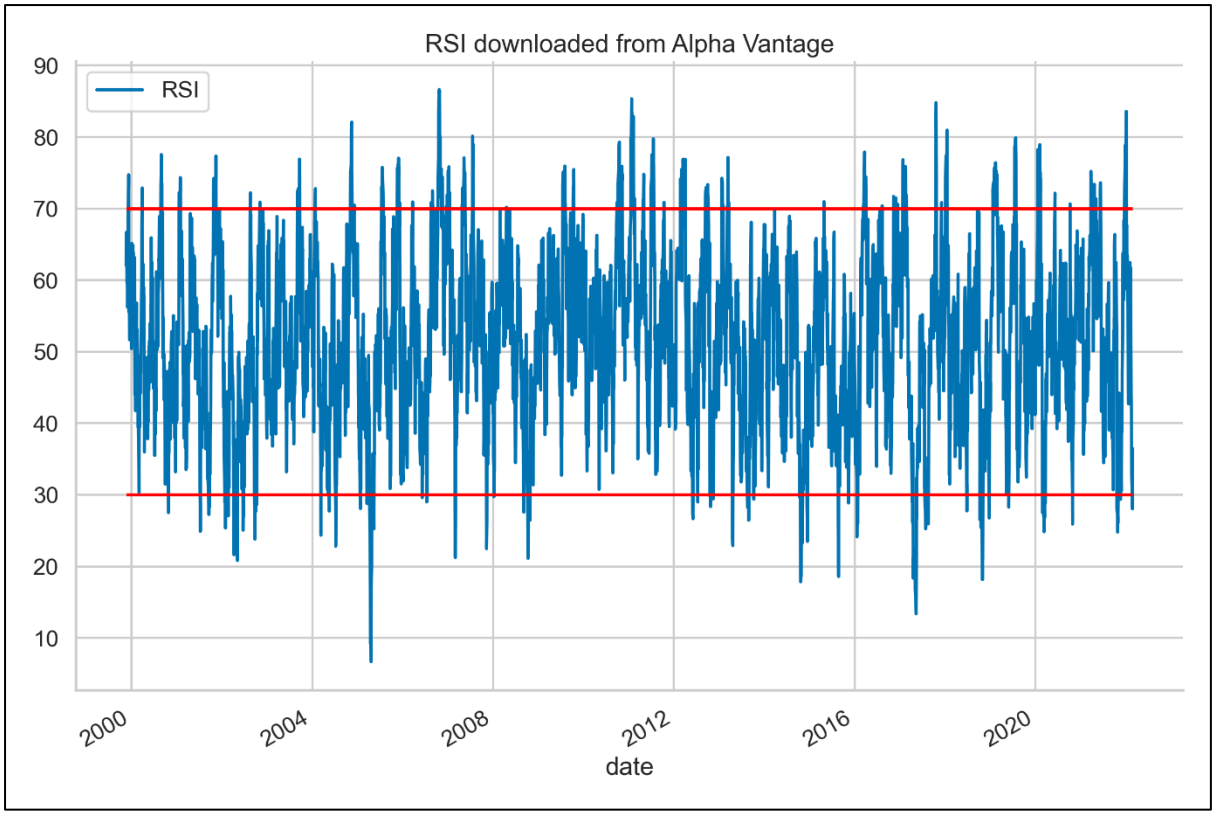
Chapter 5: Technical Analysis and Building Interactive Dashboards

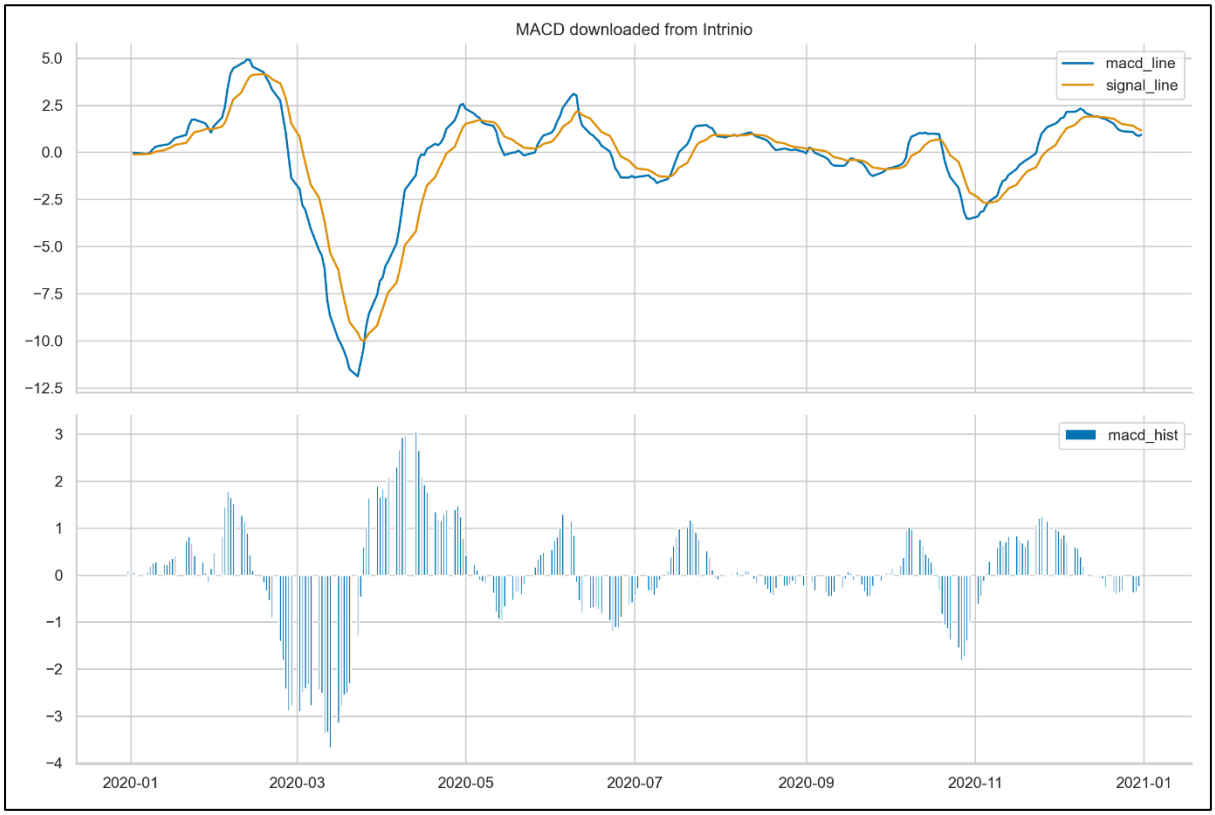




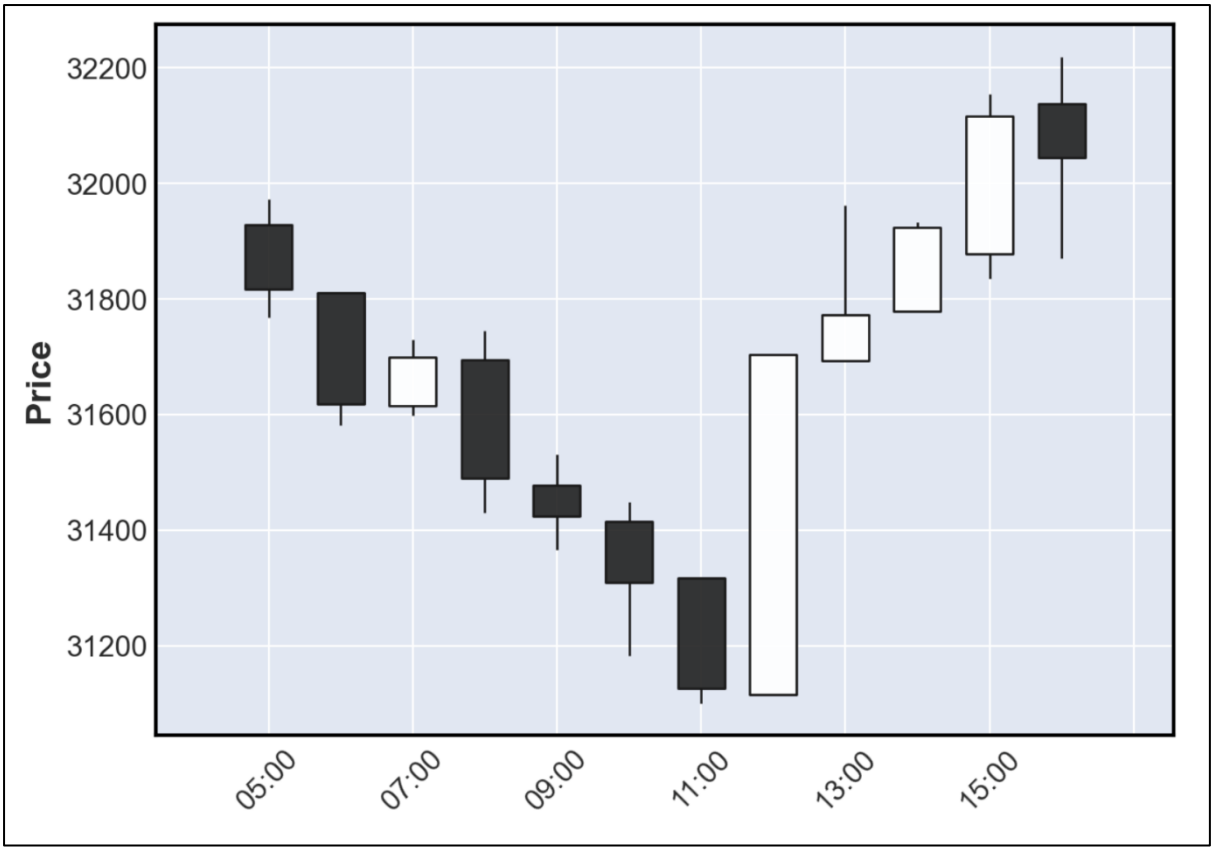

Relative Strength Index (RSI)
80
70
60
50
40
30
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01
Date


Moving Average Convergence Divergence (MACD)
macd
macdsignal
4
2
0
−2
−4
−6
−8
−10
macd_hist
2
1
0
−1
−2
−3
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
2020-09
2020-10
2020-11
2020-12
2021-01

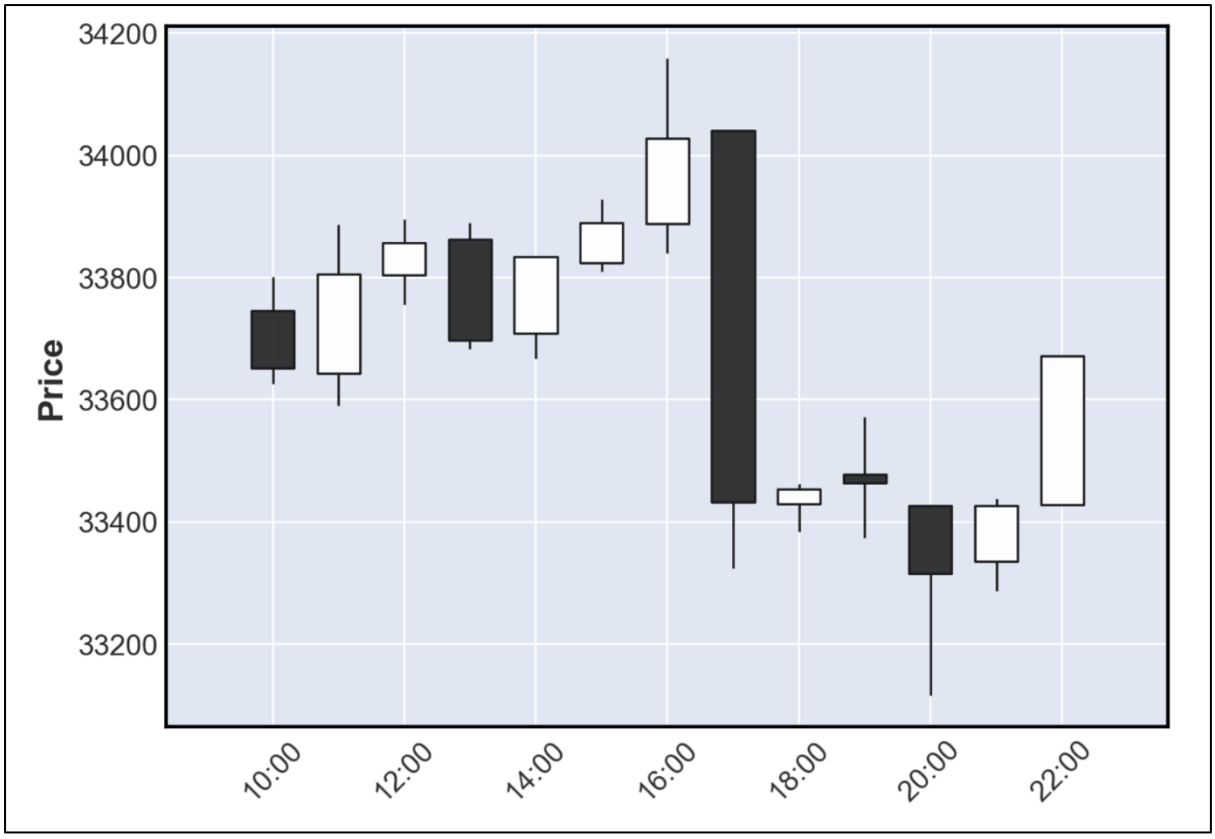

RSI downloaded from Alpha Vantage
RSI
90
80
70
60
50
40
30
20
10
2000
2004
2008
2012
2016
2020
date


MACD downloaded from Intrinio
macd_line
signal_line
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
macd_hist
3
2
1
0
−1
−2
−3
−4
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01

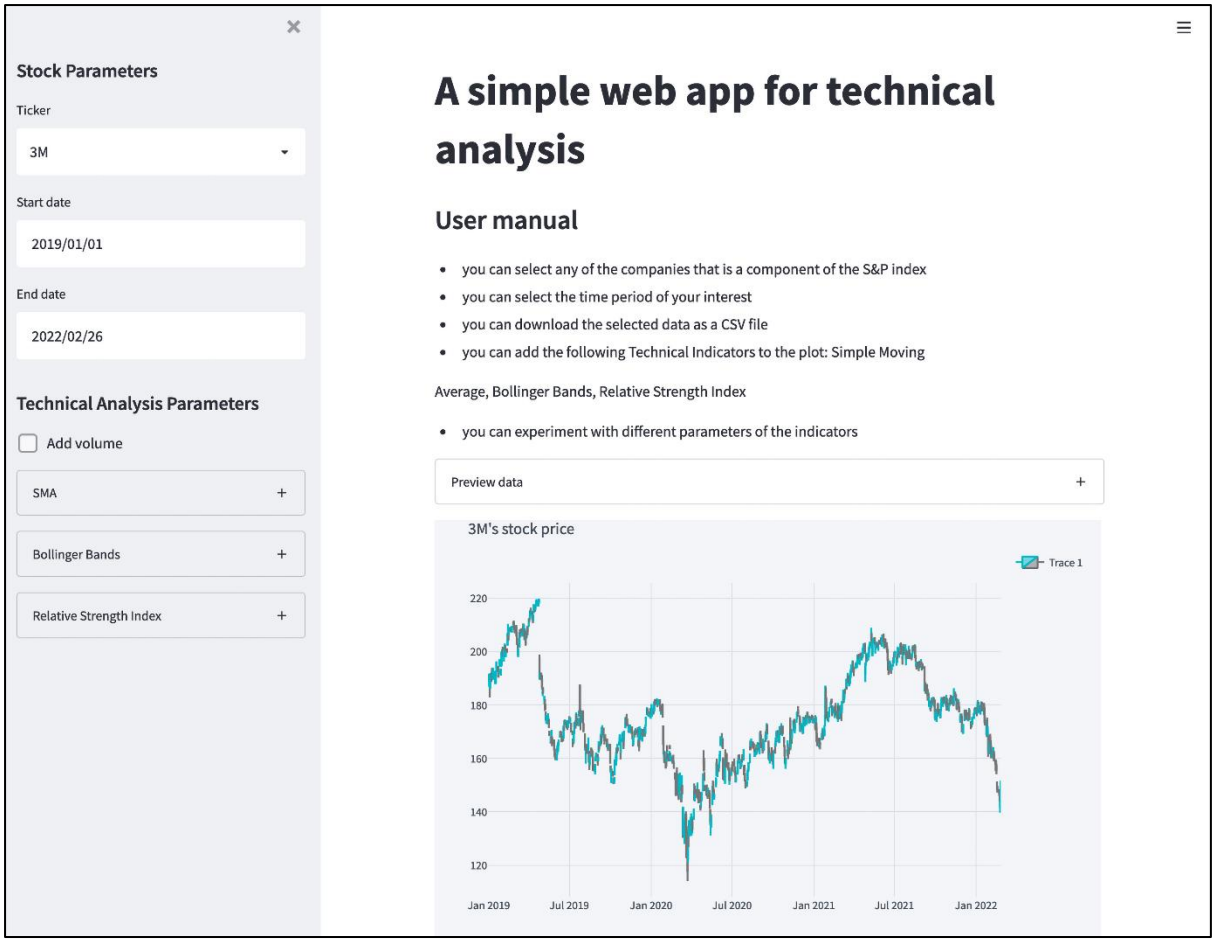
	Open	High	Low	Close	Adj Close	Volume	3_line_strike
2021-06-06 14:00:00+00:00	35655.64	36185.68	35544.90	36124.10	36124.10	131508224	-100
2021-06-13 15:00:00+00:00	35807.91	36082.75	35807.91	36082.75	36082.75	0	-100
2021-07-03 17:00:00+00:00	34546.72	34909.26	34546.72	34793.32	34793.32	24389632	-100
2021-07-08 19:00:00+00:00	32843.35	33088.62	32657.65	33013.81	33013.81	343470080	-100
2021-07-16 12:00:00+00:00	31115.04	31703.58	31115.04	31703.58	31703.58	351070208	-100

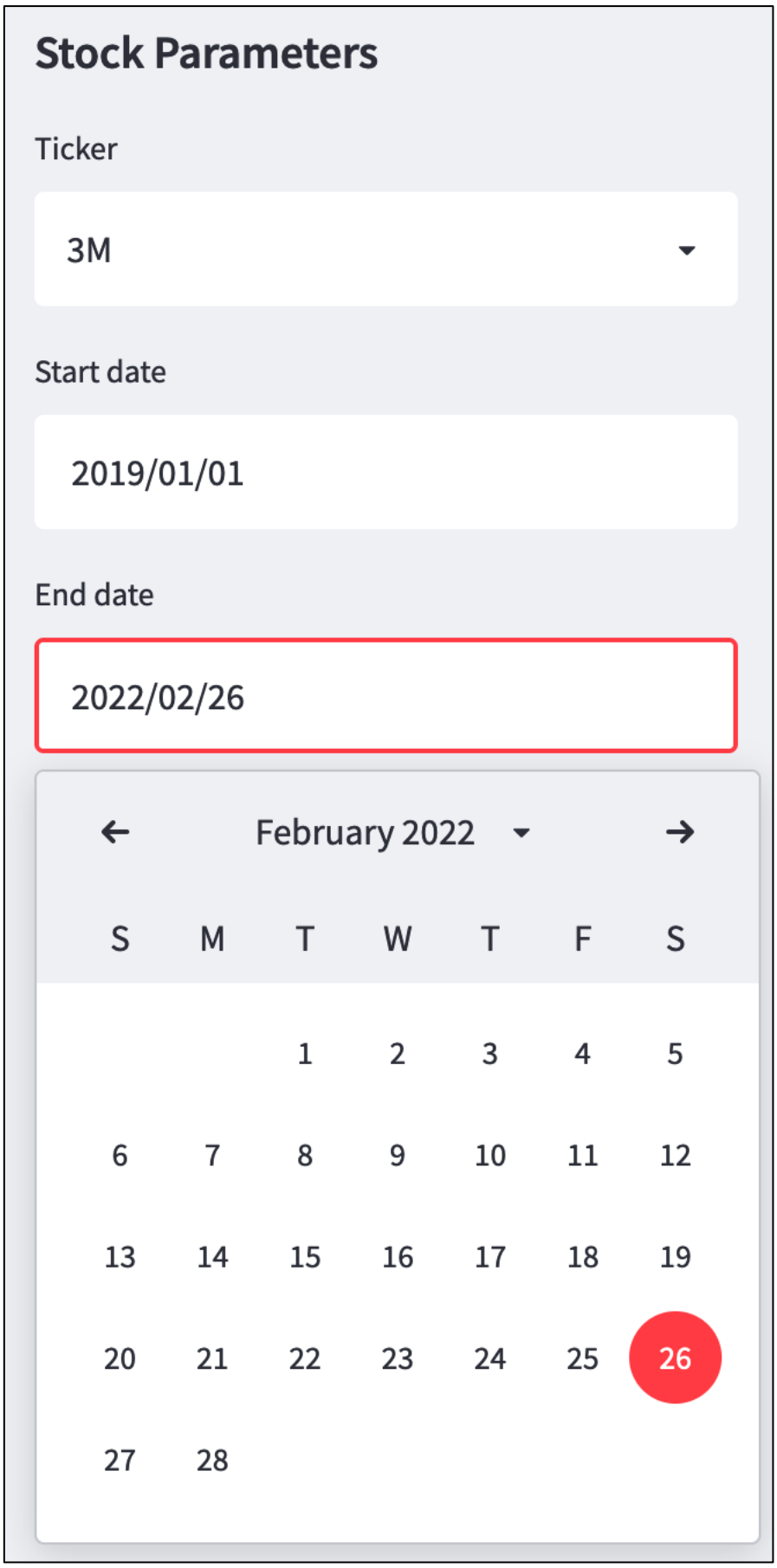


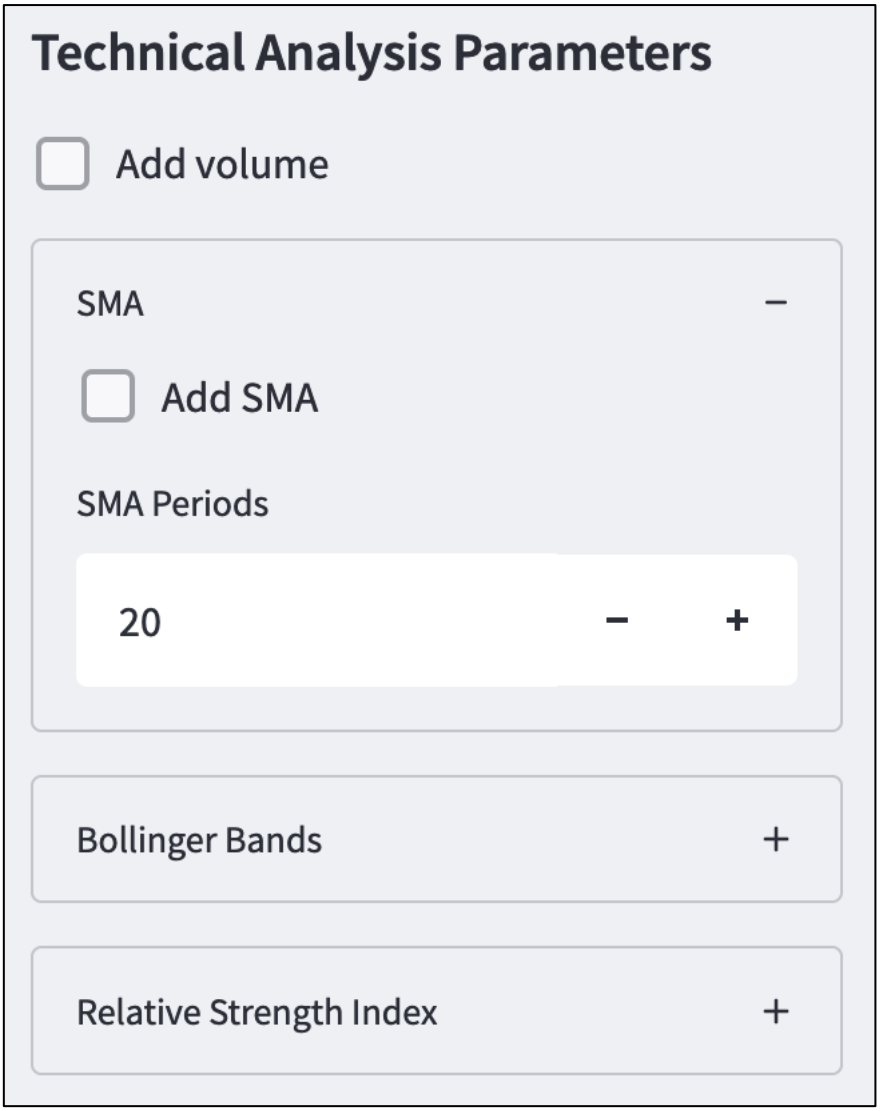
	Open	High	Low	Close	Adj Close	Volume	3_line_strike
2021-06-08 06:00:00+00:00	32932.72	32971.01	32620.67	32637.23	32637.23	359575552	100
2021-06-30 08:00:00+00:00	35244.68	35279.57	34594.18	34654.98	34654.98	0	100
2021-07-02 01:00:00+00:00	33775.50	33775.50	33276.16	33276.16	33276.16	0	100
2021-07-05 11:00:00+00:00	34478.20	34491.51	33429.94	33461.20	33461.20	1175277568	100
2021-07-10 17:00:00+00:00	34041.45	34041.45	33324.12	33432.79	33432.79	0	100



	count	mean	std	min	25%	50%	75%	max
CDL2CROWS	6454.0	-0.11	3.29	-100.0	0.0	0.0	0.0	0.0
CDL3BLACKCROWS	6454.0	-0.06	2.49	-100.0	0.0	0.0	0.0	0.0
CDL3INSIDE	6454.0	0.03	10.99	-100.0	0.0	0.0	0.0	100.0
CDL3LINESTRIKE	6454.0	0.08	6.70	-100.0	0.0	0.0	0.0	100.0
CDL3OUTSIDE	6454.0	0.26	23.39	-100.0	0.0	0.0	0.0	100.0
CDL3STARSINSOUTH	6454.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0
CDL3WHITESOLDIERS	6454.0	0.19	4.31	0.0	0.0	0.0	0.0	100.0
CDLABANDONEDBABY	6454.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0
CDLADVANCEBLOCK	6454.0	-1.30	11.33	-100.0	0.0	0.0	0.0	0.0
CDLBELTHOLD	6454.0	-0.20	42.63	-100.0	0.0	0.0	0.0	100.0


Stock Parameters
Ticker
3M
Start date
2019/01/01
End date
2022/02/26
Technical Analysis Parameters
Add volume
SMA
Bollinger Bands
Relative Strength Index
A simple web app for technical analysis
User manual
you can select any of the companies that is a component of the S&P index
you can select the time period of your interest
you can download the selected data as a CSV file
you can add the following Technical Indicators to the plot: Simple Moving
Average, Bollinger Bands, Relative Strength Index
you can experiment with different parameters of the indicators
Preview data
3M's stock price
Trace 1
220
200
180
160
140
120
Jan 2019
Jul 2019
Jan 2020
Jul 2020
Jan 2021
Jul 2021
Jan 2022


Stock Parameters
Ticker
3M
Start date
2019/01/01
End date
2022/02/26
February 2022
S M T W T F S
1 2 3 4 5
6 7 8 9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28


Technical Analysis Parameters
Add volume
SMA
Add SMA
SMA Periods
20
Bollinger Bands
Relative Strength Index

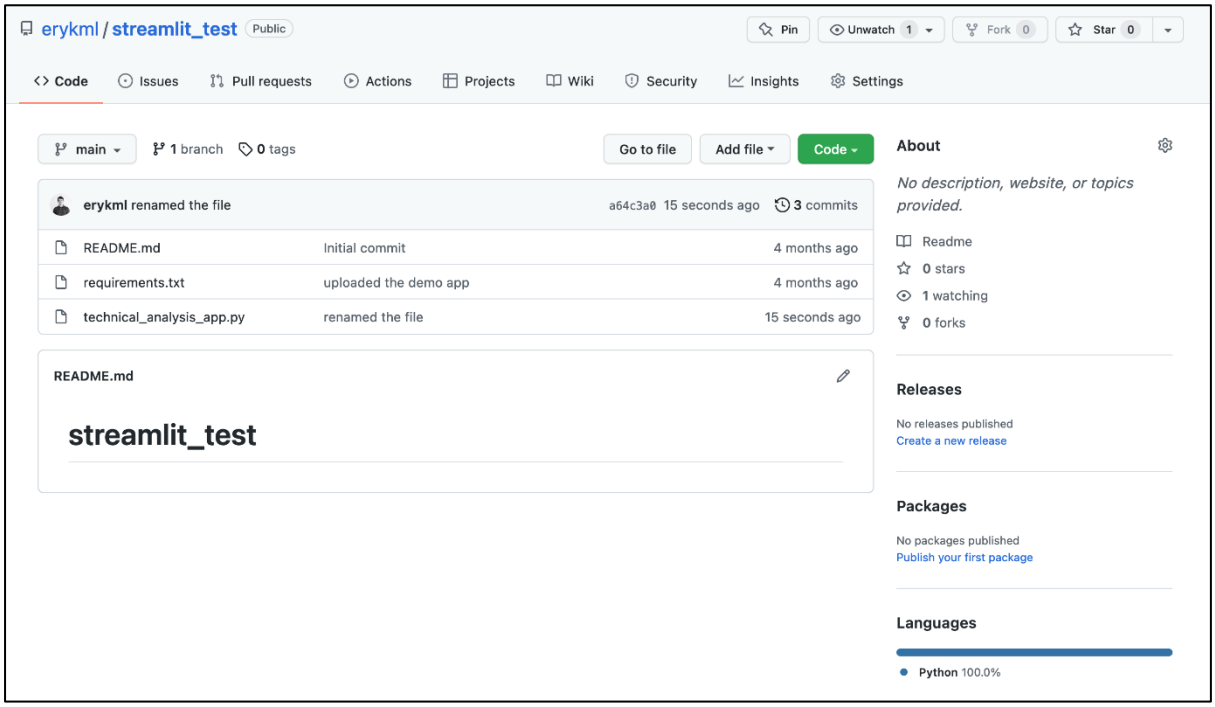
Preview data

Columns

Open × High × Low × Close × Adj Close × Volume ×

	Open	High	Low	Close	Adj Close	Vo
2018-12-31T00:00:00	190.3400	191.6500	188.5000	190.5400	170.5956	
2019-01-02T00:00:00	187.8200	190.9900	186.7000	190.9500	170.9627	
2019-01-03T00:00:00	188.2800	188.2800	182.8900	183.7600	164.5253	
2019-01-04T00:00:00	186.7500	191.9800	186.0300	191.3200	171.2940	
2019-01-07T00:00:00	191.3600	192.3000	188.6600	190.8800	170.9000	
2019-01-08T00:00:00	193.0000	194.1100	189.5800	191.6800	171.6163	
2019-01-09T00:00:00	193.2500	193.9400	191.3800	192.3000	172.1714	
2019-01-10T00:00:00	190.8700	193.8100	189.4000	193.6000	173.3353	
2019-01-11T00:00:00	191.8400	192.6900	190.8600	192.2100	172.0909	
2019-01-14T00:00:00						

Download selected as CSV



Deploy an app

Apps are deployed directly from their GitHub repo. Enter the location of your app below.

Repository Paste GitHub URL

erykml/streamlit_test

Branch

main

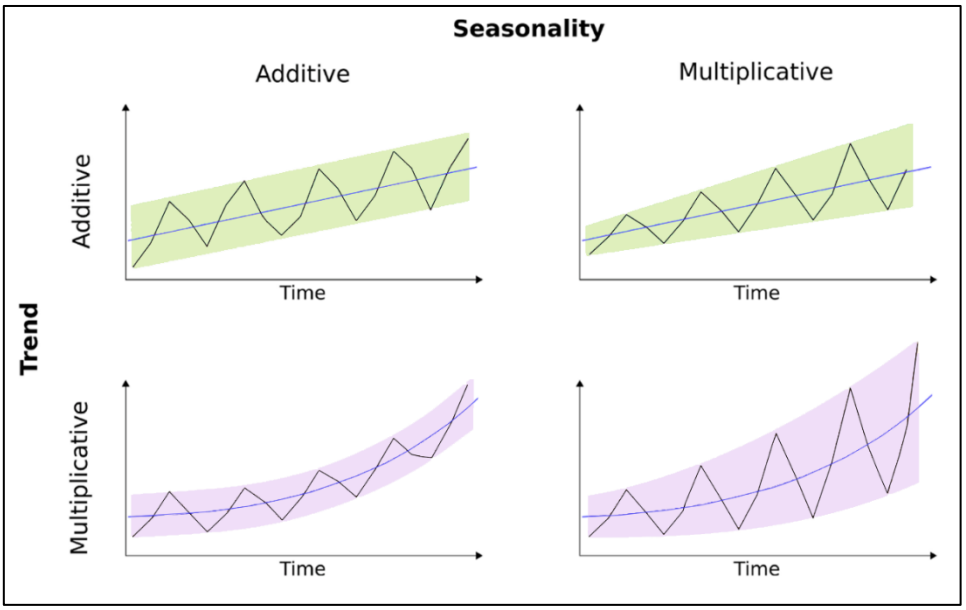
Main file path

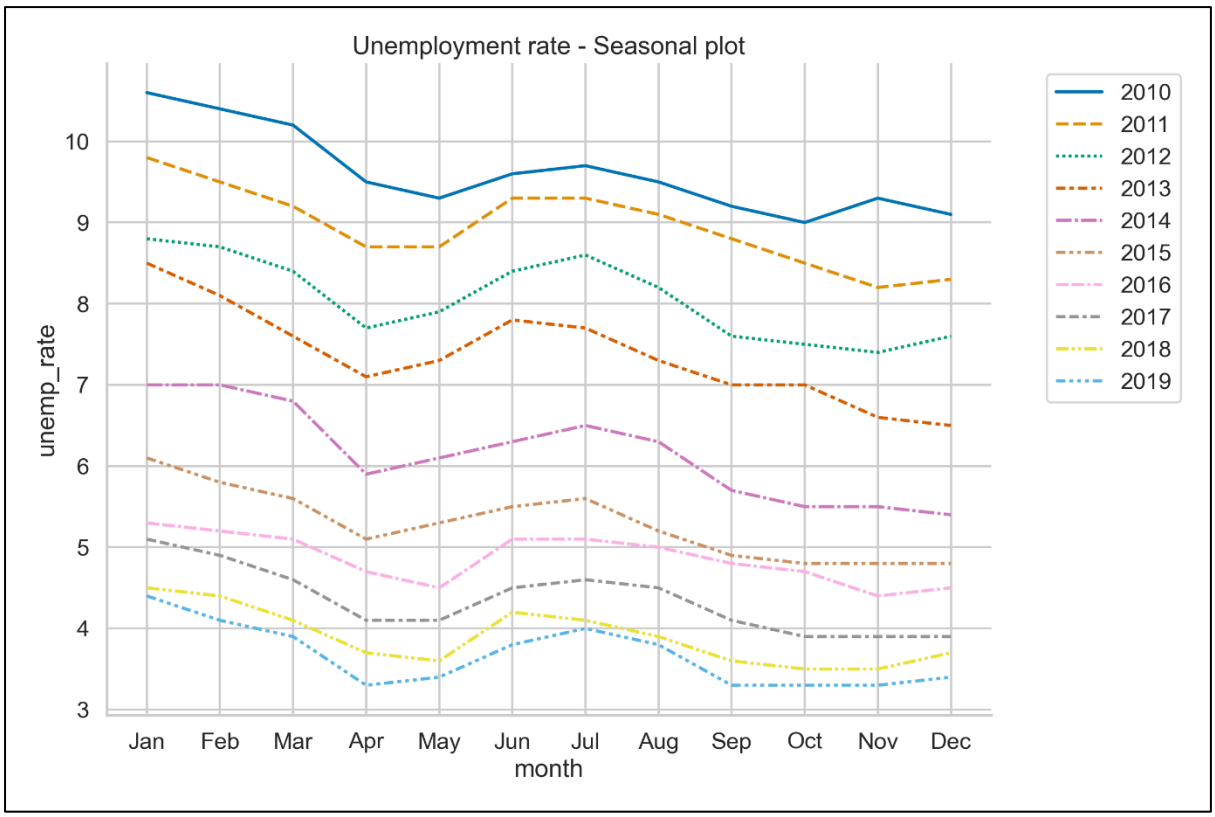
technical_analysis_app.py

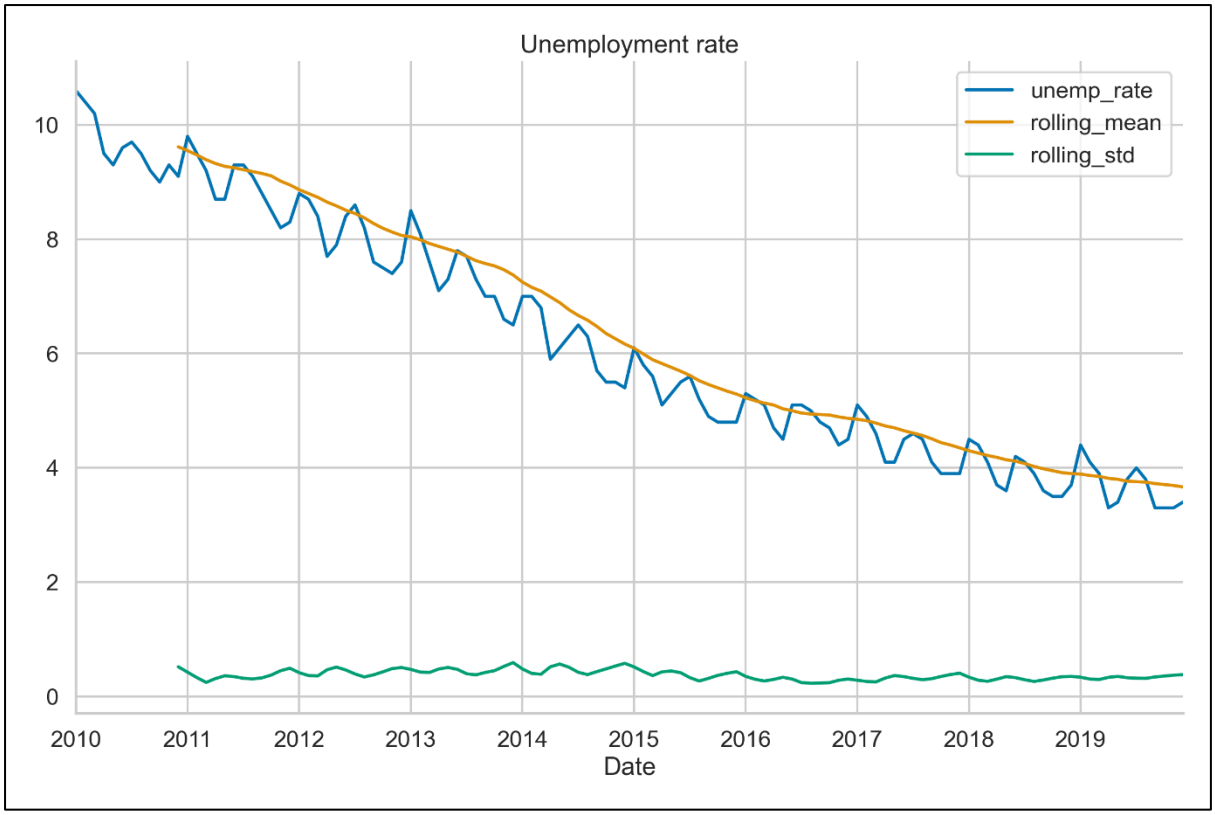
Advanced settings...

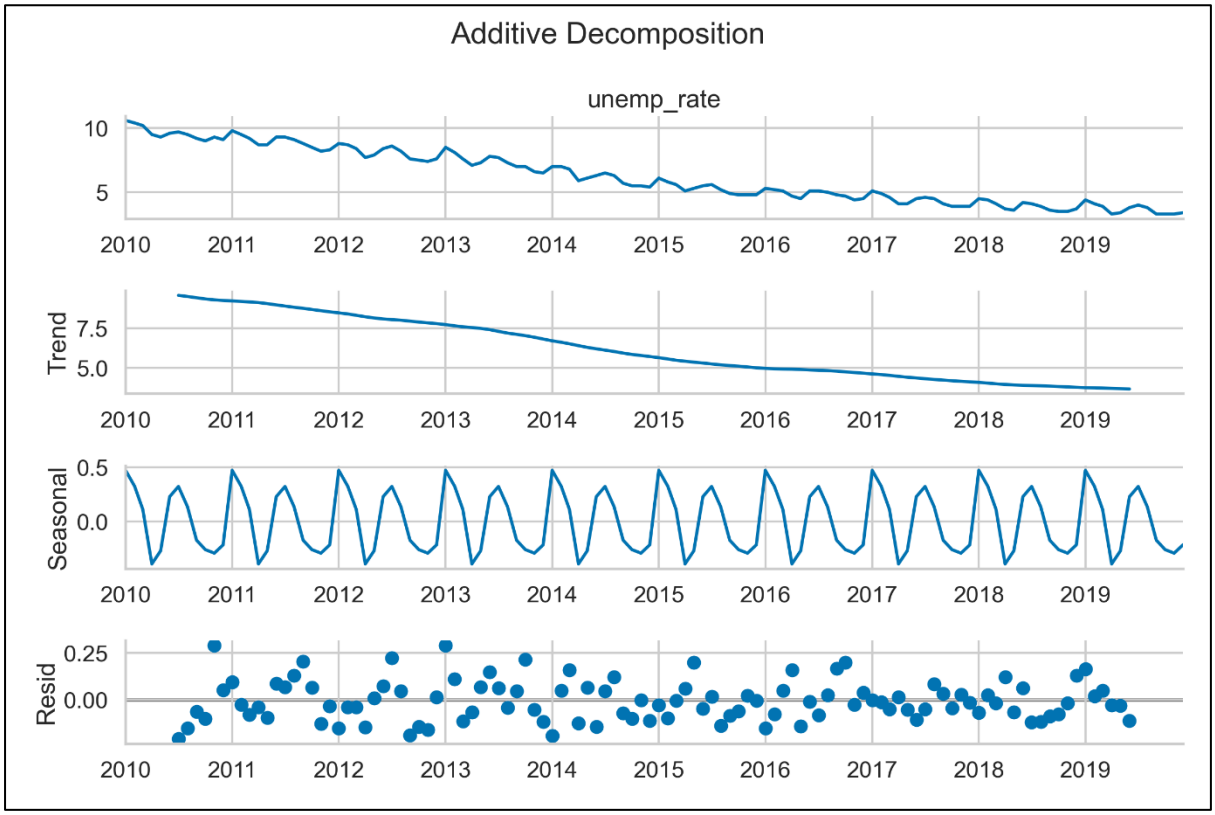
Deploy!

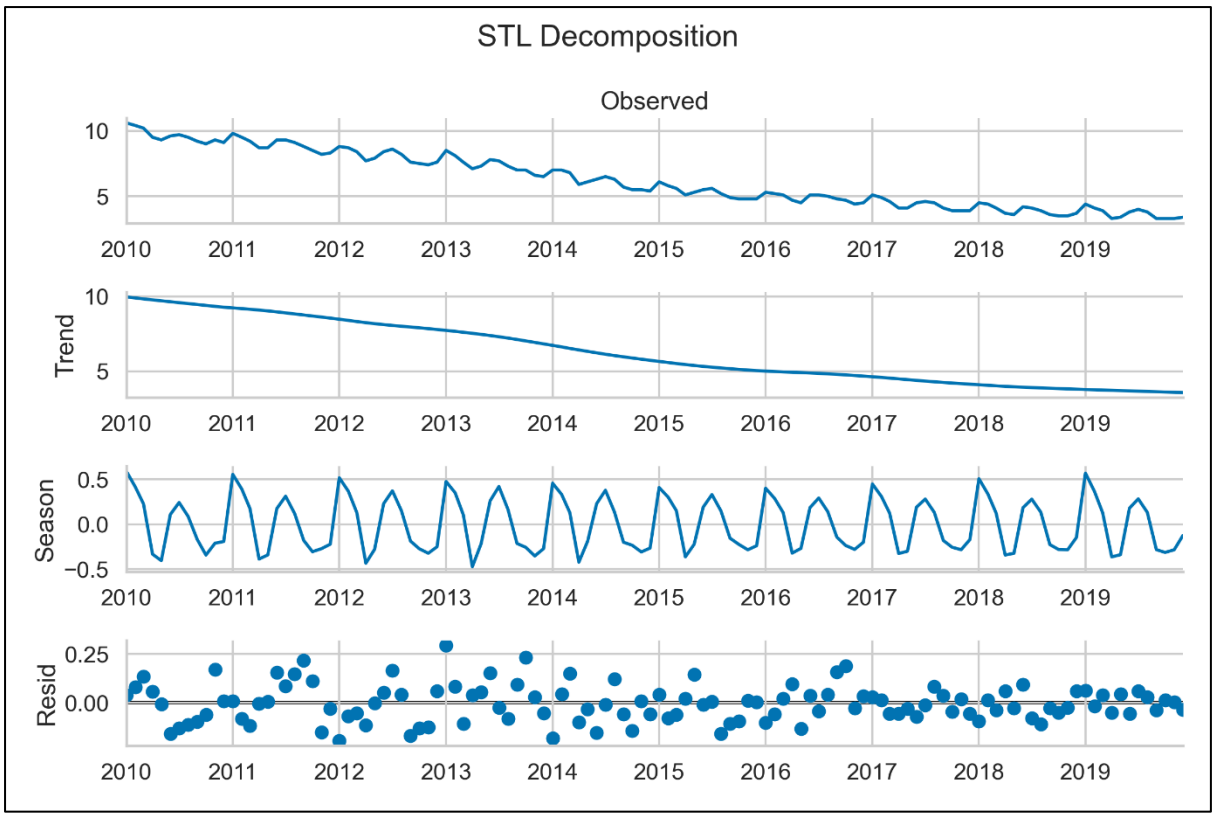
Chapter 6: Time Series Analysis and Forecasting

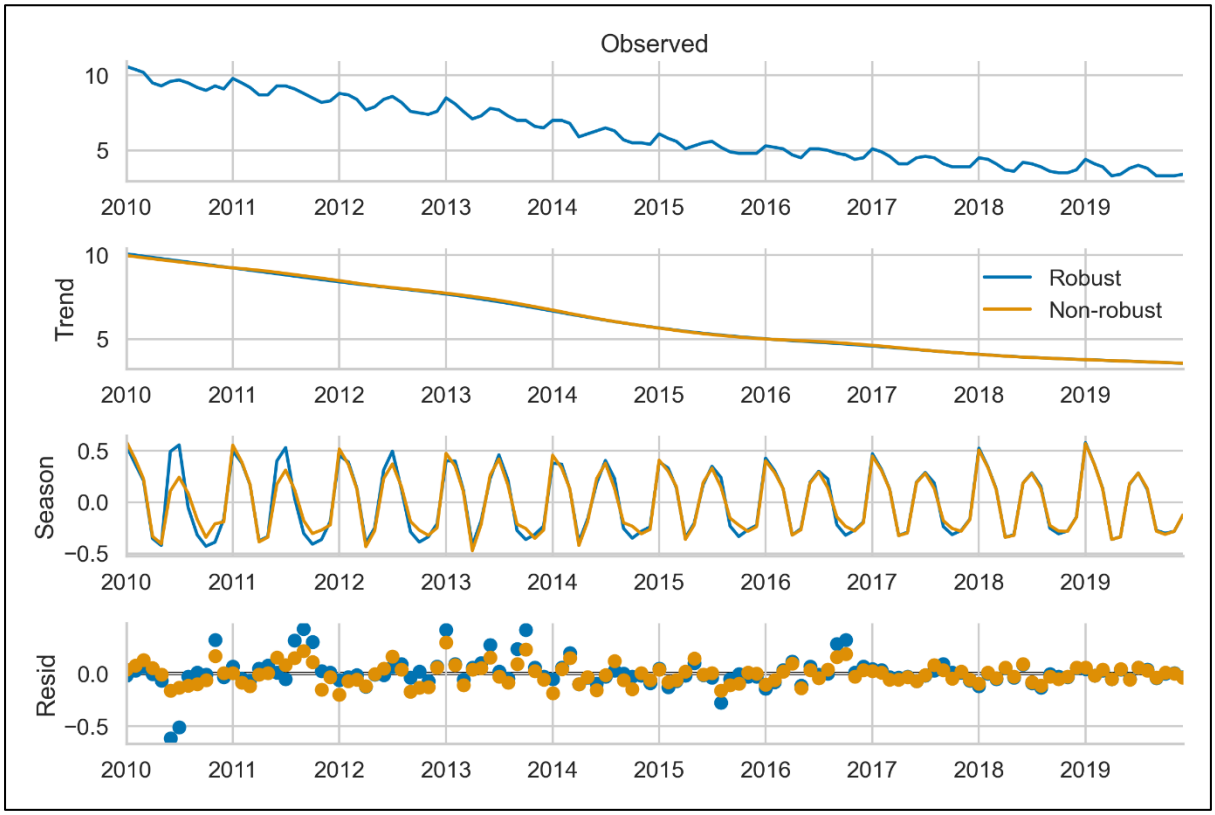


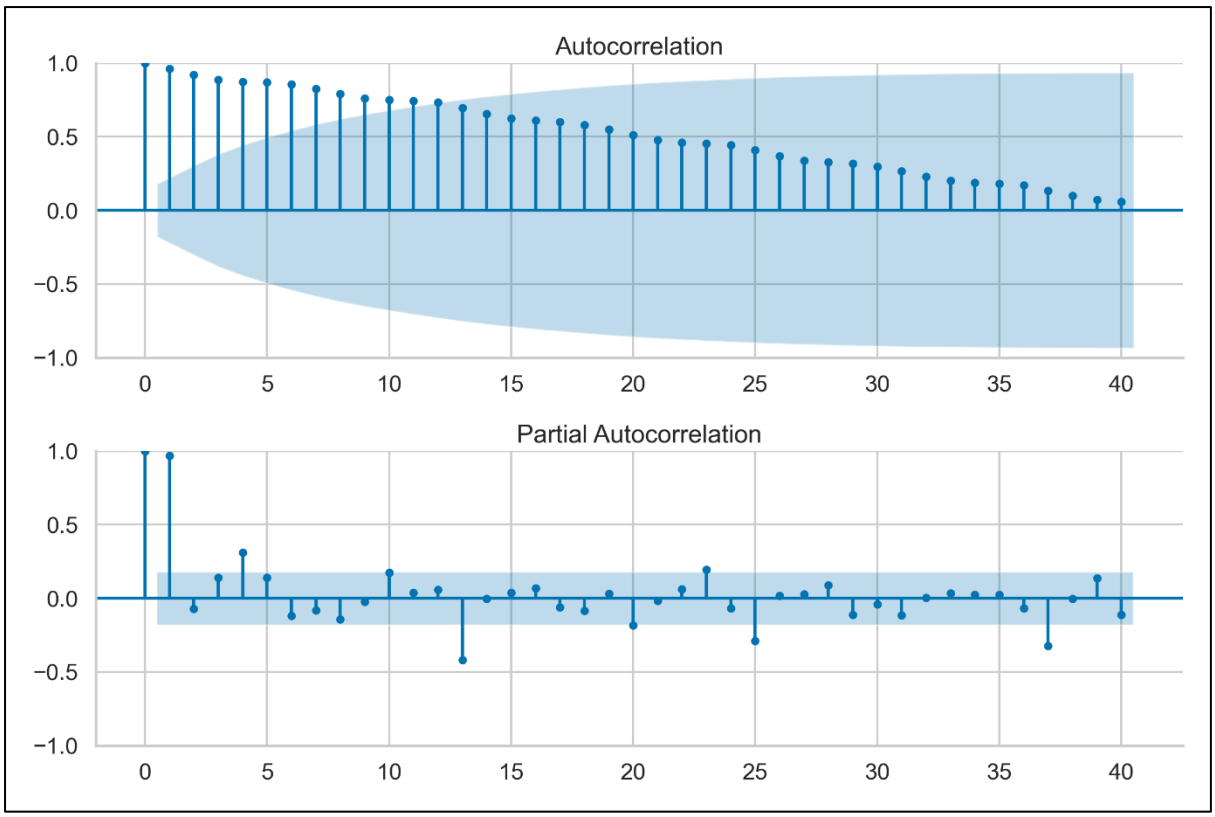


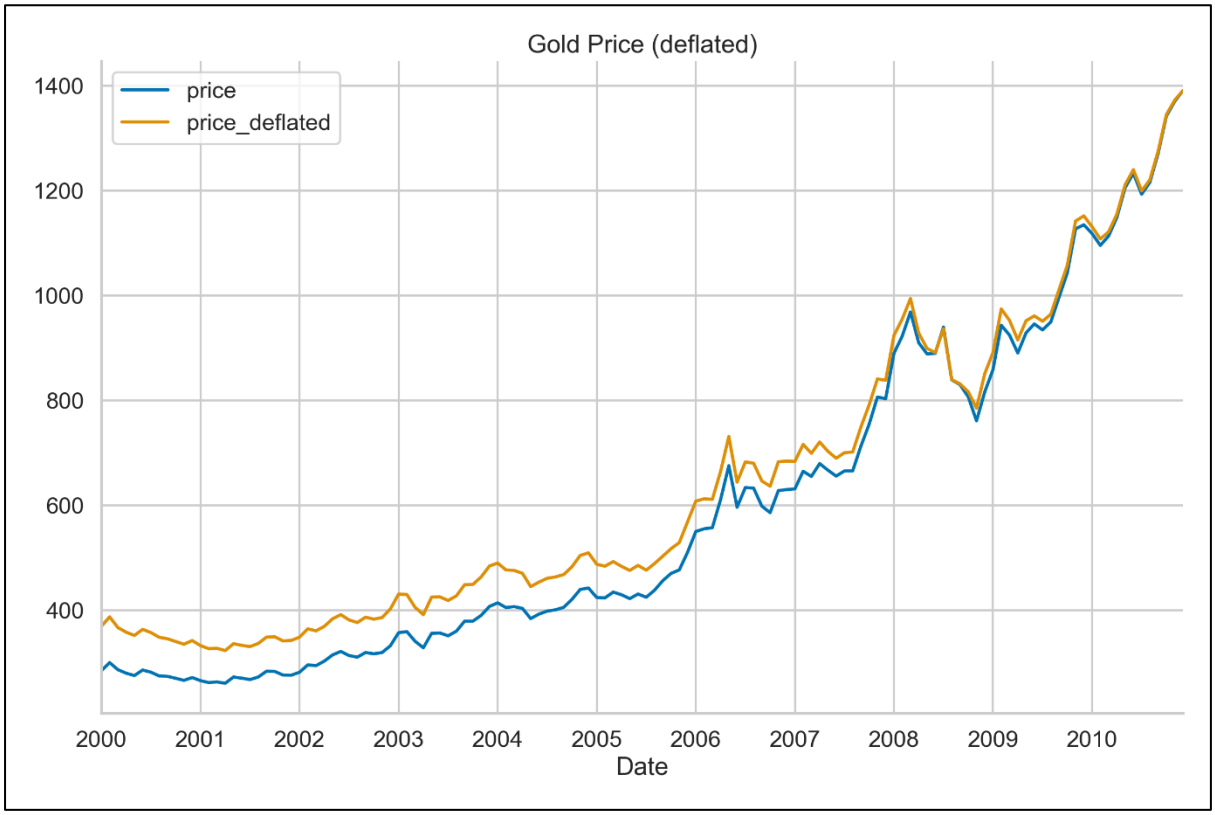

Unemployment rate
unemp_rate
rolling_mean
rolling_std
10
8
6
4
2
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Date

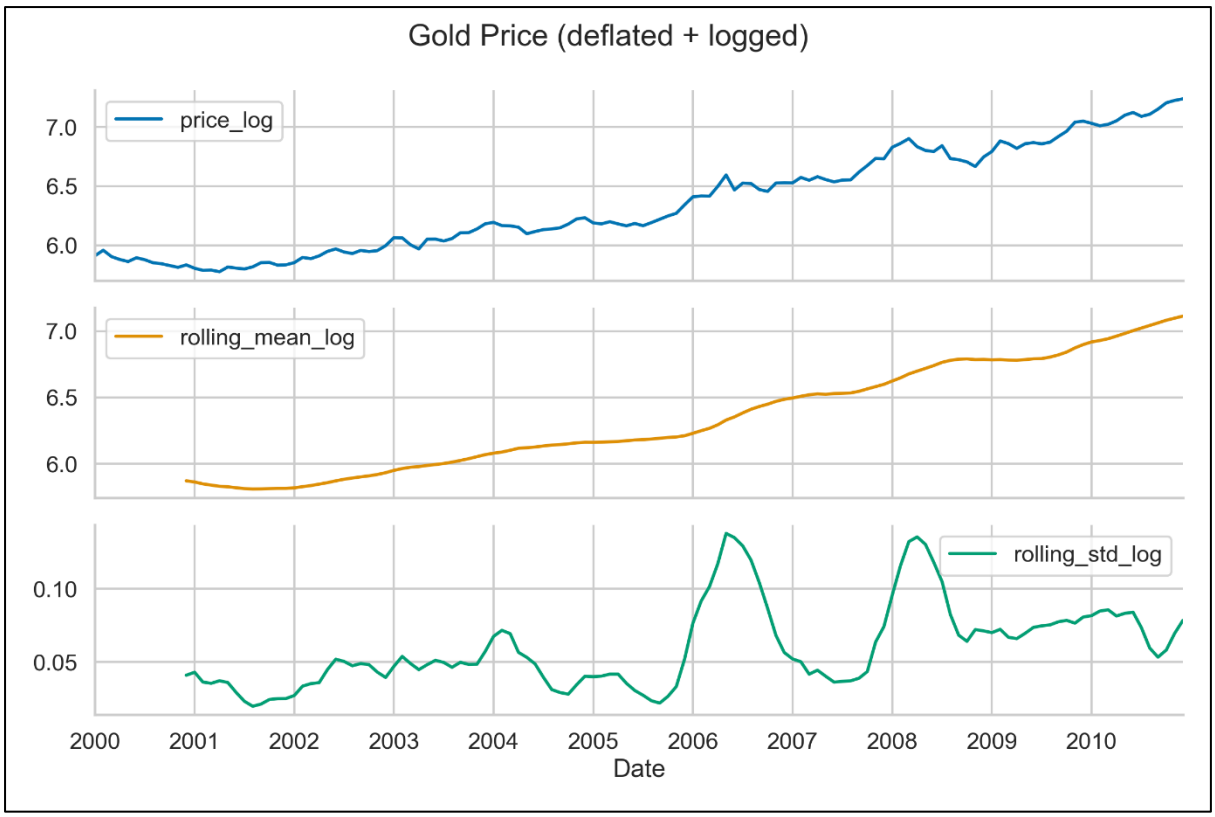

Additive Decomposition
unemp_rate
10
5
Trend
7.5
5.0
Seasonal
0.5
0.0
Resid
0.25
0.00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

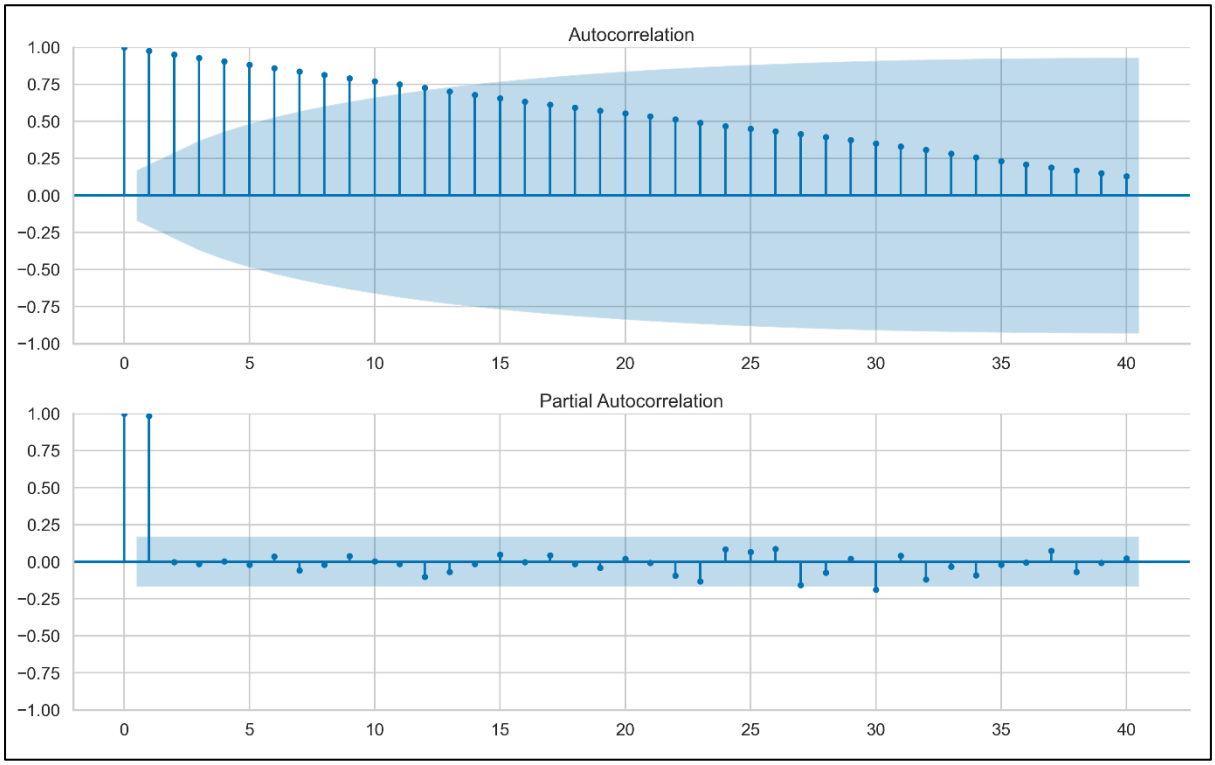

STL Decomposition
Observed
Trend
Season
Resid
10
5
0.5
0.0
−0.5
0.25
0.00
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

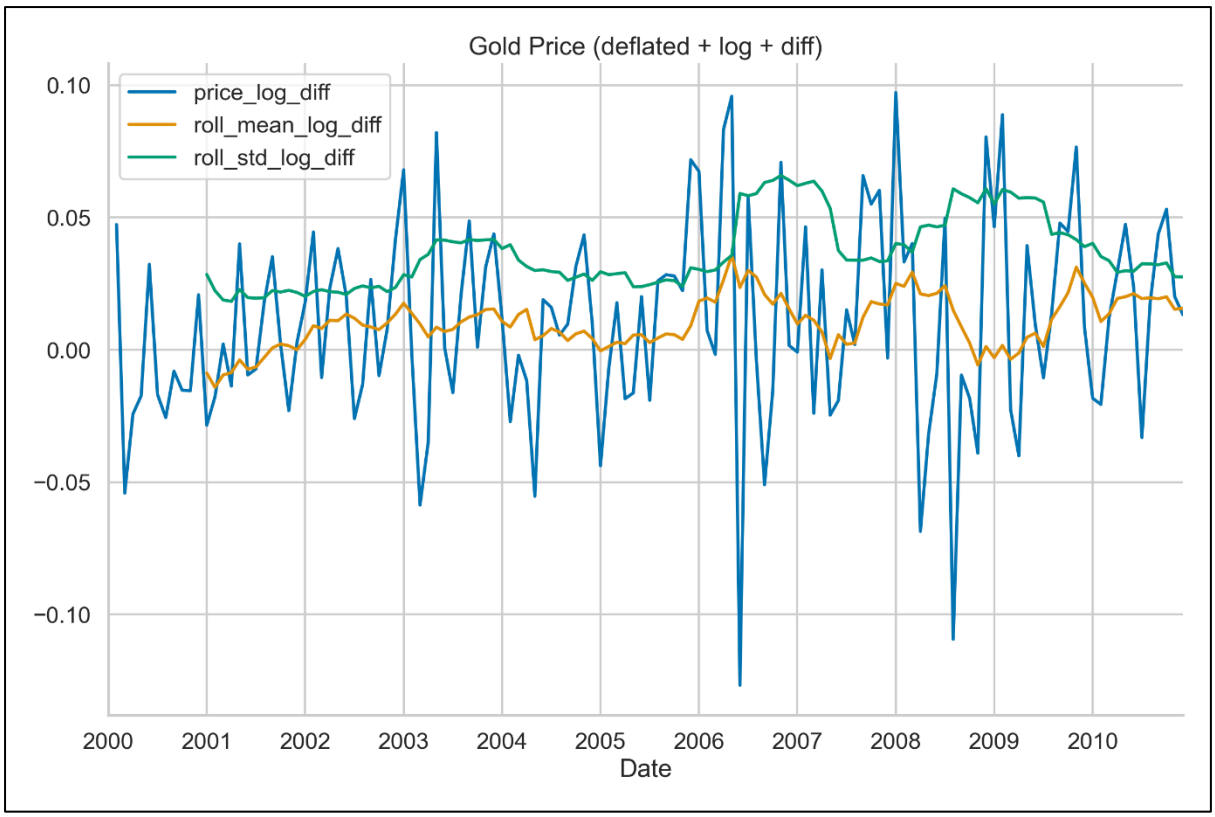

Observed
Trend
Season
Resid
Robust
Non-robust
10
5
0.5
0.0
−0.5
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

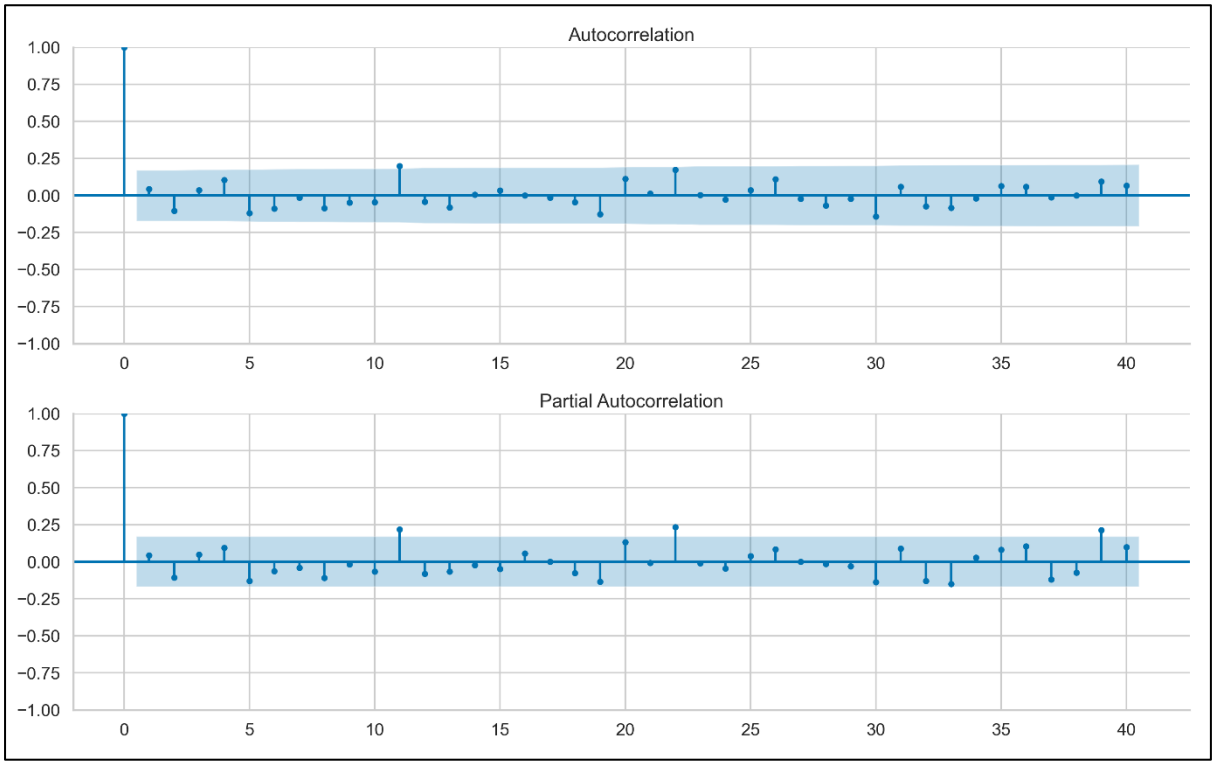

Autocorrelation
1.0
0.5
0.0
−0.5
−1.0
0
5
10
15
20
25
30
35
40
Partial Autocorrelation
1.0
0.5
0.0
−0.5
−1.0
0
5
10
15
20
25
30
35
40


Gold Price (deflated)
price
price_deflated
1400
1200
1000
800
600
400
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Date

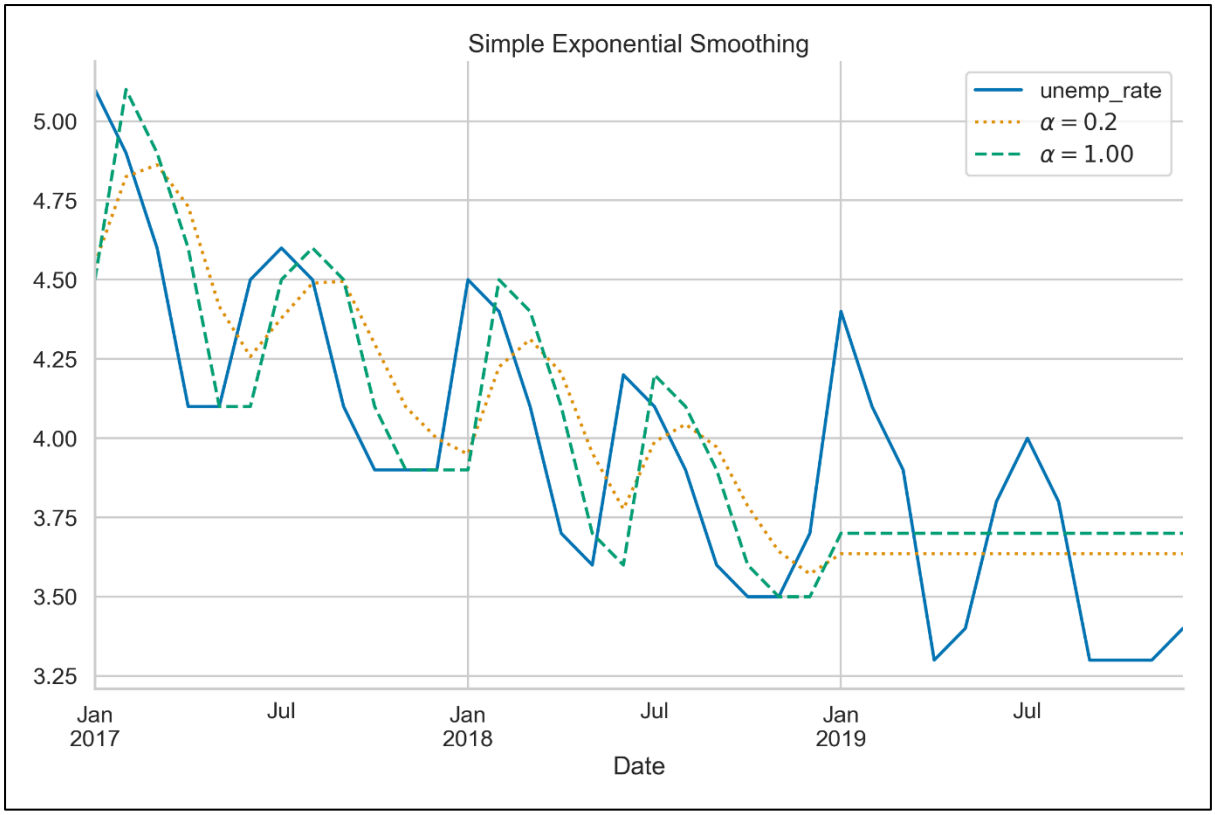

Gold Price (deflated + logged)
price_log
rolling_mean_log
rolling_std_log
7.0
6.5
6.0
0.10
0.05
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Date

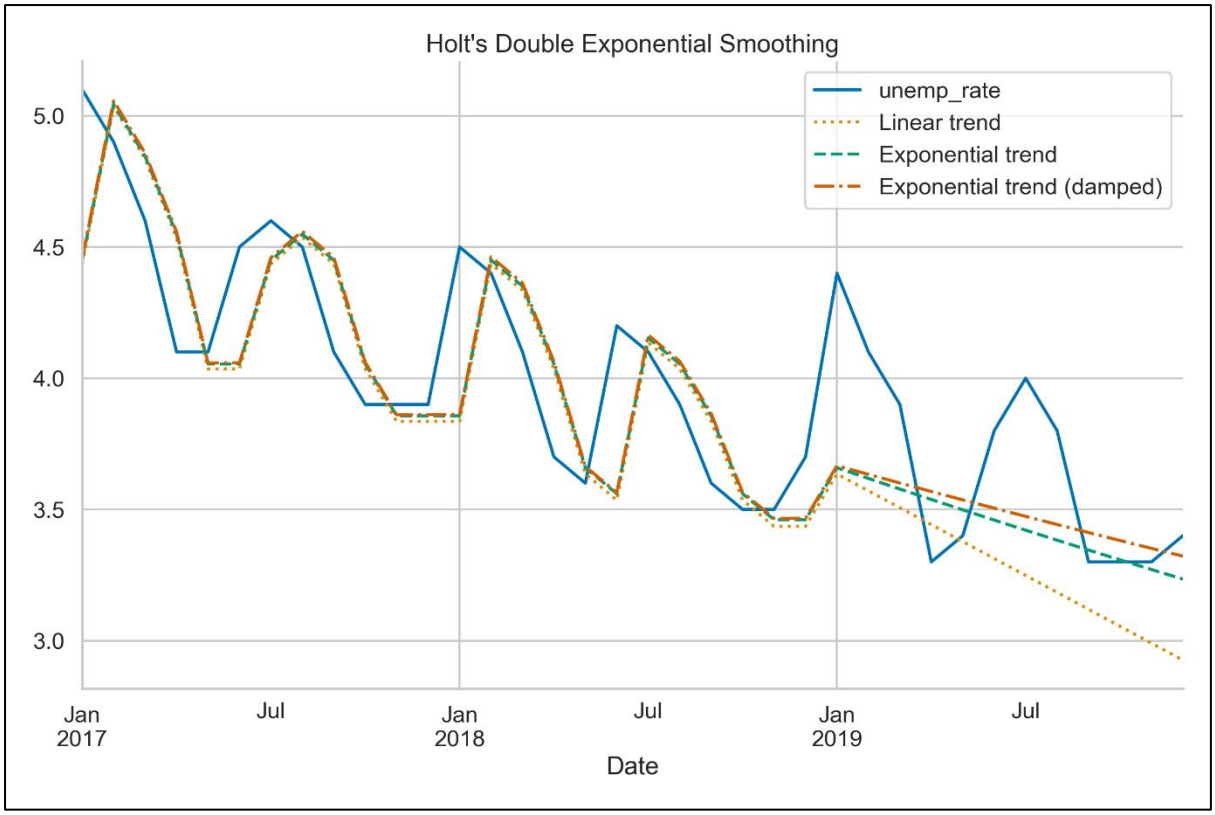

Autocorrelation
Partial Autocorrelation
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
5
10
15
20
25
30
35
40

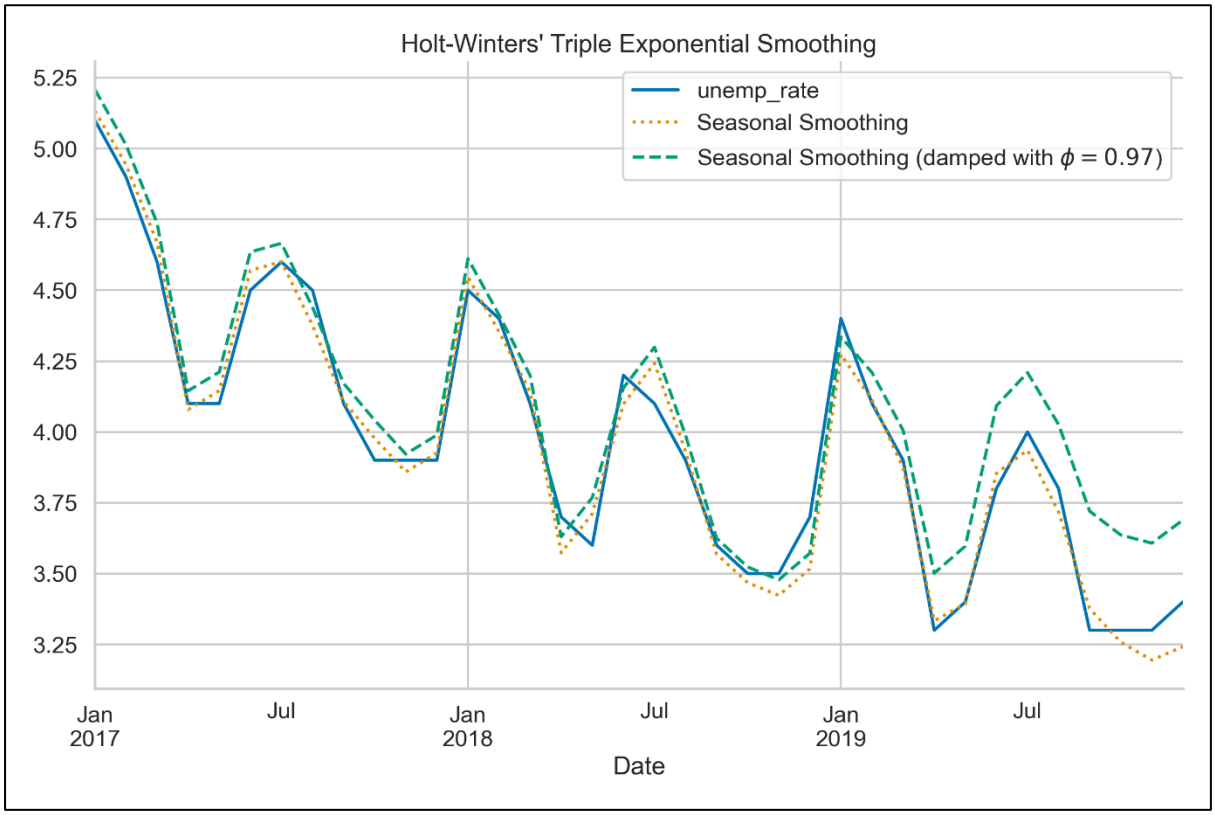

Gold Price (deflated + log + diff)
price_log_diff
roll_mean_log_diff
roll_std_log_diff
0.10
0.05
0.00
−0.05
−0.10
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Date

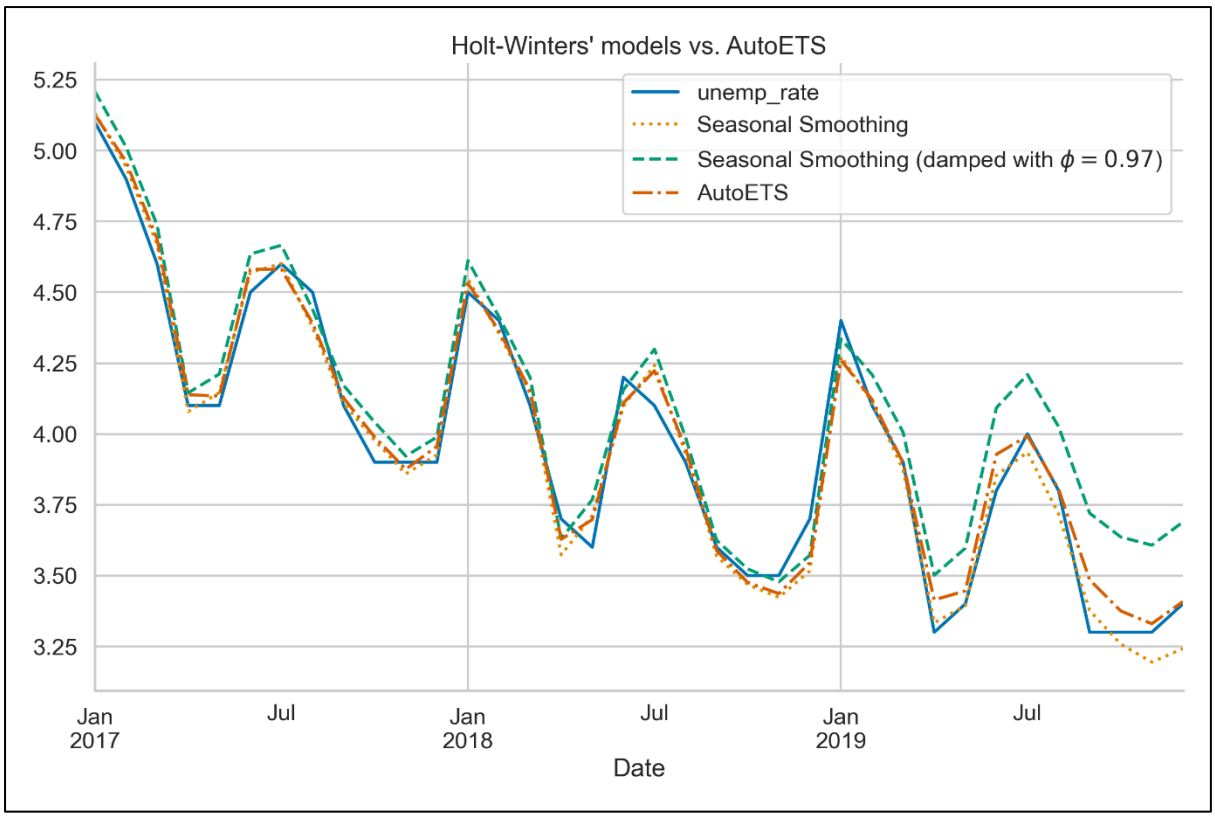

Autocorrelation
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
5
10
15
20
25
30
35
40
Partial Autocorrelation
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
5
10
15
20
25
30
35
40

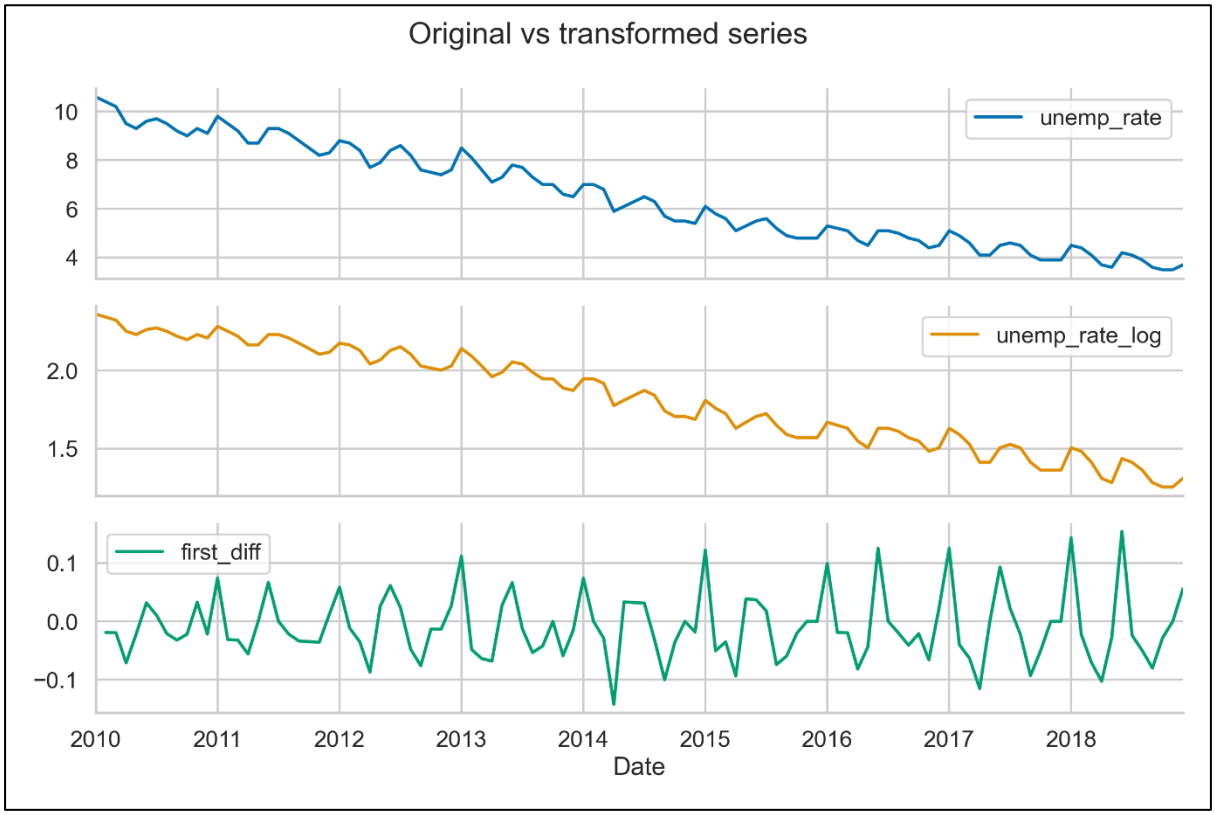
	name	param	optimized
smoothing_level	alpha	0.500000	False
initial_level	l.0	10.358112	True

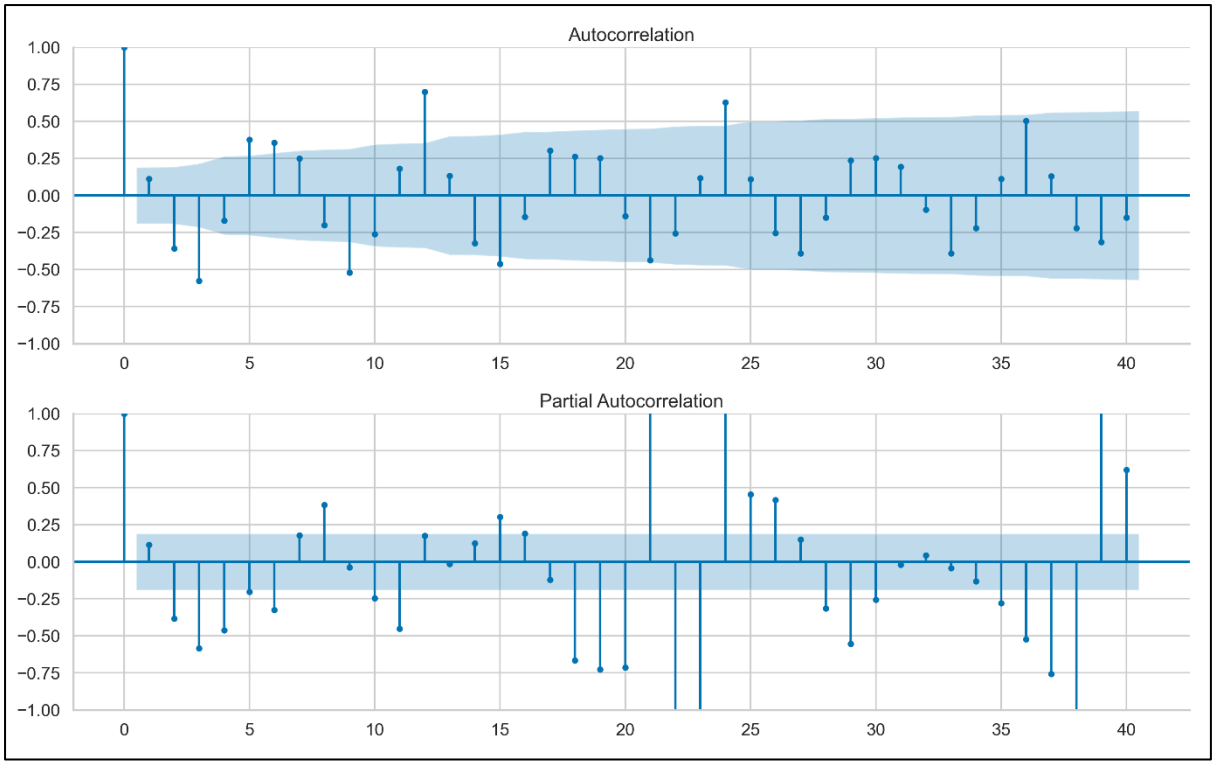



Holt's Double Exponential Smoothing
unemp_rate
Linear trend
Exponential trend
Exponential trend (damped)
5.0
4.5
4.0
3.5
3.0
Jan
2017
Jul
Jan
2018
Jul
Jan
2019
Jul
Date


Holt-Winters' Triple Exponential Smoothing
unemp_rate
Seasonal Smoothing
Seasonal Smoothing (damped with $\phi = 0.97$)
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
Jan
2017
Jul
Jan
2018
Jul
Jan
2019
Jul
Date


Holt-Winters' models vs. AutoETS
unemp_rate
Seasonal Smoothing
Seasonal Smoothing (damped with $\phi = 0.97$)
AutoETS
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
Jan 2017
Jul
Jan 2018
Jul
Jan 2019
Jul
Date


Original vs transformed series
unemp_rate
unemp_rate_log
first_diff
10
8
6
4
2.0
1.5
0.1
0.0
−0.1
2010
2011
2012
2013
2014
2015
2016
2017
2018
Date



SARIMAX Results

Dep. Variable:	unemp_rate_log	No. Observations:	108
Model:	ARIMA(1, 1, 1)	Log Likelihood	157.020
Date:	Thu, 12 May 2022	AIC	-308.040
Time:	00:14:40	BIC	-300.021
Sample:	01-01-2010	HQIC	-304.789
	- 12-01-2018		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	0.5541	0.401	1.381	0.167	-0.232	1.340
ma.L1	-0.7314	0.306	-2.391	0.017	-1.331	-0.132
sigma2	0.0031	0.000	6.823	0.000	0.002	0.004

Ljung-Box (L1) (Q):	2.55	Jarque-Bera (JB):	9.59
Prob(Q):	0.11	Prob(JB):	0.01
Heteroskedasticity (H):	2.33	Skew:	0.64
Prob(H) (two-sided):	0.01	Kurtosis:	3.71

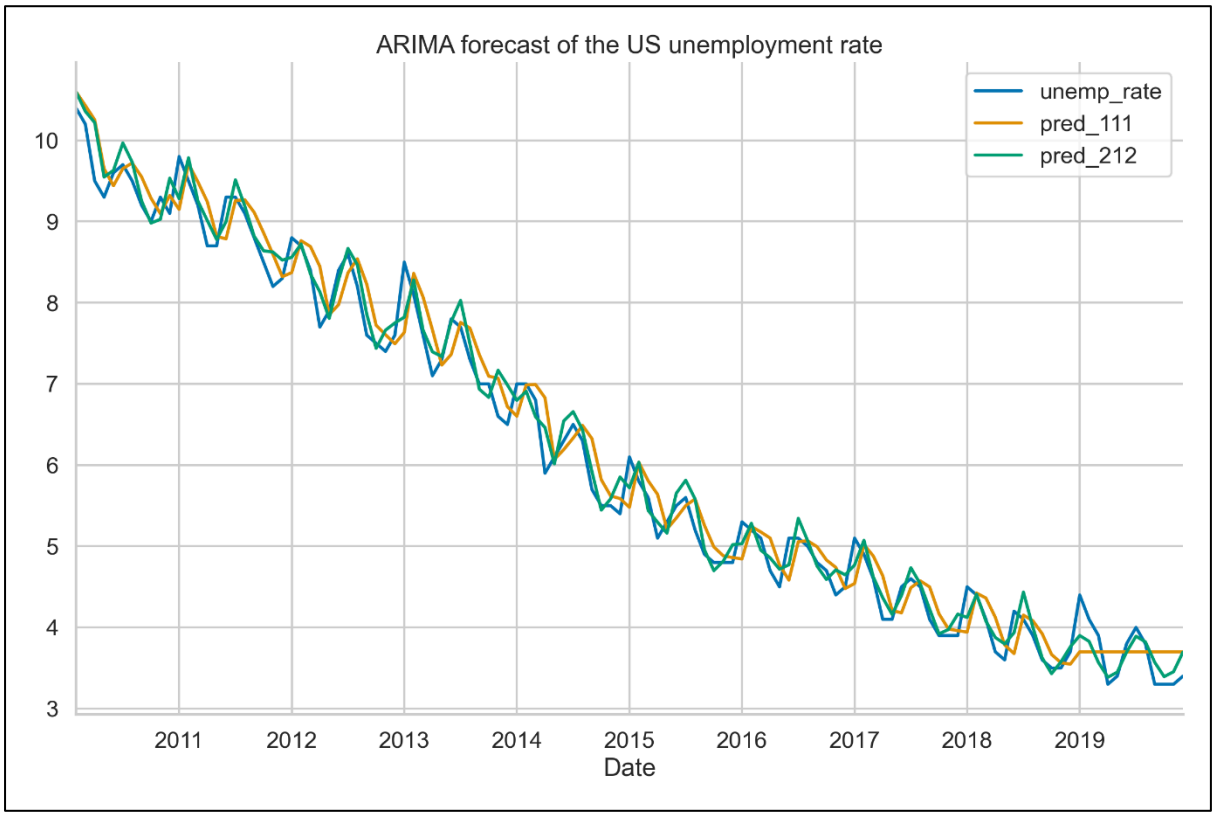
SARIMAX Results

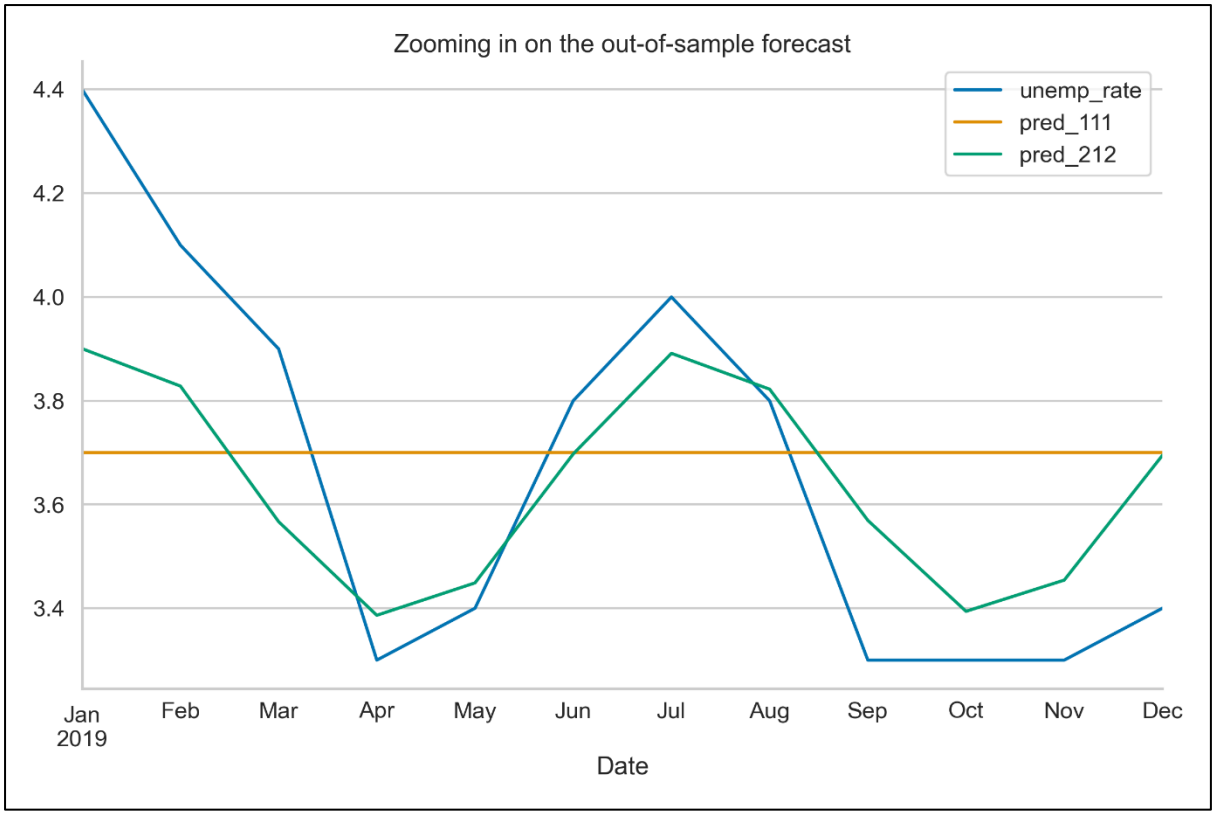
Dep. Variable:	unemp_rate_log	No. Observations:	108
Model:	ARIMA(2, 1, 2)	Log Likelihood	196.744
Date:	Thu, 12 May 2022	AIC	-383.488
Time:	00:14:40	BIC	-370.124
Sample:	01-01-2010	HQIC	-378.070
	- 12-01-2018		
Covariance Type:	opg		

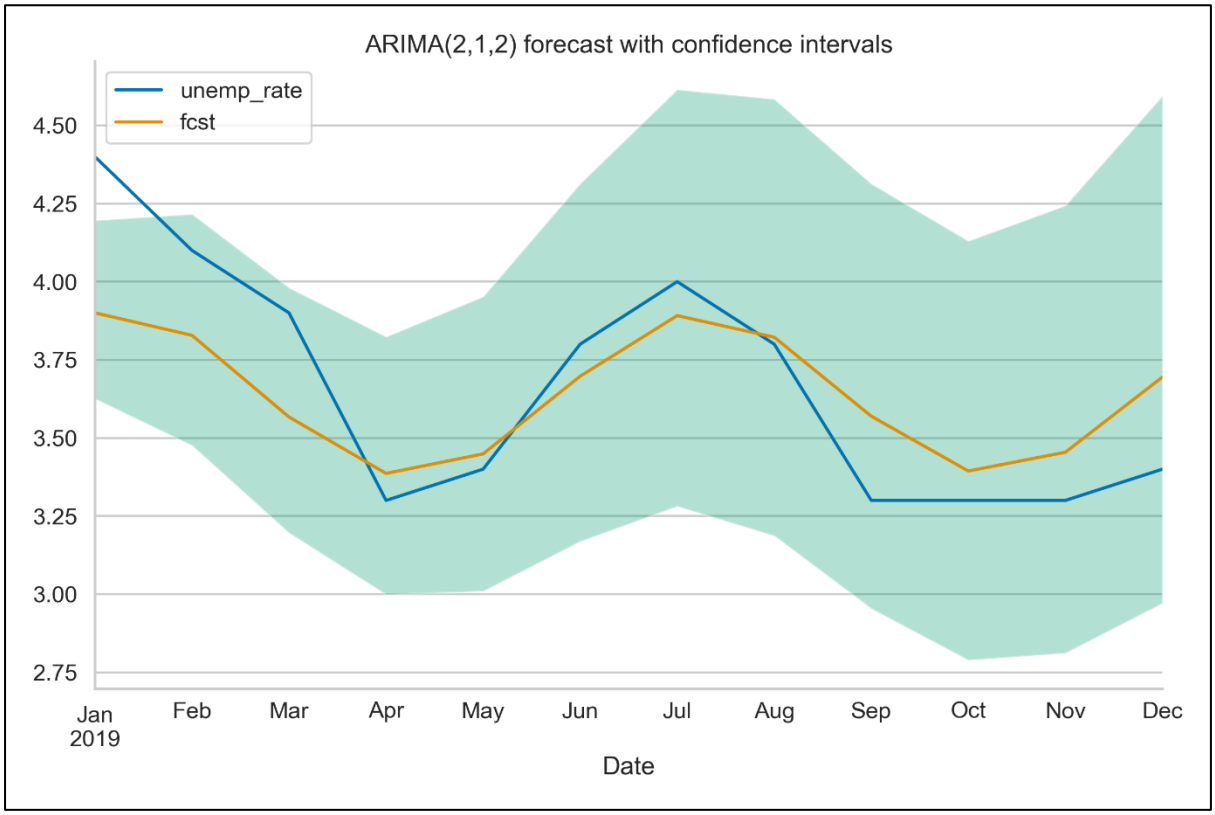
	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	0.9952	0.014	69.577	0.000	0.967	1.023
ar.L2	-0.9893	0.014	-69.952	0.000	-1.017	-0.962
ma.L1	-1.1437	38.973	-0.029	0.977	-77.530	75.243
ma.L2	1.0000	68.159	0.015	0.988	-132.589	134.589
sigma2	0.0014	0.093	0.015	0.988	-0.181	0.184

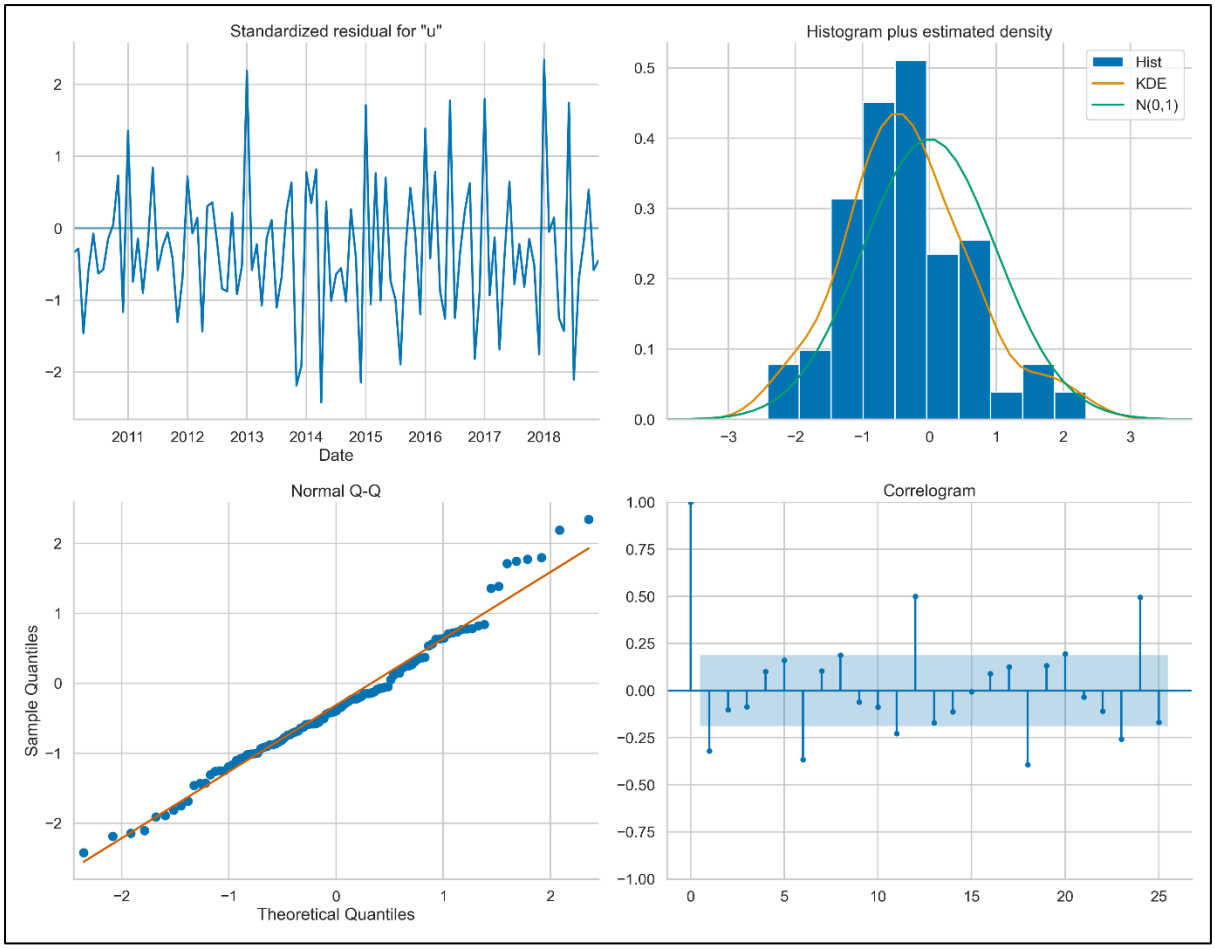
Ljung-Box (L1) (Q):	11.30	Jarque-Bera (JB):	3.25
Prob(Q):	0.00	Prob(JB):	0.20
Heteroskedasticity (H):	1.99	Skew:	0.40
Prob(H) (two-sided):	0.04	Kurtosis:	3.28

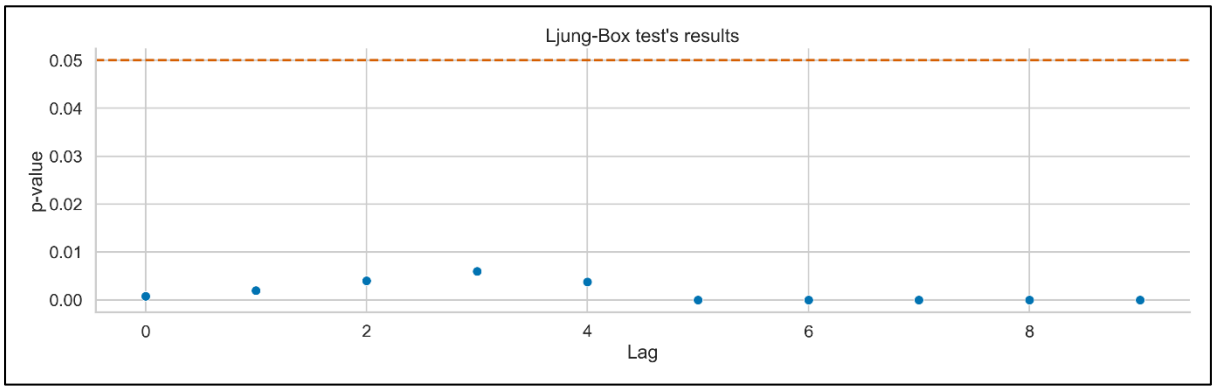
Date	unemp_rate	pred_111_log	pred_111	pred_212_log	pred_212
2010-01-01	10.6	0.000000	1.000000	0.000000	1.000000
2010-02-01	10.4	2.360854	10.600000	2.360854	10.600000
2010-03-01	10.2	2.344579	10.428881	2.337674	10.357115
2010-04-01	9.5	2.327491	10.252189	2.324158	10.218076
2010-05-01	9.3	2.266964	9.650060	2.256346	9.548141
...	...	...	...	...	...
2019-08-01	3.8	1.308394	3.700225	1.340842	3.822261
2019-09-01	3.3	1.308394	3.700226	1.272401	3.569413
2019-10-01	3.3	1.308394	3.700227	1.222022	3.394045
2019-11-01	3.3	1.308394	3.700227	1.239597	3.454222
2019-12-01	3.4	1.308394	3.700227	1.306928	3.694807




Zooming in on the out-of-sample forecast
unemp_rate
pred_111
pred_212
4.4
4.2
4.0
3.8
3.6
3.4
Jan
2019
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Date


ARIMA(2,1,2) forecast with confidence intervals
unemp_rate
fcst
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
Jan
2019
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Date


Standardized residual for "u"
Date
Histogram plus estimated density
Hist
KDE
N(0,1)
Normal Q-Q
Sample Quantiles
Theoretical Quantiles
Correlogram

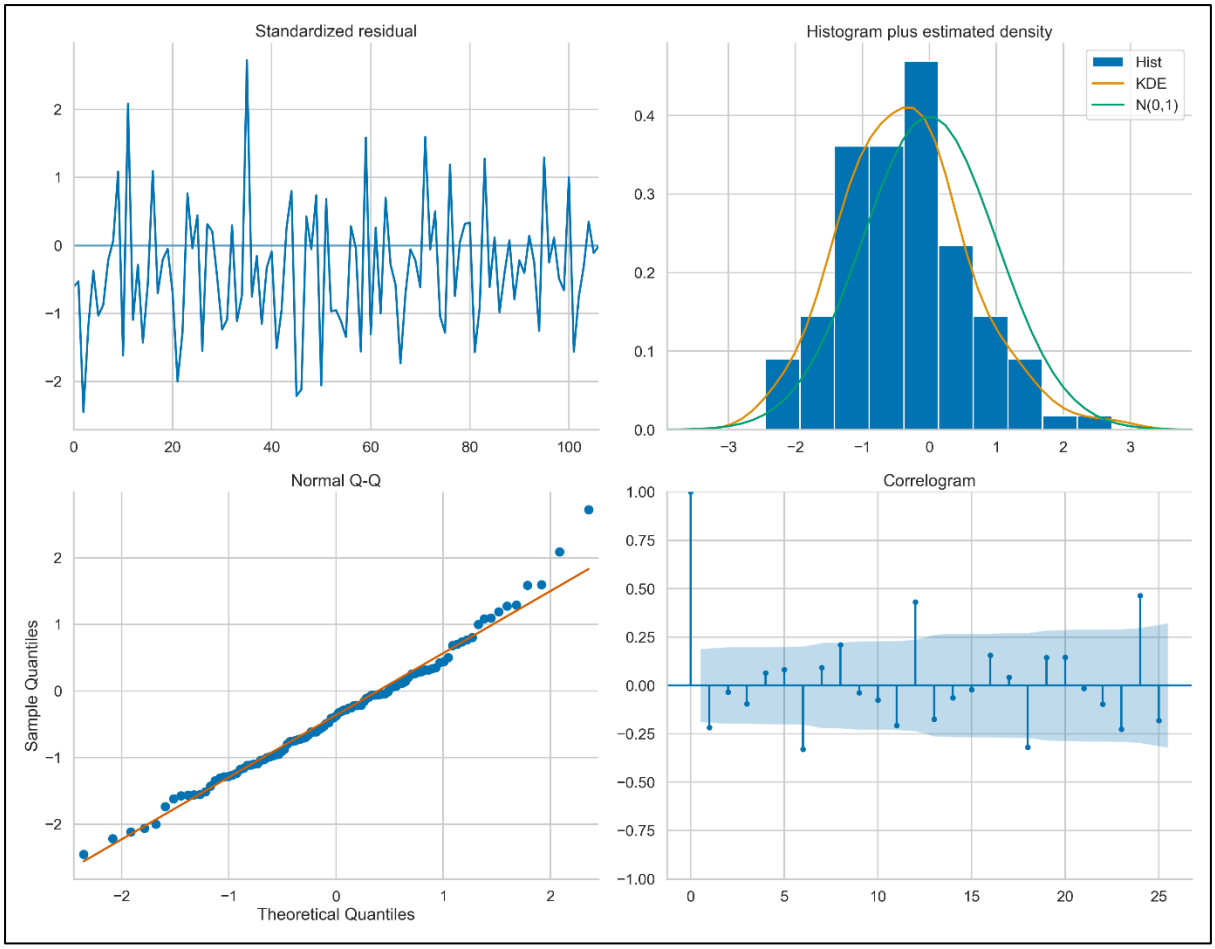

Ljung-Box test's results
p-value
Lag

SARIMAX Results

Dep. Variable:	y	No. Observations:	108
Model:	SARIMAX(2, 1, 2)	Log Likelihood	1.294
Date:	Thu, 12 May 2022	AIC	7.411
Time:	00:14:44	BIC	20.775
Sample:	0	HQIC	12.829
	- 108		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	0.9882	0.028	34.788	0.000	0.933	1.044
ar.L2	-0.9630	0.023	-41.667	0.000	-1.008	-0.918
ma.L1	-1.1926	0.057	-21.093	0.000	-1.303	-1.082
ma.L2	0.9241	0.063	14.580	0.000	0.800	1.048
sigma2	0.0550	0.009	6.065	0.000	0.037	0.073

Ljung-Box (L1) (Q):	5.22	Jarque-Bera (JB):	4.47
Prob(Q):	0.02	Prob(JB):	0.11
Heteroskedasticity (H):	0.52	Skew:	0.44
Prob(H) (two-sided):	0.05	Kurtosis:	3.48

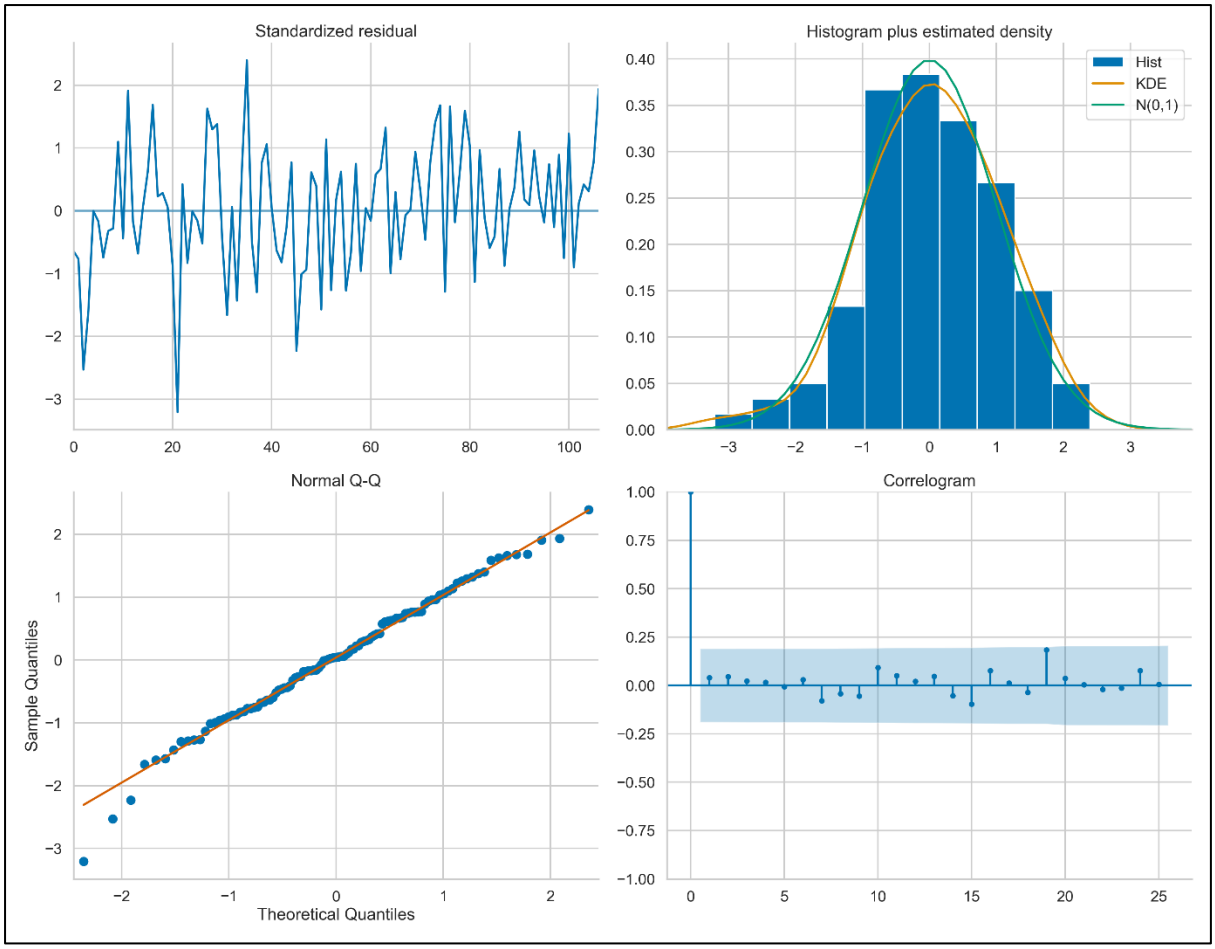

Standardized residual
Histogram plus estimated density
Hist
KDE
N(0,1)
Normal Q-Q
Sample Quantiles
Theoretical Quantiles
Correlogram

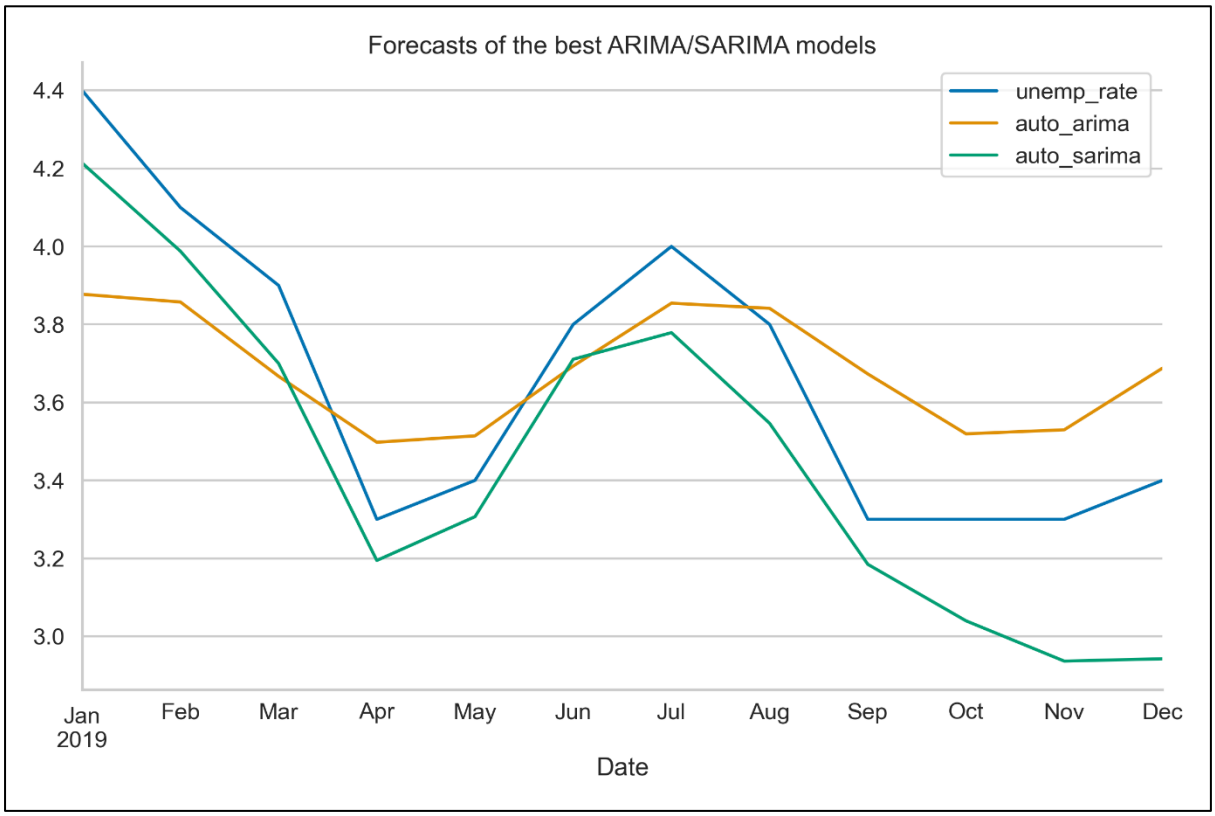
SARIMAX Results

Dep. Variable:	y	No. Observations:	108
Model:	SARIMAX(0, 1, 5)x(2, 0, [1], 12)	Log Likelihood	41.060
Date:	Thu, 12 May 2022	AIC	-64.120
Time:	00:15:12	BIC	-40.065
Sample:	0	HQIC	-54.368
	- 108		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ma.L1	-0.2808	0.115	-2.449	0.014	-0.506	-0.056
ma.L2	-0.1211	0.112	-1.078	0.281	-0.341	0.099
ma.L3	-0.2031	0.129	-1.575	0.115	-0.456	0.050
ma.L4	0.0749	0.122	0.616	0.538	-0.164	0.313
ma.L5	0.2473	0.105	2.363	0.018	0.042	0.452
ar.S.L12	0.8702	0.160	5.455	0.000	0.558	1.183
ar.S.L24	0.1275	0.152	0.838	0.402	-0.171	0.426
ma.S.L12	-0.8719	0.344	-2.536	0.011	-1.546	-0.198
sigma2	0.0200	0.006	3.589	0.000	0.009	0.031

Ljung-Box (L1) (Q):	0.18	Jarque-Bera (JB):	1.98
Prob(Q):	0.67	Prob(JB):	0.37
Heteroskedasticity (H):	0.60	Skew:	-0.29
Prob(H) (two-sided):	0.13	Kurtosis:	3.31


Standardized residual
Histogram plus estimated density
Hist
KDE
N(0,1)
Normal Q-Q
Sample Quantiles
Theoretical Quantiles
Correlogram

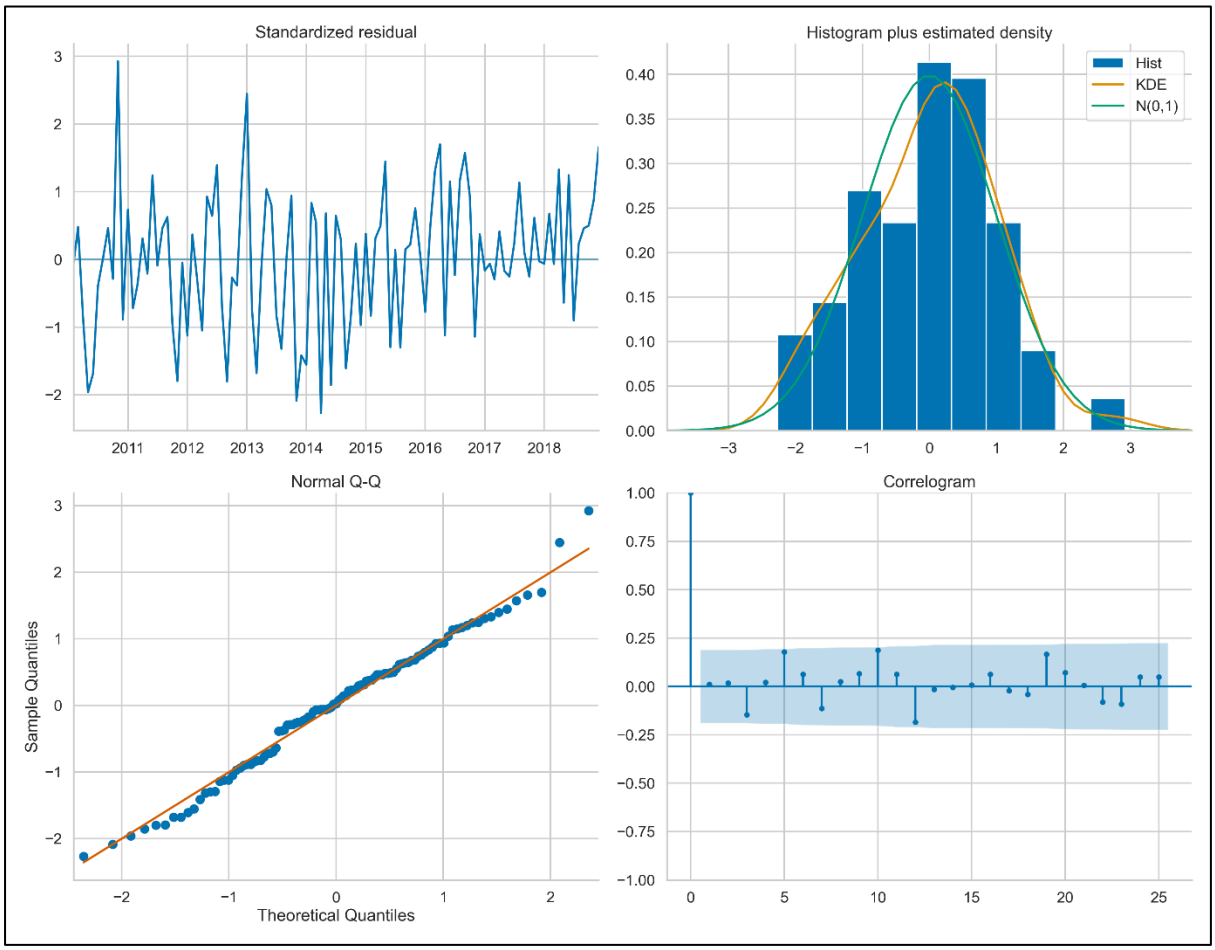

Forecasts of the best ARIMA/SARIMA models
unemp_rate
auto_arima
auto_sarima
Jan
2019
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Date

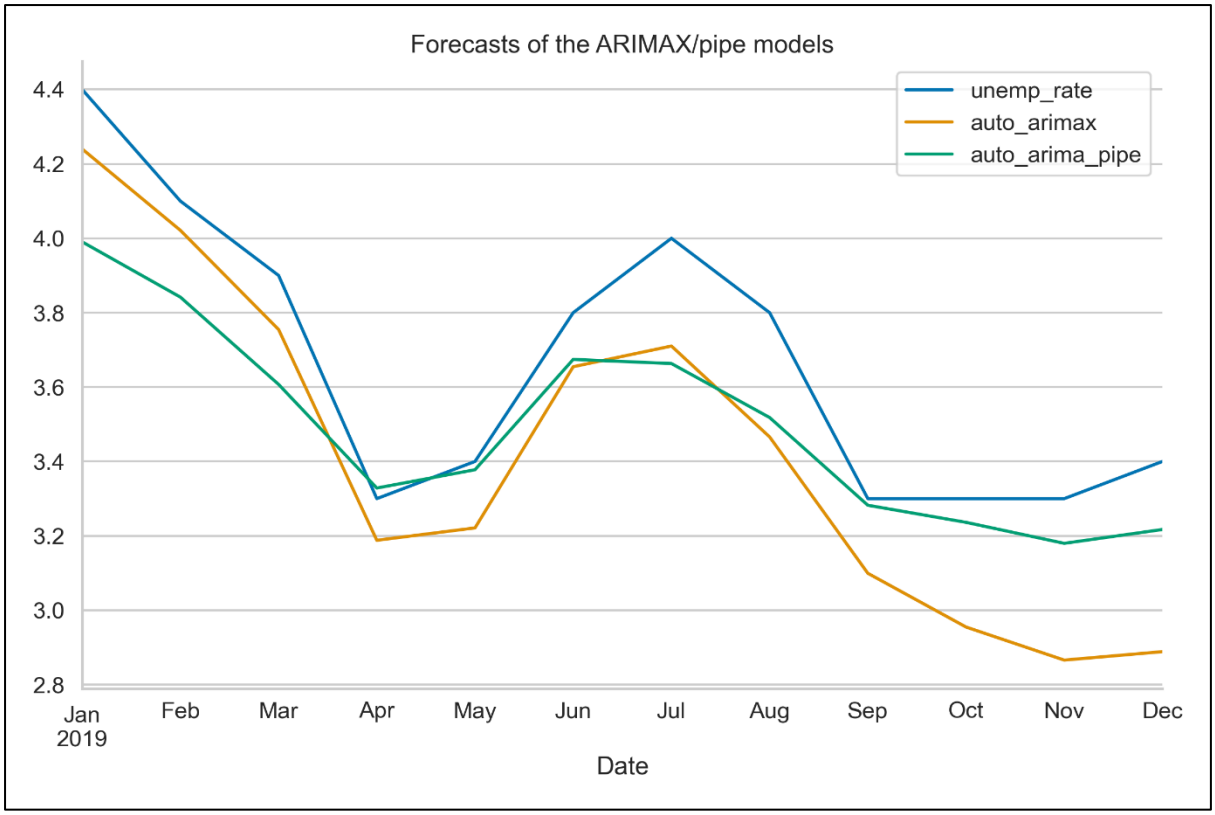
SARIMAX Results

Dep. Variable:	y	No. Observations:	108
Model:	SARIMAX(0, 1, 2)	Log Likelihood	64.959
Date:	Sat, 30 Jul 2022	AIC	-99.917
Time:	00:02:14	BIC	-59.825
Sample:	01-01-2010	HQIC	-83.664
	- 12-01-2018		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
intercept	-0.0590	0.009	-6.760	0.000	-0.076	-0.042
month__2	-0.1329	0.072	-1.856	0.063	-0.273	0.007
month__3	-0.3405	0.074	-4.593	0.000	-0.486	-0.195
month__4	-0.8482	0.066	-12.846	0.000	-0.978	-0.719
month__5	-0.7560	0.067	-11.337	0.000	-0.887	-0.625
month__6	-0.2637	0.066	-3.996	0.000	-0.393	-0.134
month__7	-0.1491	0.074	-2.016	0.044	-0.294	-0.004
month__8	-0.3345	0.070	-4.778	0.000	-0.472	-0.197
month__9	-0.6422	0.068	-9.434	0.000	-0.776	-0.509
month__10	-0.7278	0.067	-10.938	0.000	-0.858	-0.597
month__11	-0.7578	0.055	-13.712	0.000	-0.866	-0.649
month__12	-0.6761	0.045	-15.036	0.000	-0.764	-0.588
ma.L1	-0.2874	0.106	-2.711	0.007	-0.495	-0.080
ma.L2	-0.1234	0.105	-1.179	0.239	-0.329	0.082
sigma2	0.0174	0.003	6.427	0.000	0.012	0.023

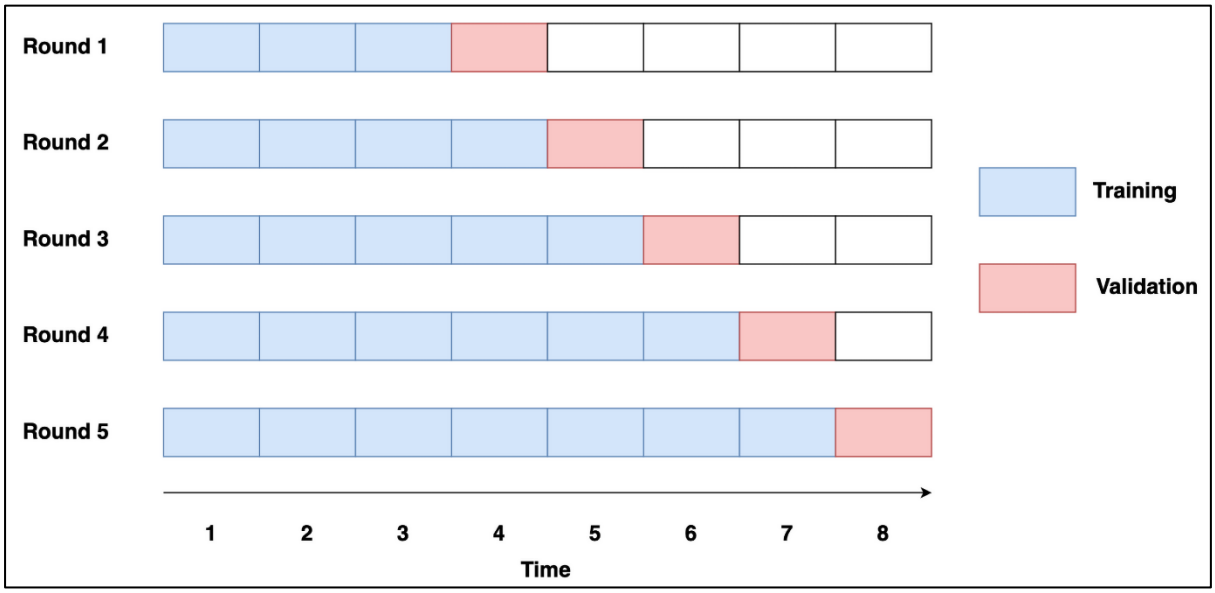
Ljung-Box (L1) (Q):	0.01	Jarque-Bera (JB):	0.05
Prob(Q):	0.91	Prob(JB):	0.98
Heteroskedasticity (H):	0.60	Skew:	-0.03
Prob(H) (two-sided):	0.13	Kurtosis:	2.91

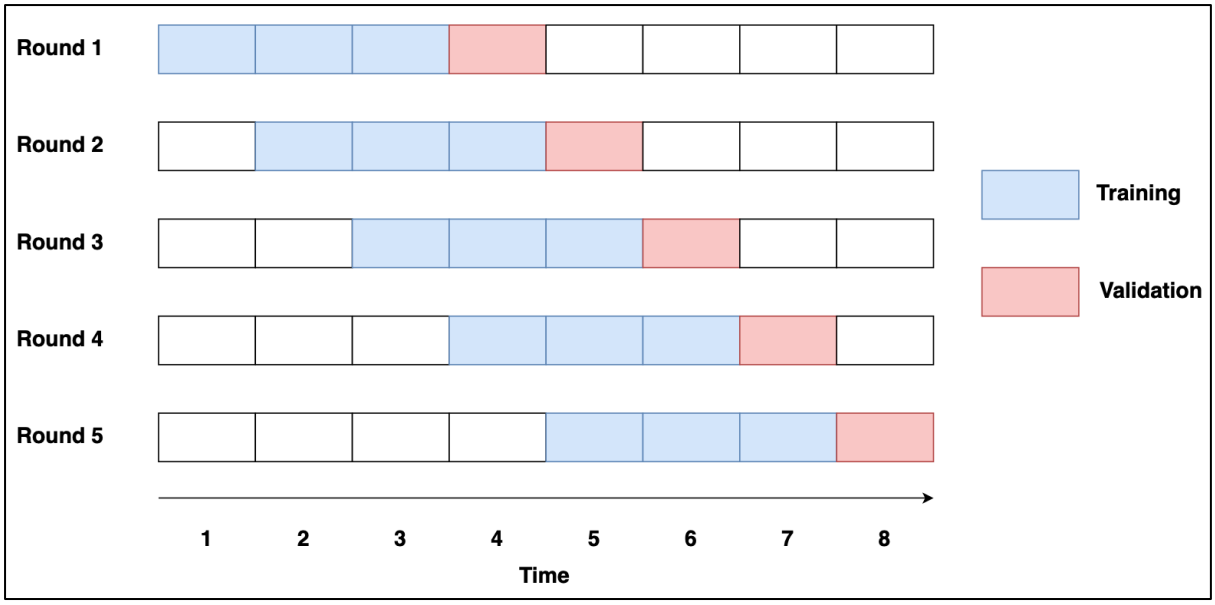

Standardized residual
3
2
1
0
−1
−2
2011
2012
2013
2014
2015
2016
2017
2018
Histogram plus estimated density
Hist
KDE
N(0,1)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−3
−2
−1
0
1
2
3
Normal Q-Q
Sample Quantiles
Theoretical Quantiles
Correlogram
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
5
10
15
20
25

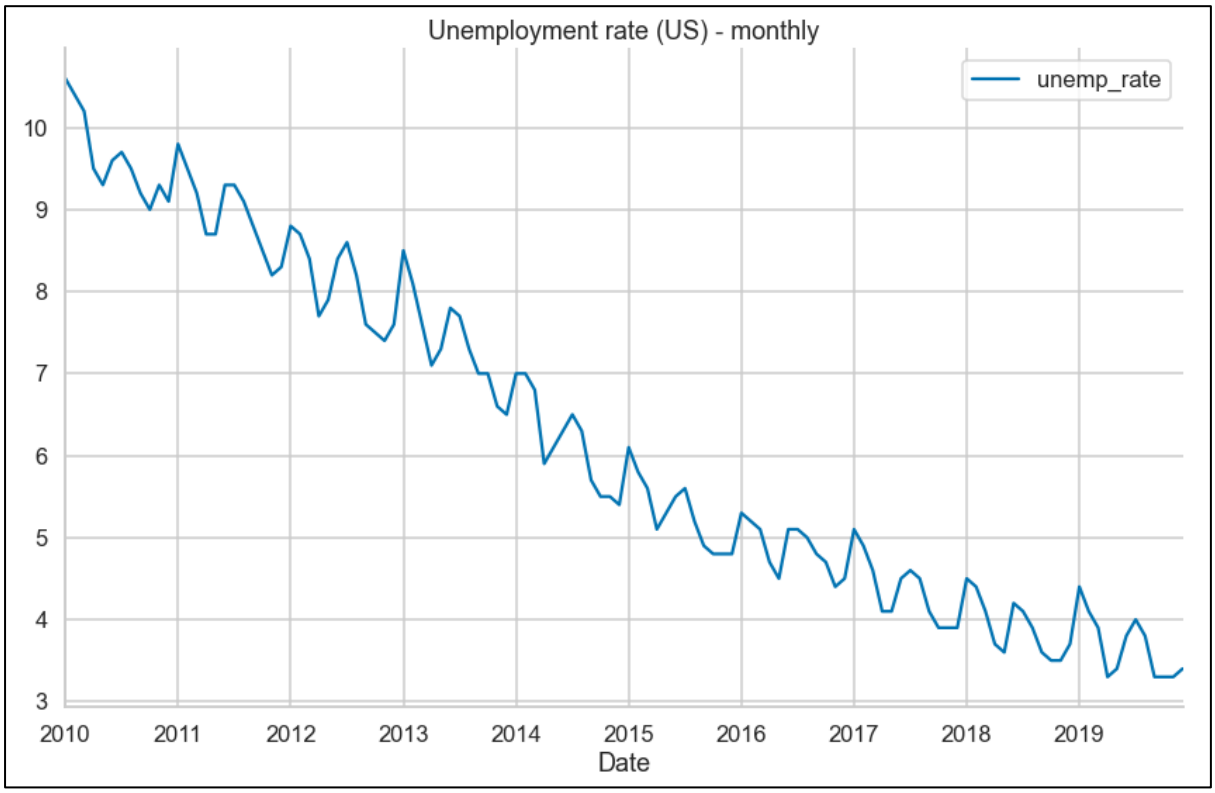

Forecasts of the ARIMAX/pipe models
unemp_rate
auto_arimax
auto_arima_pipe
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
Jan
2019
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Date

Chapter 7: Machine Learning-Based Approaches to Time Series Forecasting



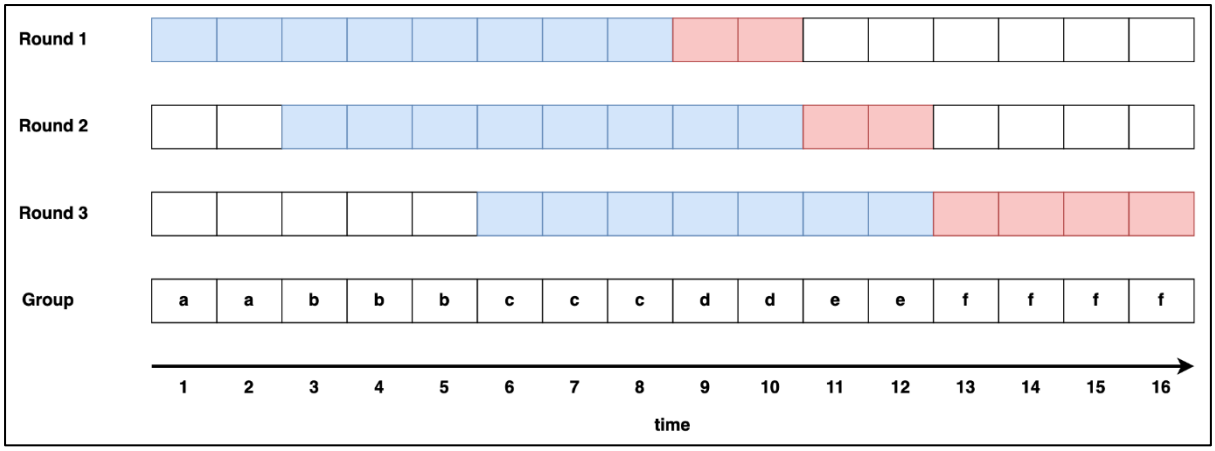


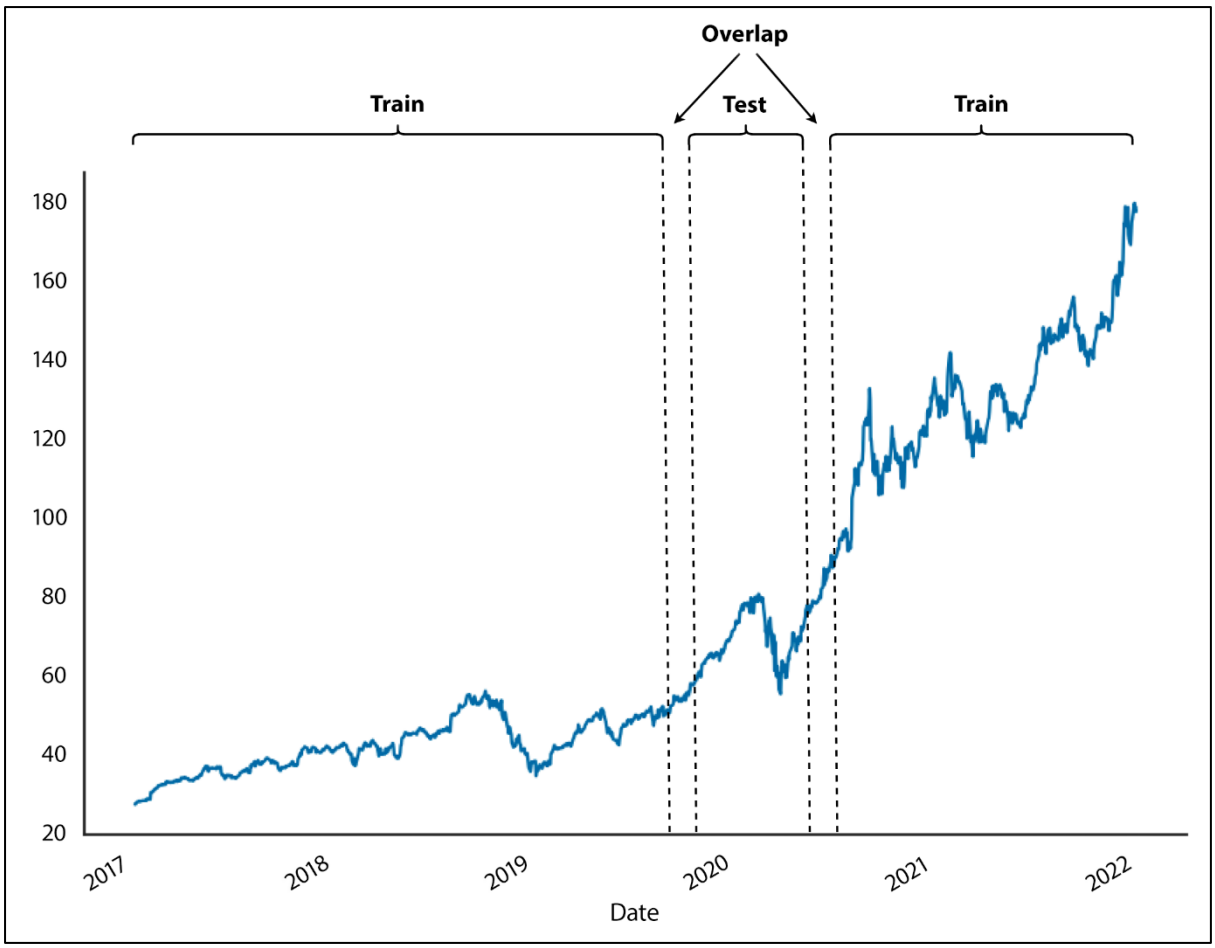


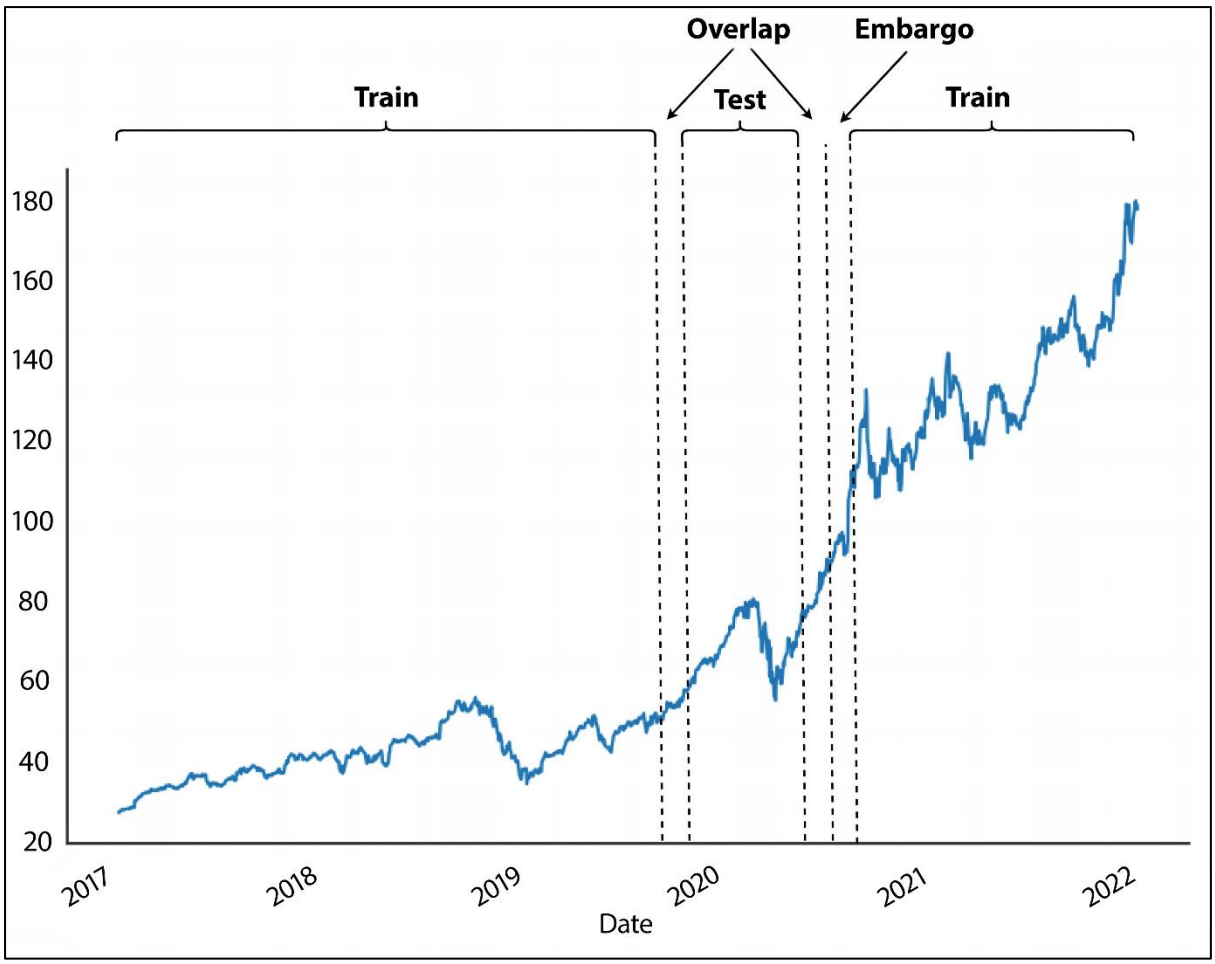


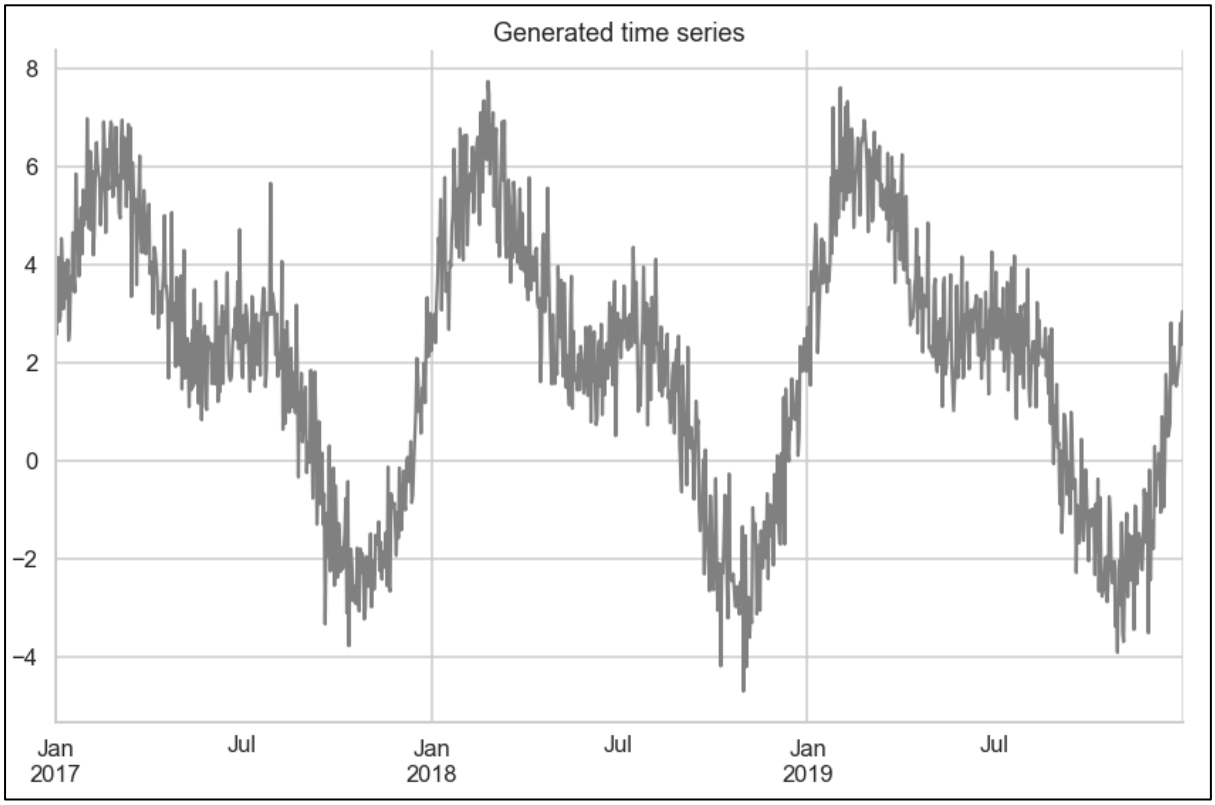
	fit_time	score_time	test_neg_mean_absolute_percentage_error	test_neg_root_mean_squared_error
0	0.001417	0.000876	-0.037051	-0.232500
1	0.001185	0.000720	-0.078284	-0.433547
2	0.001209	0.000726	-0.119811	-0.520073
3	0.001082	0.000693	-0.168295	-0.662540
4	0.001085	0.000777	-0.254605	-0.928998

	fit_time	score_time	test_neg_mean_absolute_percentage_error	test_neg_root_mean_squared_error
0	0.002245	0.001034	-0.037051	-0.232500
1	0.001400	0.000886	-0.097125	-0.524333
2	0.001330	0.000882	-0.126609	-0.550749
3	0.001364	0.000881	-0.129454	-0.518194
4	0.001397	0.000830	-0.108759	-0.407428

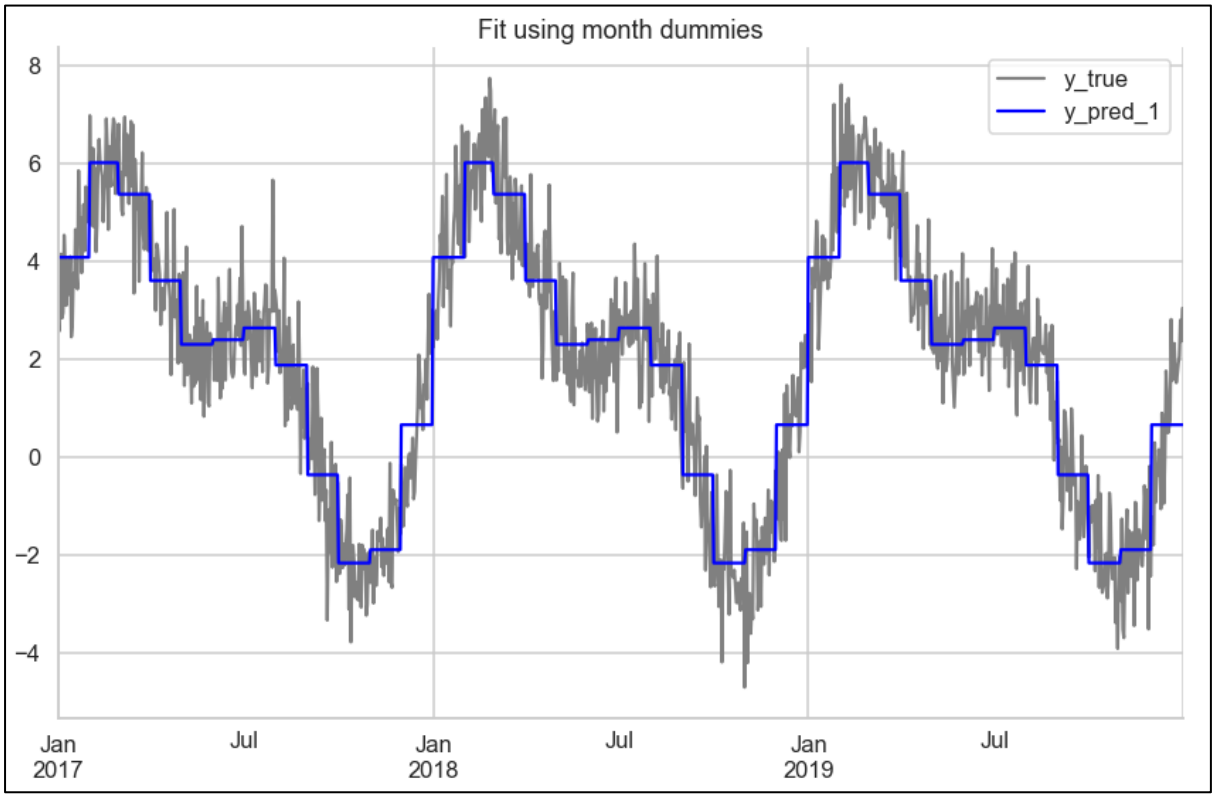


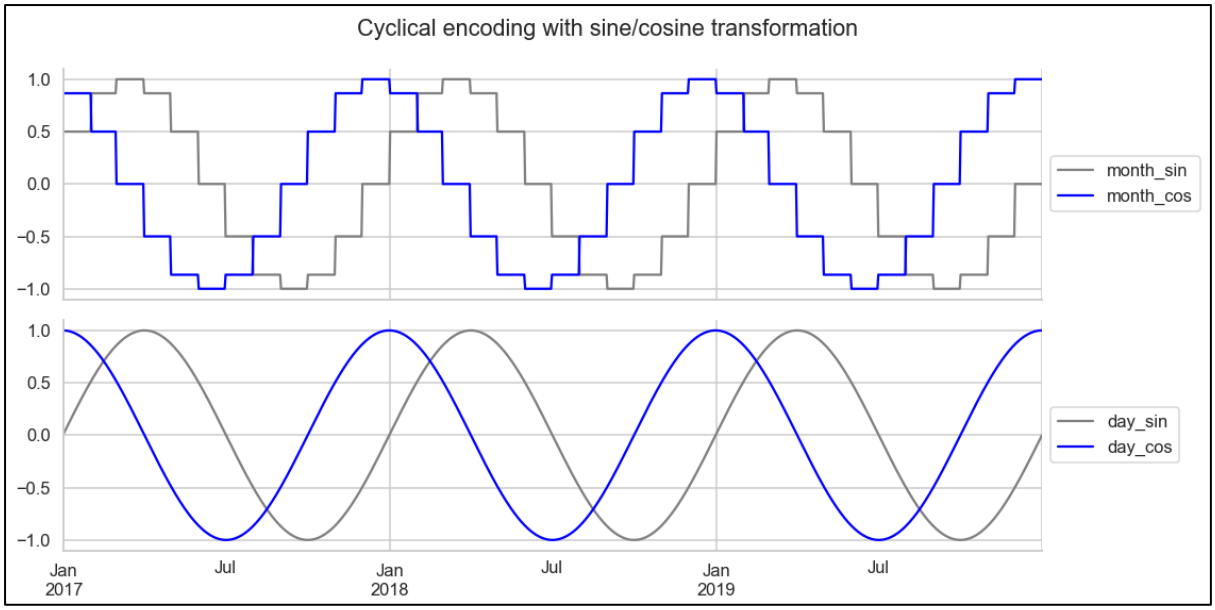


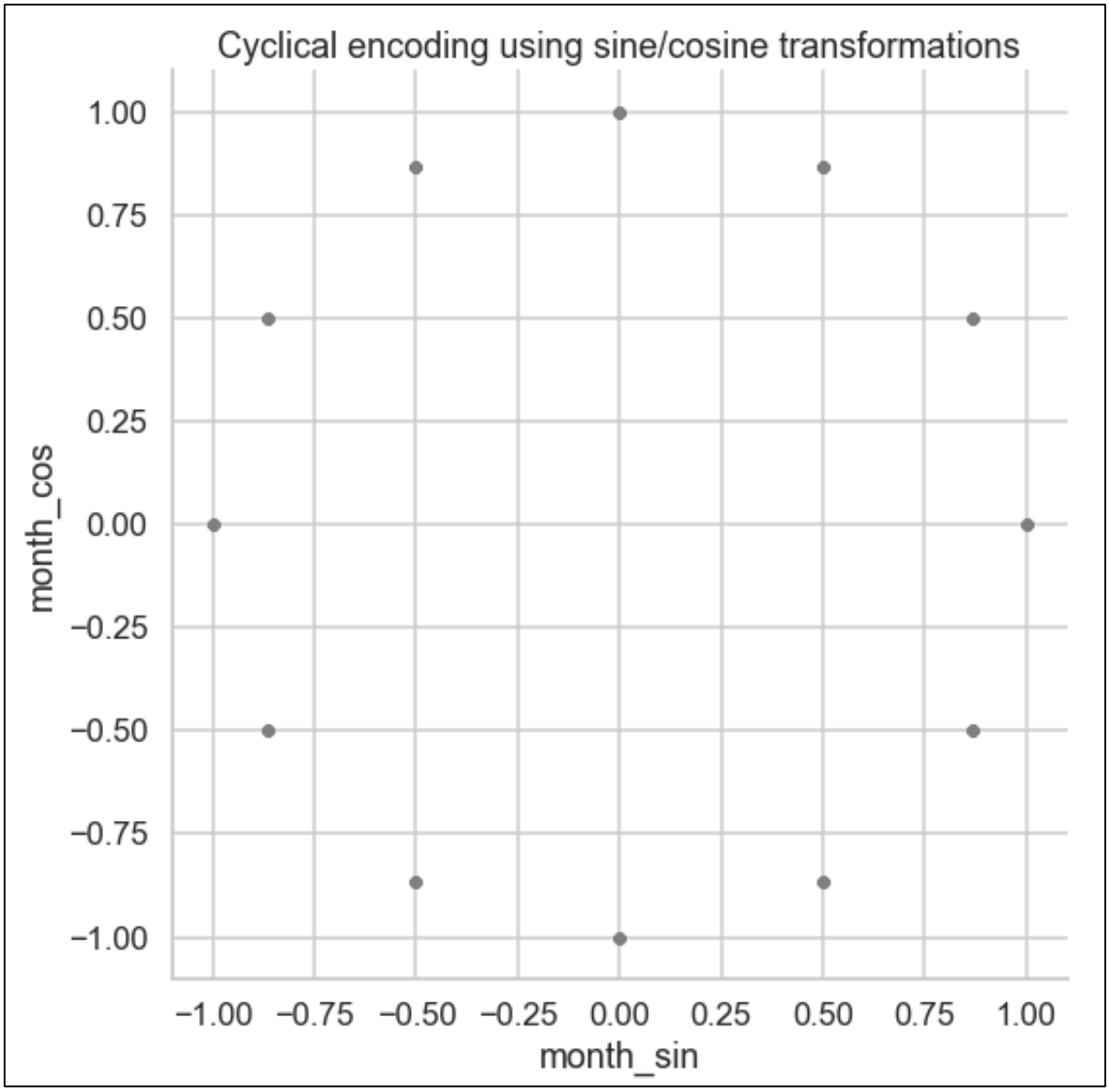

Overlap
Embargo
Train
Test
Train
180
160
140
120
100
80
60
40
20
2017
2018
2019
2020
2021
2022
Date

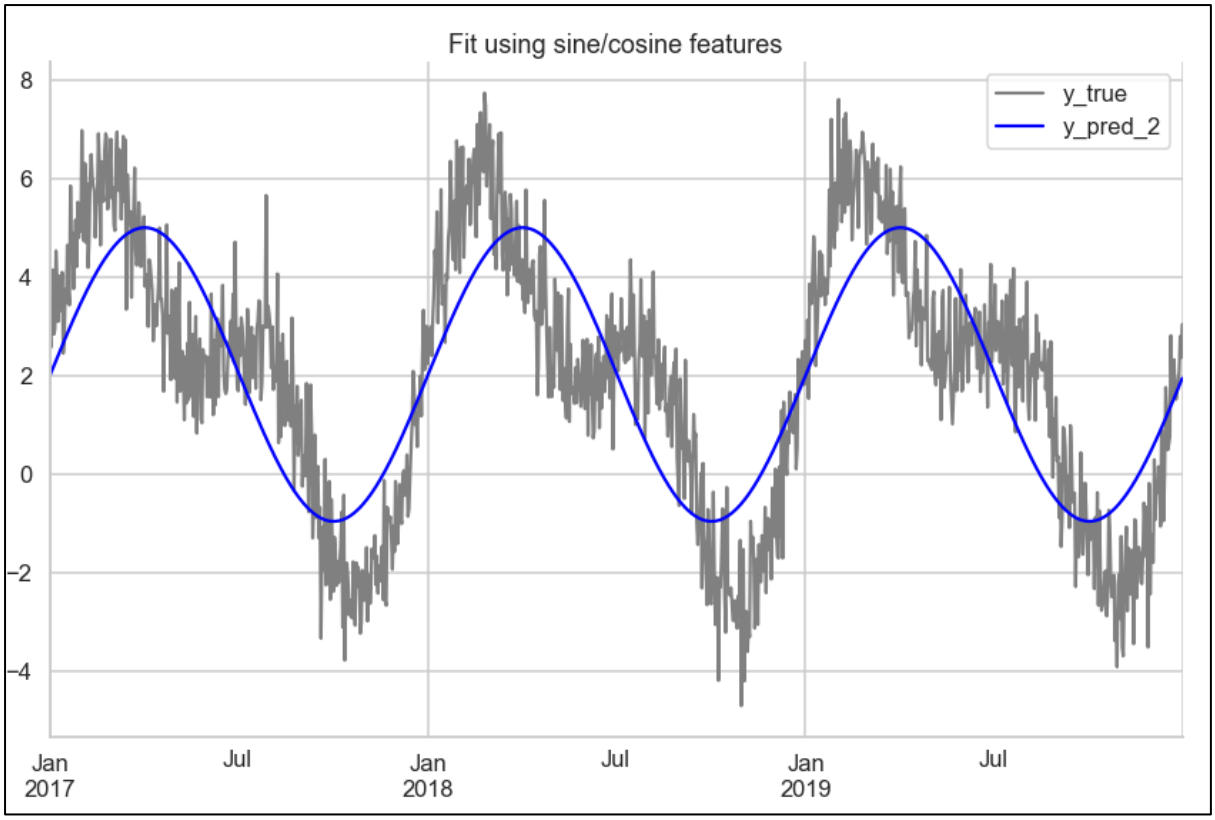

Generated time series
8
6
4
2
0
−2
−4
Jan
2017
Jul
Jan
2018
Jul
Jan
2019
Jul

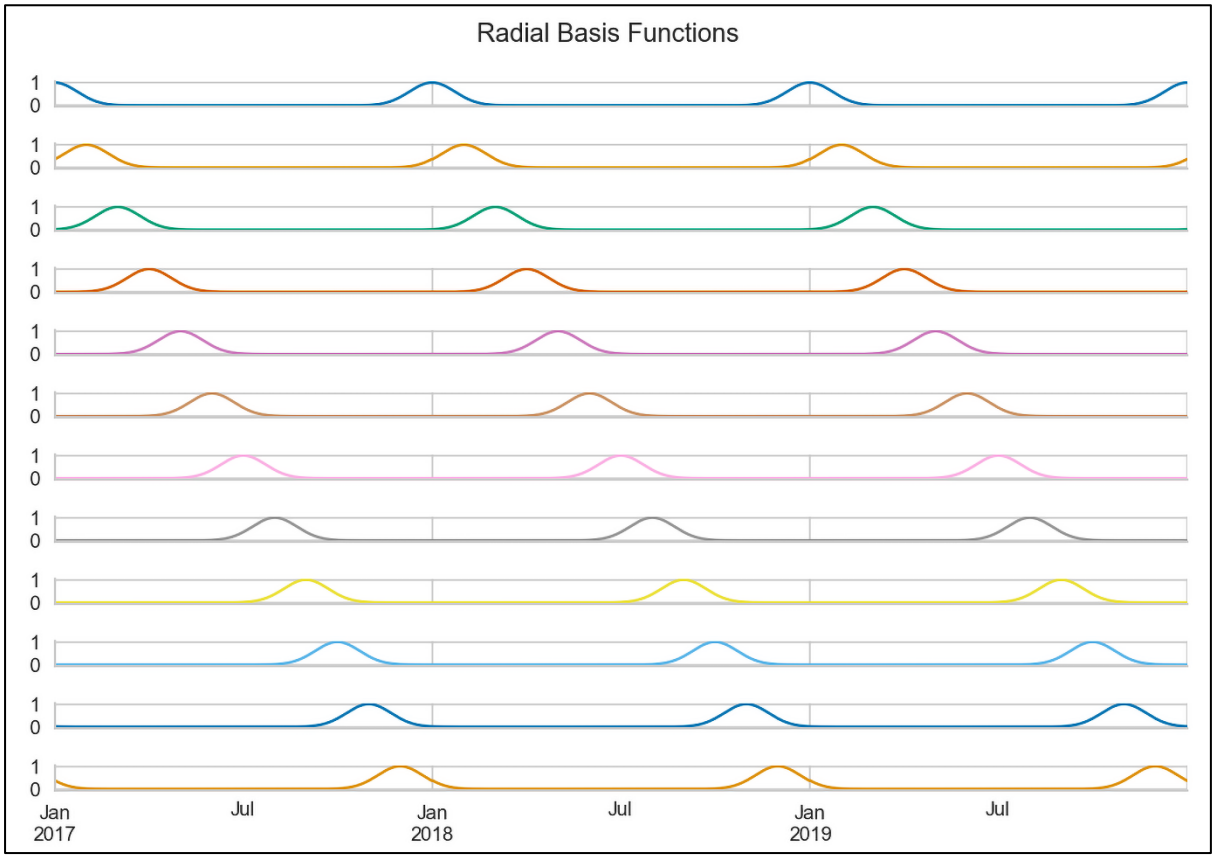
	month_2	month_3	month_4	month_5	month_6	month_7	month_8	month_9	month_10	month_11	month_12
2017-01-01	0	0	0	0	0	0	0	0	0	0	0
2017-01-02	0	0	0	0	0	0	0	0	0	0	0
2017-01-03	0	0	0	0	0	0	0	0	0	0	0
2017-01-04	0	0	0	0	0	0	0	0	0	0	0
2017-01-05	0	0	0	0	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...	...	...	...
2019-12-27	0	0	0	0	0	0	0	0	0	0	1
2019-12-28	0	0	0	0	0	0	0	0	0	0	1
2019-12-29	0	0	0	0	0	0	0	0	0	0	1
2019-12-30	0	0	0	0	0	0	0	0	0	0	1
2019-12-31	0	0	0	0	0	0	0	0	0	0	1

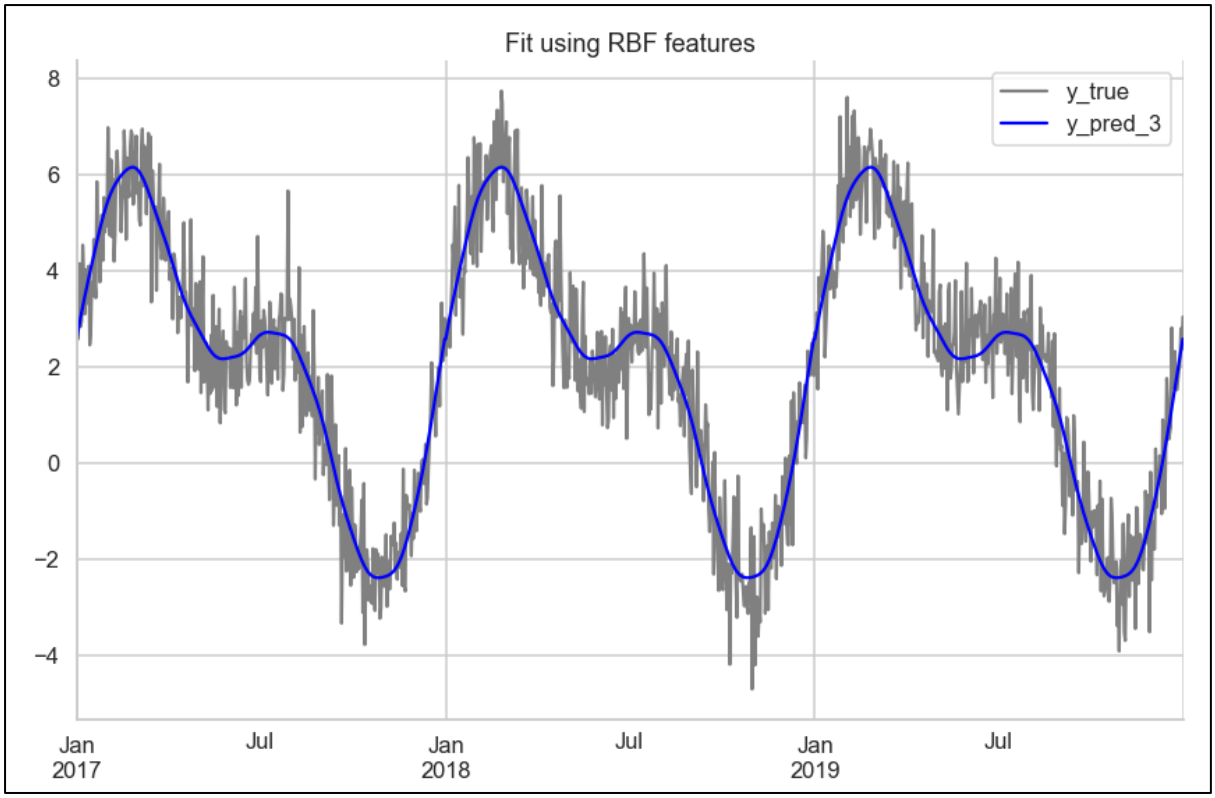



Cyclical encoding with sine/cosine transformation
1.0
0.5
0.0
−0.5
−1.0
month_sin
month_cos
day_sin
day_cos
Jan
2017
Jul
Jan
2018
Jul
Jan
2019
Jul


Cyclical encoding using sine/cosine transformations
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
month_cos
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
month_sin


Fit using sine/cosine features
y_true
y_pred_2
8
6
4
2
0
−2
−4
Jan
2017
Jul
Jan
2018
Jul
Jan
2019
Jul


Radial Basis Functions
1
0
Jan
2017
Jul
Jan
2018
Jul
Jan
2019
Jul



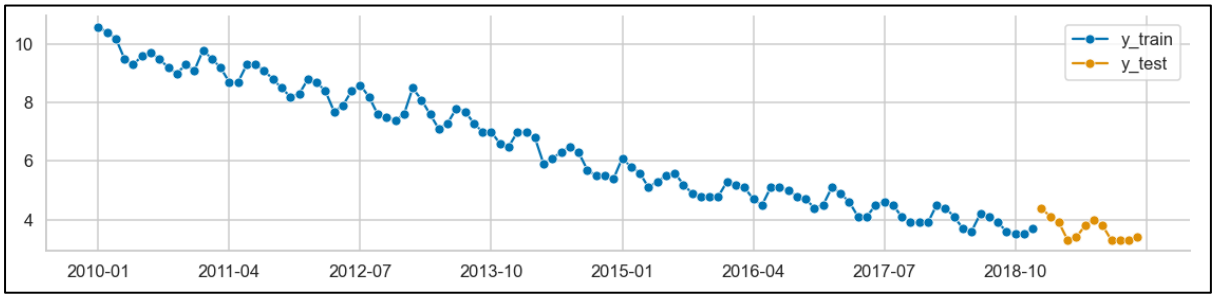
	y	year	quarter	month	week_of_year	day	month_of_quarter	week_of_quarter	day_of_quarter	week_of_month	day	weekday
2017-01-01	2.969692	2017	1	1	52	1	1	1	1	1	1	6
2017-01-02	2.572678	2017	1	1	1	2	1	2	2	1	2	0
2017-01-03	3.325853	2017	1	1	1	3	1	2	3	1	3	1
2017-01-04	4.150575	2017	1	1	1	4	1	2	4	1	4	2
2017-01-05	2.842004	2017	1	1	1	5	1	2	5	1	5	3

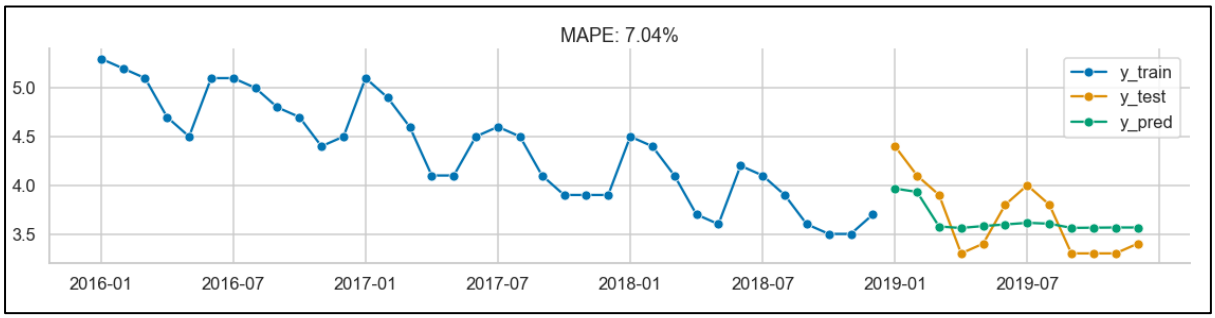
	date	y	id
3410	2017-01-01	2.969692	(a, 2017-01-08 00:00:00)
3411	2017-01-02	2.572678	(a, 2017-01-08 00:00:00)
3412	2017-01-03	3.325853	(a, 2017-01-08 00:00:00)
3413	2017-01-04	4.150575	(a, 2017-01-08 00:00:00)
3414	2017-01-05	2.842004	(a, 2017-01-08 00:00:00)
...	...	...	...
33447	2019-12-27	1.914564	(a, 2019-12-31 00:00:00)
33448	2019-12-28	2.062146	(a, 2019-12-31 00:00:00)
33449	2019-12-29	2.801118	(a, 2019-12-31 00:00:00)
33450	2019-12-30	2.372868	(a, 2019-12-31 00:00:00)
33451	2019-12-31	3.042800	(a, 2019-12-31 00:00:00)

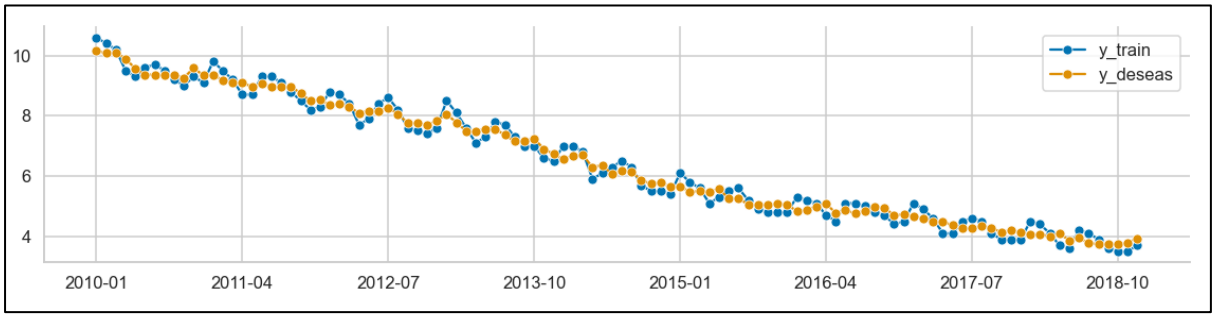
last_date	y__sum_values	y__median	y__mean	y__length	y__standard_deviation	y__variance	y__maximum	y__minimum
2017-01-08	27.3446	3.1478	3.4181	8.0	0.6696	0.4484	4.5371	2.5727
2017-01-09	30.4437	3.0991	3.3826	9.0	0.6392	0.4086	4.5371	2.5727
2017-01-10	34.4712	3.2125	3.4471	10.0	0.6365	0.4052	4.5371	2.5727
2017-01-11	37.7911	3.3199	3.4356	11.0	0.6080	0.3697	4.5371	2.5727
2017-01-12	41.2148	3.3229	3.4346	12.0	0.5821	0.3389	4.5371	2.5727
2017-01-13	45.3157	3.3259	3.4858	13.0	0.5868	0.3443	4.5371	2.5727
2017-01-14	47.7731	3.3229	3.4124	14.0	0.6244	0.3899	4.5371	2.4575
2017-01-15	50.4837	3.3199	3.3656	15.0	0.6281	0.3945	4.5371	2.4575
2017-01-16	54.2347	3.3229	3.3897	16.0	0.6153	0.3786	4.5371	2.4575
2017-01-17	57.7174	3.3259	3.3951	17.0	0.5973	0.3568	4.5371	2.4575
2017-01-18	62.3698	3.3748	3.4650	18.0	0.6480	0.4199	4.6524	2.4575
2017-01-19	66.1248	3.4237	3.4803	19.0	0.6340	0.4020	4.6524	2.4575
2017-01-20	69.5618	3.4304	3.4781	20.0	0.6180	0.3820	4.6524	2.4575
2017-01-21	75.4183	3.4370	3.5913	21.0	0.7876	0.6203	5.8565	2.4575
2017-01-22	79.9908	3.4599	3.6359	22.0	0.7962	0.6339	5.8565	2.4575
2017-01-23	84.8846	3.4827	3.6906	23.0	0.8198	0.6721	5.8565	2.4575
2017-01-24	88.6509	3.6168	3.6938	24.0	0.8027	0.6444	5.8565	2.4575
2017-01-25	93.2093	3.7510	3.7284	25.0	0.8045	0.6473	5.8565	2.4575
2017-01-26	98.3749	3.7530	3.7836	26.0	0.8359	0.6988	5.8565	2.4575
2017-01-27	102.5922	3.7550	3.7997	27.0	0.8244	0.6796	5.8565	2.4575
2017-01-28	108.1175	3.7607	3.8613	28.0	0.8706	0.7579	5.8565	2.4575
2017-01-29	112.9206	3.7664	3.8938	29.0	0.8725	0.7613	5.8565	2.4575
2017-01-30	118.0400	3.8787	3.9347	30.0	0.8856	0.7843	5.8565	2.4575
2017-01-31	122.9716	3.9909	3.9668	31.0	0.8888	0.7900	5.8565	2.4575
2017-02-01	126.9819	4.0275	4.0962	31.0	1.0169	1.0341	6.9799	2.4575

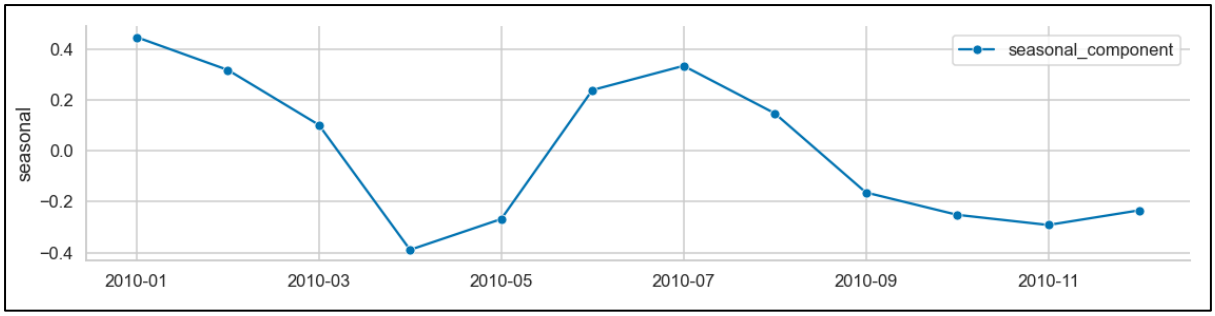
y
1
2
3
4
...
99
100

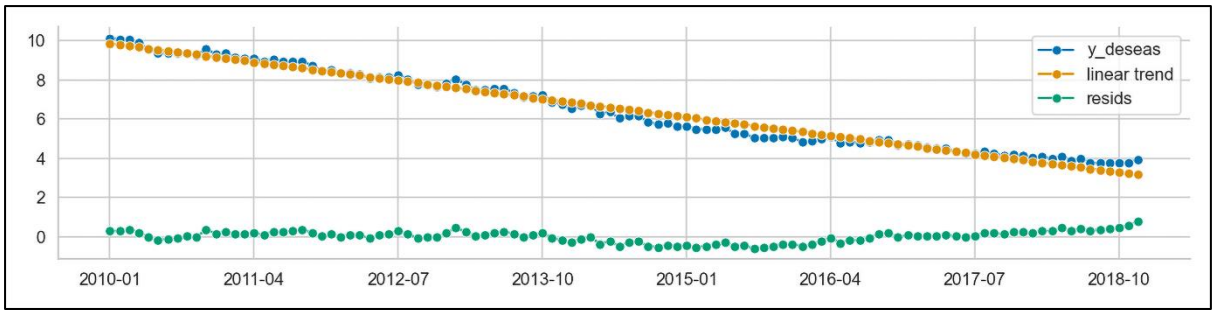
y	X			
	lag_1	lag_2	lag_3	lag_4
5	4	3	2	1
6	5	4	3	2
7	6	5	4	3
	...			
100	99	98	97	96

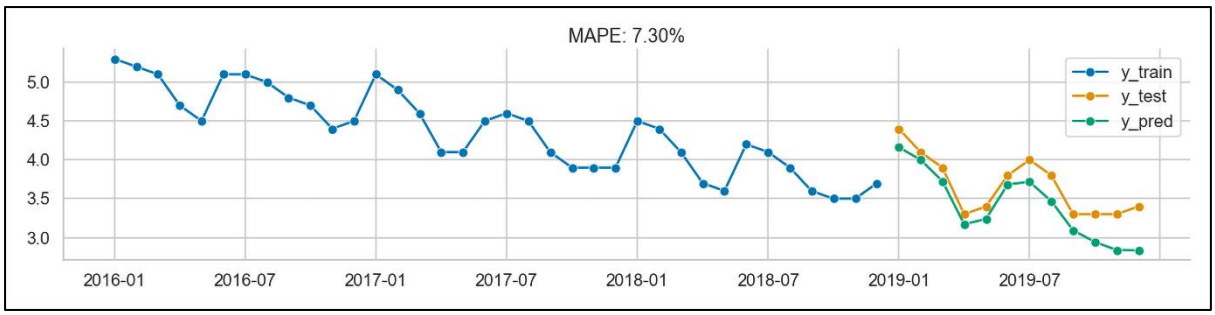




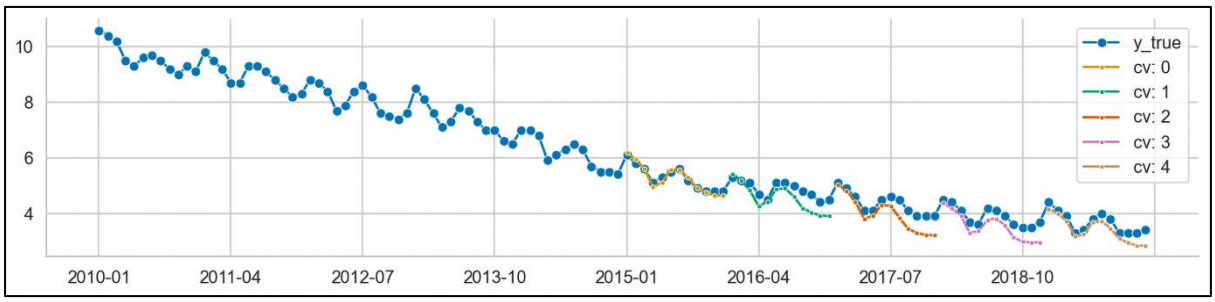


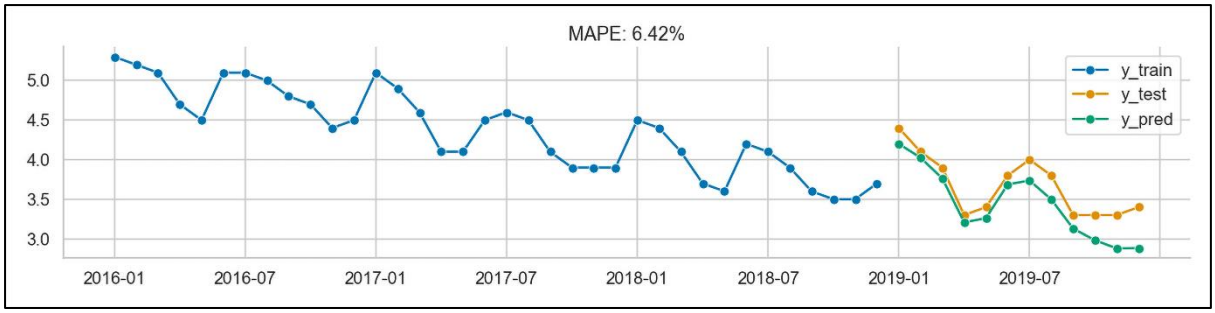


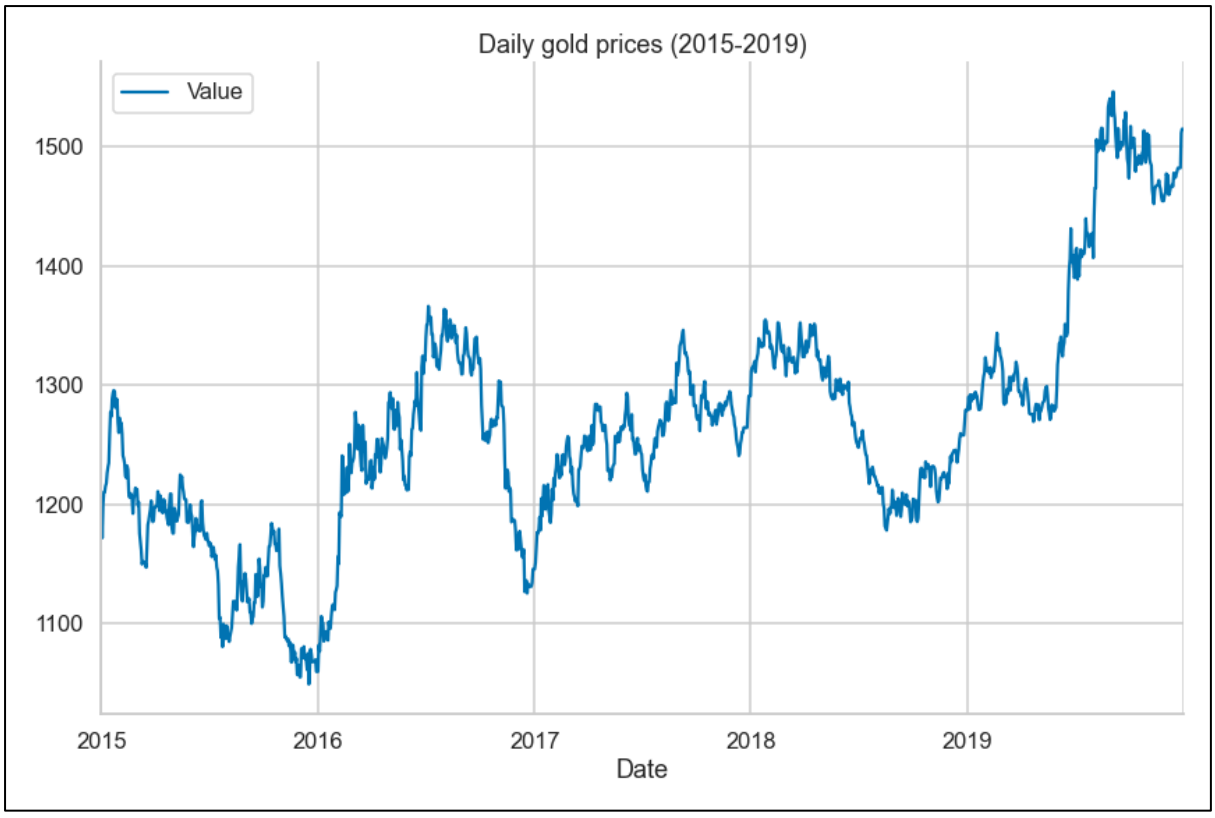


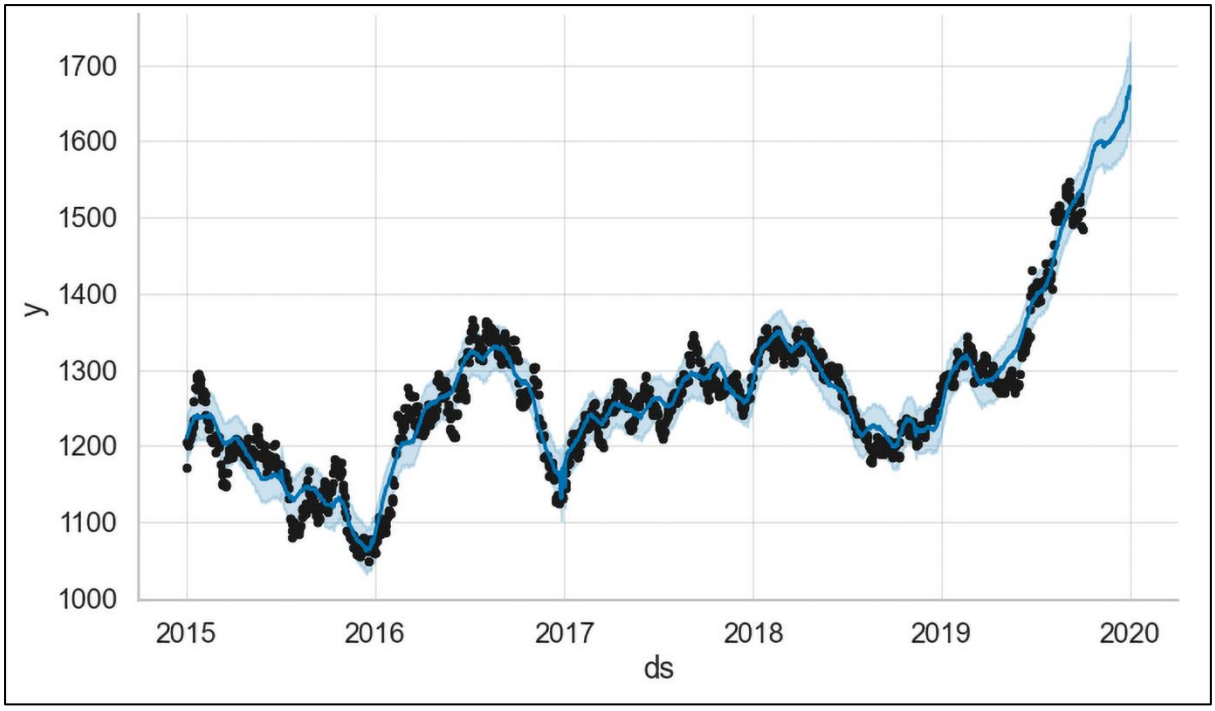


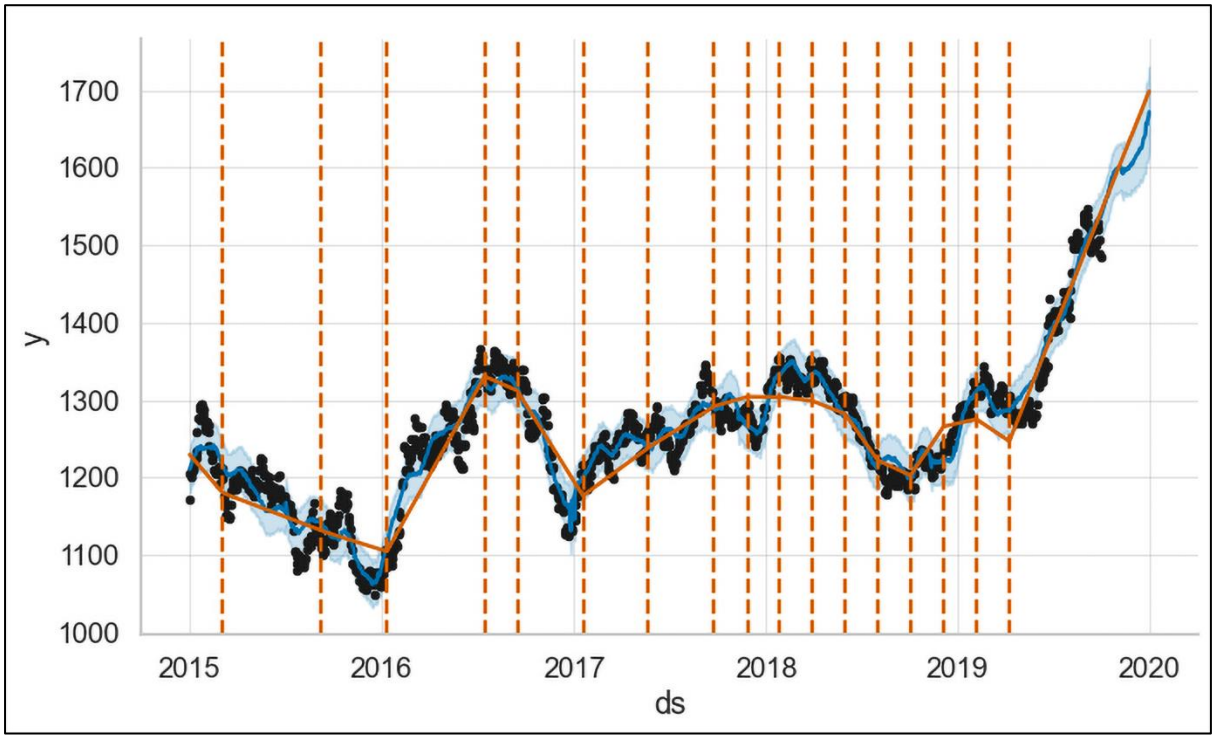
	test_MeanAbsolutePercentageError	fit_time	pred_time	len_train_window	cutoff	y_train	y_test	y_pred
0	0.017968	0.060766	0.032131	60	2014-12	unemp_rate 2010-01 10.6 2010-0...	unemp_rate 2015-01 6.1 2015-0...	unemp_rate 2015-01 6.189424 2015-0...
1	0.072160	0.058252	0.032728	72	2015-12	unemp_rate 2010-01 10.6 2010-0...	unemp_rate 2016-01 5.3 2016-0...	unemp_rate 2016-01 5.424690 2016-0...
2	0.092562	0.058367	0.032157	84	2016-12	unemp_rate 2010-01 10.6 2010-0...	unemp_rate 2017-01 5.1 2017-0...	unemp_rate 2017-01 5.043032 2017-0...
3	0.098999	0.060876	0.031808	96	2017-12	unemp_rate 2010-01 10.6 2010-0...	unemp_rate 2018-01 4.5 2018-0...	unemp_rate 2018-01 4.380789 2018-0...
4	0.072970	0.064576	0.032254	108	2018-12	unemp_rate 2010-01 10.6 2010-0...	unemp_rate 2019-01 4.4 2019-0...	unemp_rate 2019-01 4.161463 2019-0...

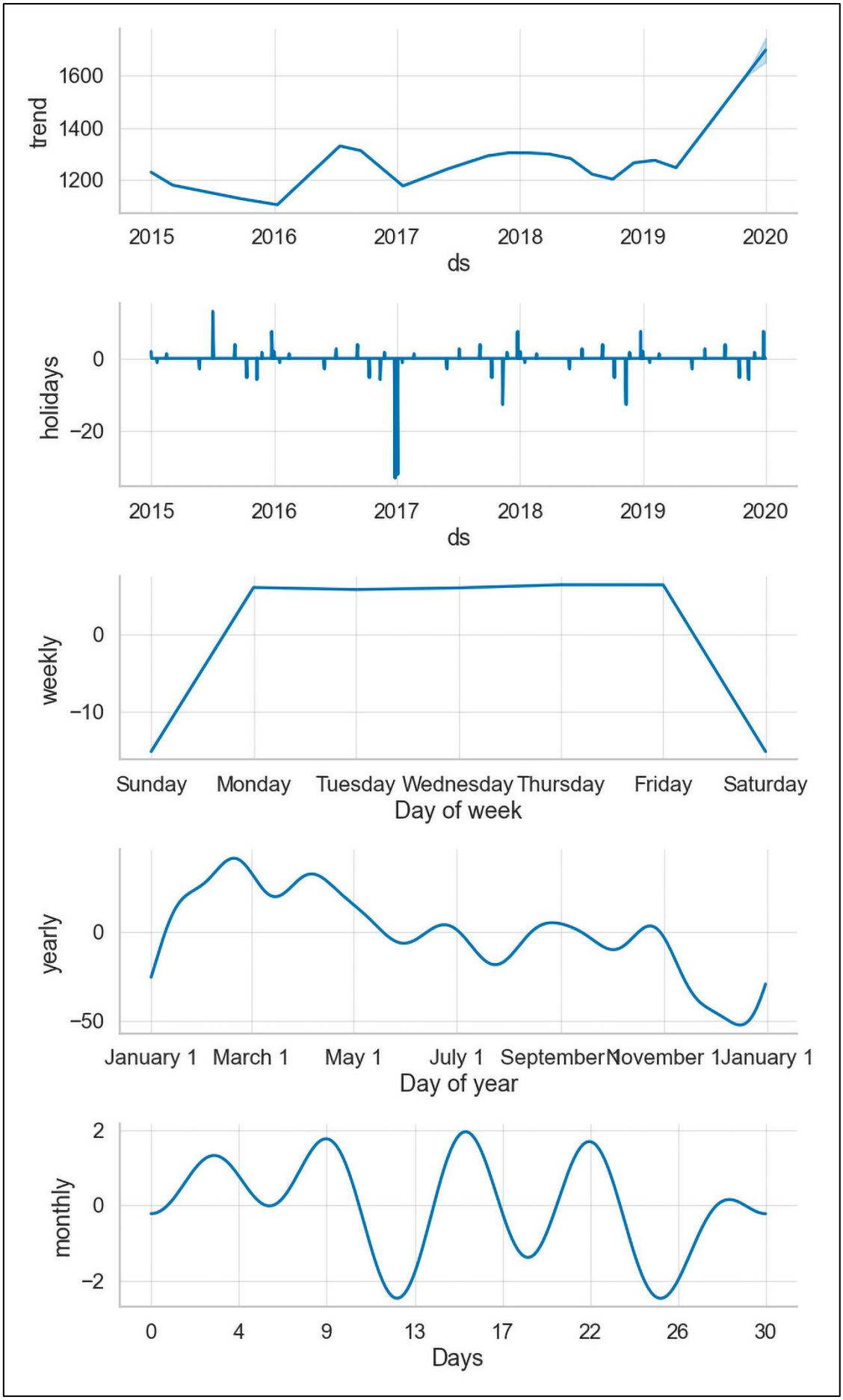


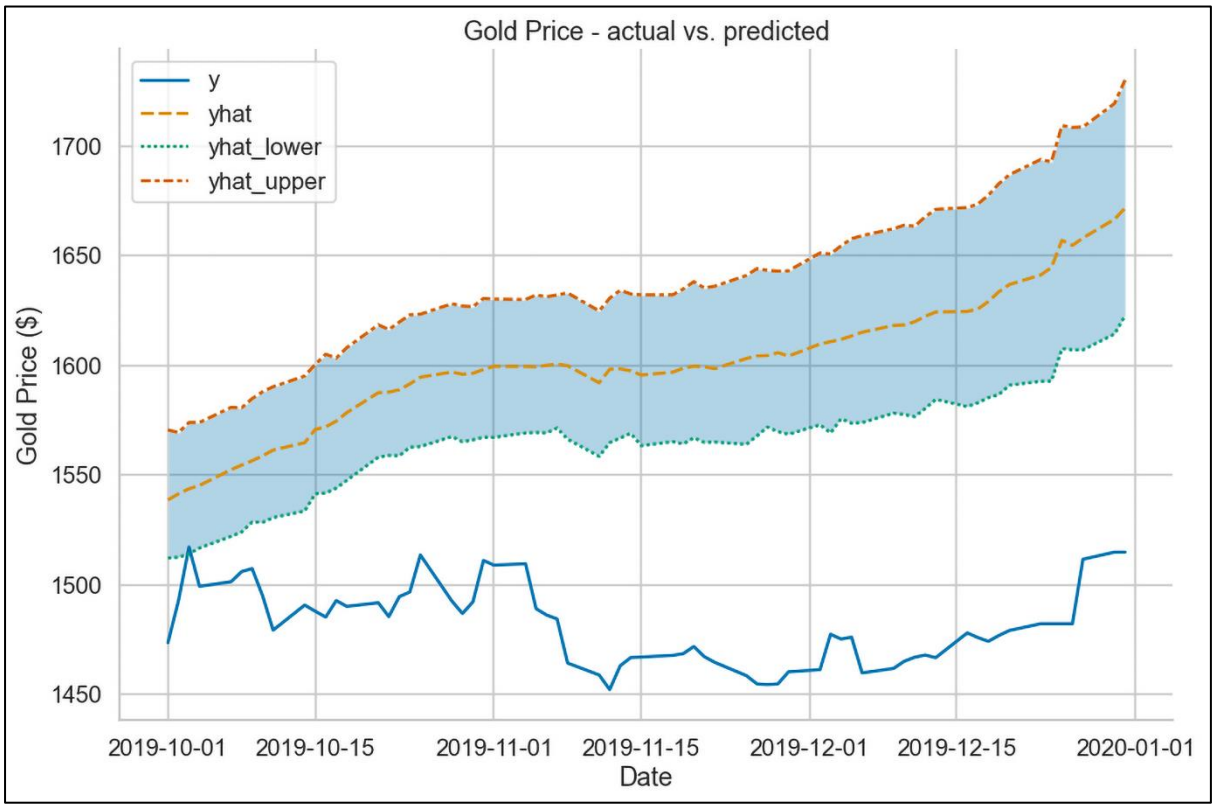

MAPE: 6.42%
y_train
y_test
y_pred
5.0
4.5
4.0
3.5
3.0
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07


Daily gold prices (2015-2019)
Value
1500
1400
1300
1200
1100
2015
2016
2017
2018
2019
Date


1700
1600
1500
1400
1300
1200
1100
1000
y
2015
2016
2017
2018
2019
2020
ds

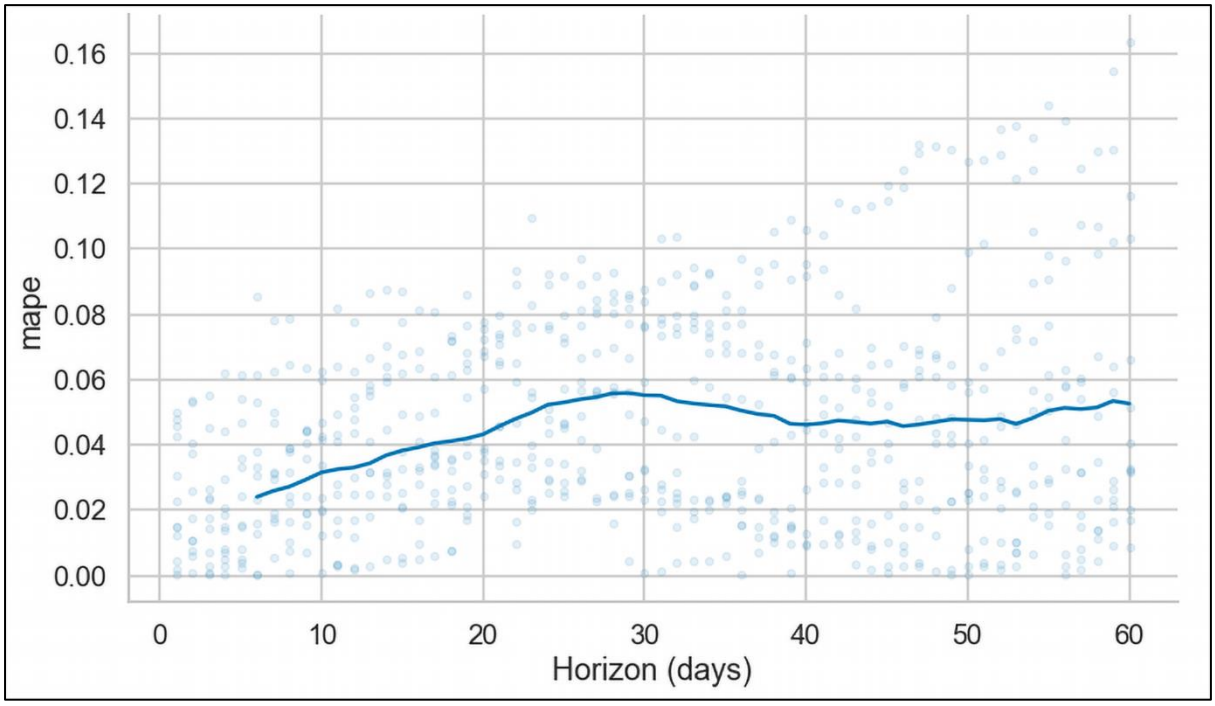

1700
1600
1500
1400
1300
1200
1100
1000
y
2015
2016
2017
2018
2019
2020
ds


trend
1600
1400
1200
2015
2016
2017
2018
2019
2020
ds
holidays
0
−20
2015
2016
2017
2018
2019
2020
ds
weekly
0
−10
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Day of week
yearly
0
−50
January 1
March 1
May 1
July 1
September 1
November 1
January 1
Day of year
monthly
2
0
−2
0
4
9
13
17
22
26
30
Days

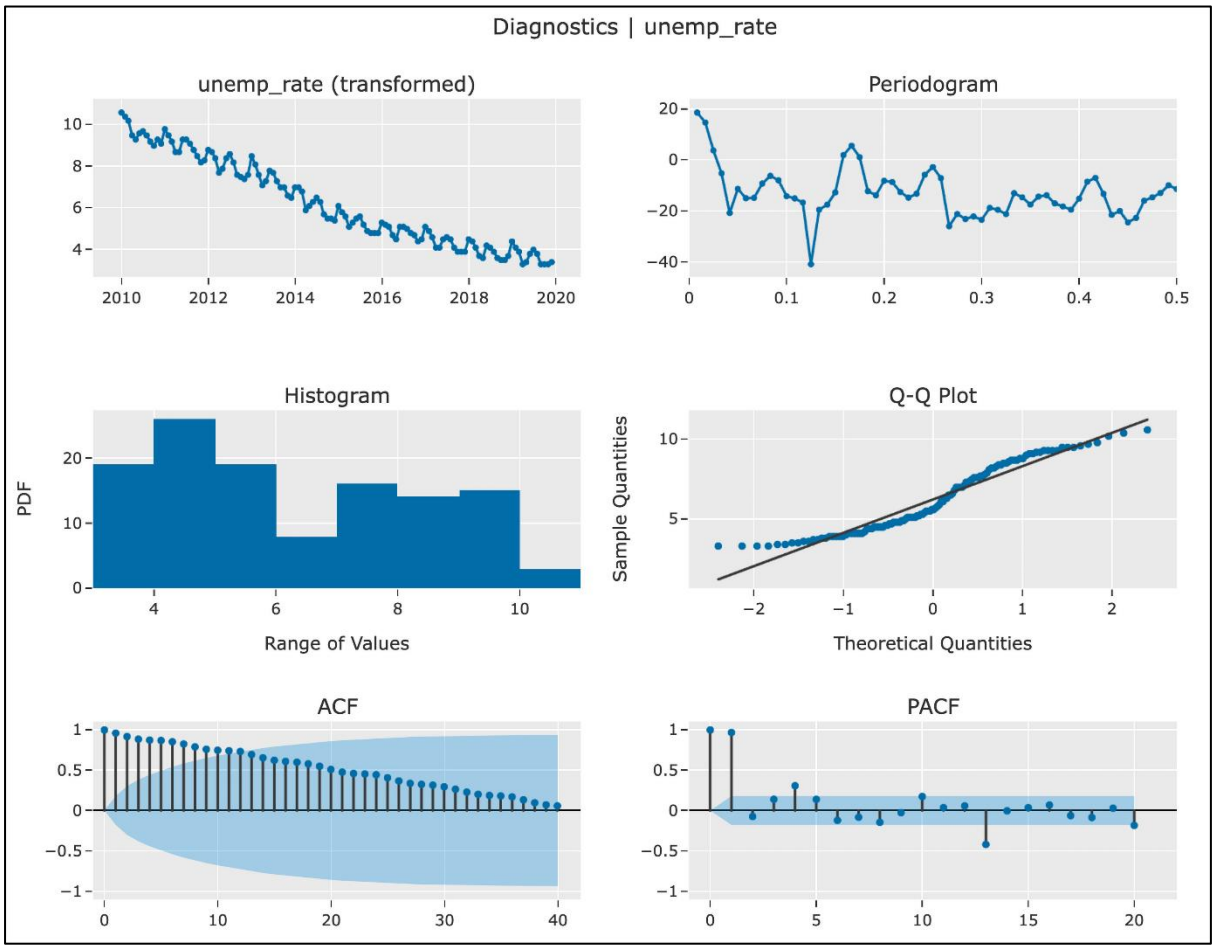


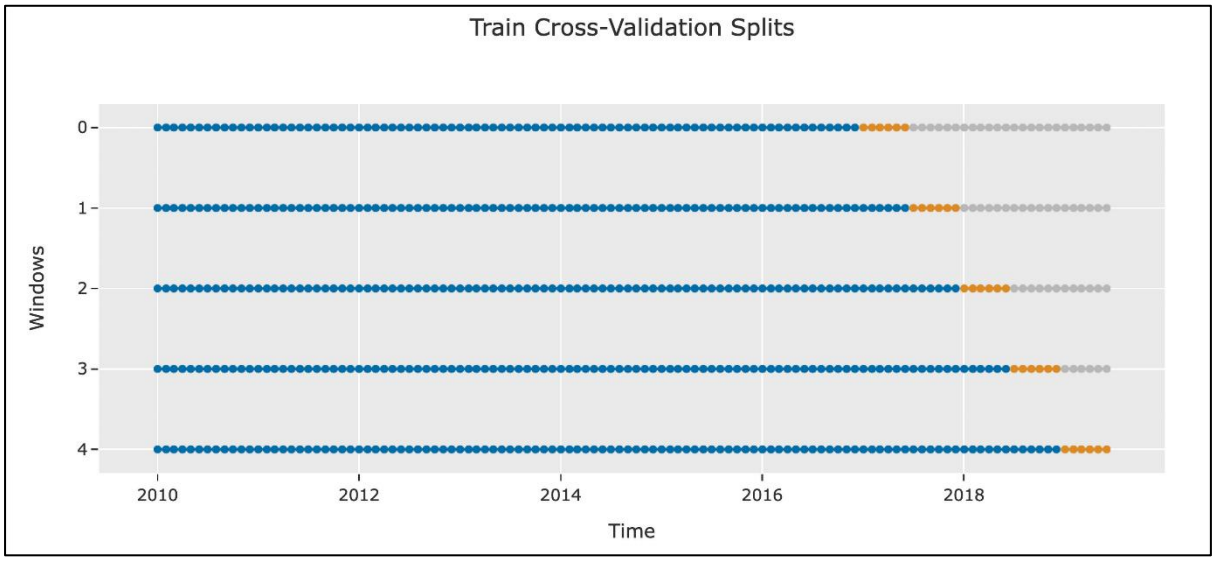
	ds	yhat	yhat_lower	yhat_upper	y	cutoff
0	2017-02-13	1240.428658	1214.075002	1266.887144	1222.25	2017-02-12
1	2017-02-14	1244.035274	1218.709804	1269.177963	1230.75	2017-02-12
2	2017-02-15	1245.784079	1219.778945	1270.415037	1224.40	2017-02-12
3	2017-02-16	1247.101206	1222.243635	1272.417761	1240.55	2017-02-12
4	2017-02-17	1247.049617	1219.427610	1273.846214	1241.95	2017-02-12
...	...	...	...	...	...	...
681	2019-09-24	1411.521433	1376.789748	1445.763547	1520.65	2019-08-01
682	2019-09-25	1411.647219	1378.678598	1447.529225	1528.75	2019-08-01
683	2019-09-26	1411.175984	1377.546582	1449.880765	1506.40	2019-08-01
684	2019-09-27	1409.462673	1374.309112	1445.839082	1489.90	2019-08-01
685	2019-09-30	1408.982620	1372.462776	1448.030593	1485.30	2019-08-01

	horizon	mse	rmse	mae	mape	mdape	smape	coverage
0	6 days	1748.610554	41.816391	31.559107	0.024066	0.018103	0.024227	0.551471
1	7 days	1989.890473	44.608188	33.977247	0.025884	0.020106	0.026108	0.529412
2	8 days	2202.222234	46.927841	35.882566	0.027195	0.022757	0.027480	0.491979
3	9 days	2367.956551	48.661654	38.572966	0.029299	0.024370	0.029526	0.459559
4	10 days	2529.118619	50.290343	41.208362	0.031576	0.031014	0.031808	0.397059
5	11 days	2691.744910	51.882029	42.421694	0.032552	0.031014	0.032844	0.367647
6	12 days	2725.613313	52.207407	43.137264	0.033074	0.030830	0.033348	0.362299
7	13 days	2937.700093	54.200554	44.898209	0.034387	0.032834	0.034652	0.333333
8	14 days	3270.445886	57.187812	47.956755	0.036807	0.034913	0.037067	0.294118
9	15 days	3656.224802	60.466725	50.168416	0.038266	0.035763	0.038576	0.288770



	Description	Value
0	session_id	42
1	Target	unemp_rate
2	Approach	Univariate
3	Exogenous Variables	Not Present
4	Original data shape	(120, 1)
5	Transformed data shape	(120, 1)
6	Transformed train set shape	(114, 1)
7	Transformed test set shape	(6, 1)
8	Rows with missing values	0.0%
9	Fold Generator	ExpandingWindowSplitter
10	Fold Number	5
11	Enforce Prediction Interval	0
12	Seasonal Period(s) Tested	12
13	Seasonality Present	1
14	Seasonalities Detected	[12]
15	Primary Seasonality	12
16	Target Strictly Positive	True
17	Target White Noise	No
18	Recommended d	1
19	Recommended Seasonal D	0
20	Preprocess	0
21	CPU Jobs	-1
22	Use GPU	0
23	Log Experiment	0
24	Experiment Name	ts-default-name
25	USI	2a00

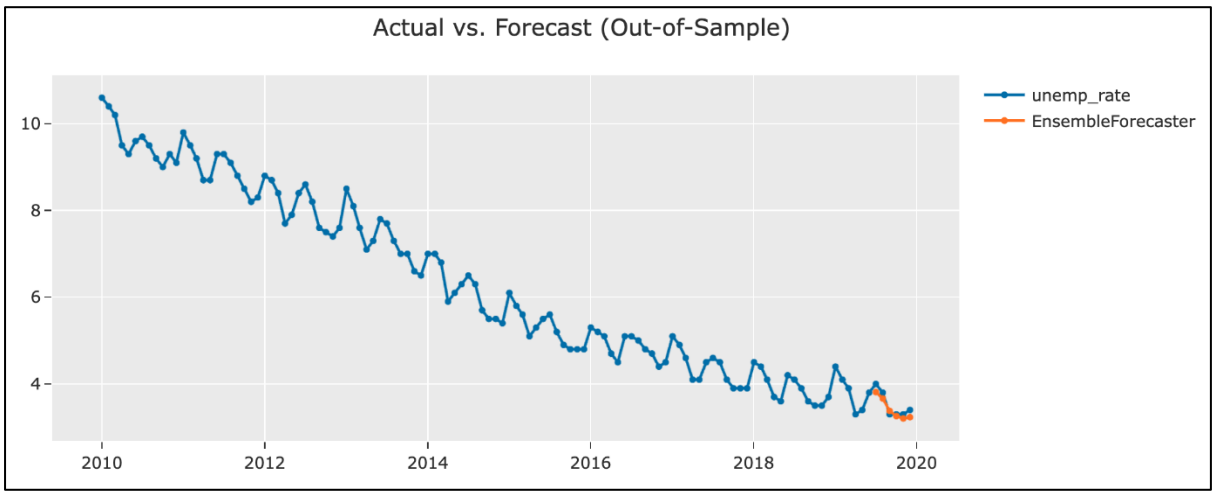

Diagnostics | unemp_rate
unemp_rate (transformed)
Periodogram
Histogram
PDF
Range of Values
Q-Q Plot
Sample Quantities
Theoretical Quantities
ACF
PACF

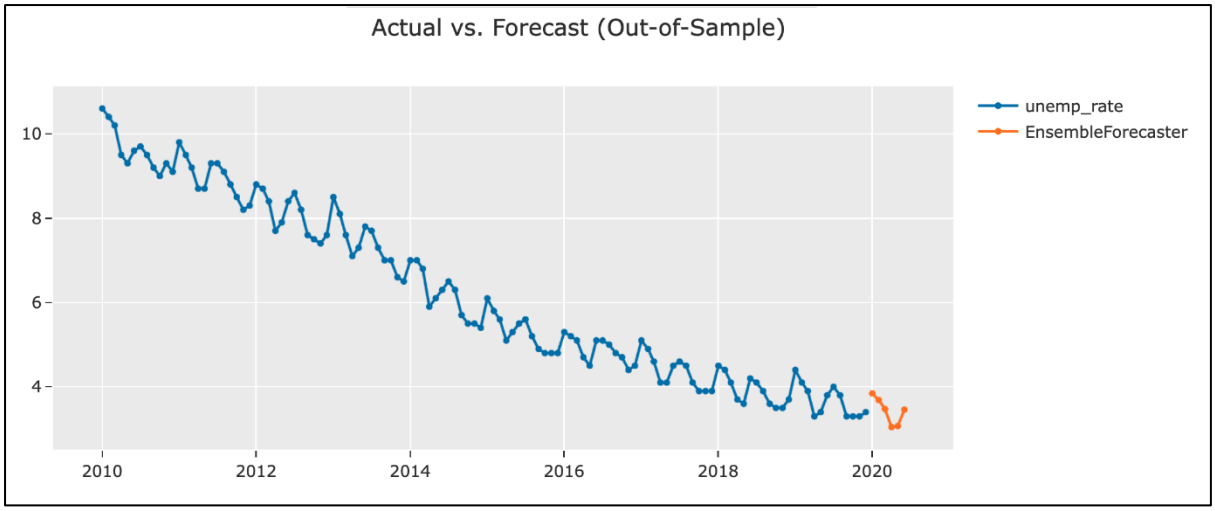

Train Cross-Validation Splits
Windows
Time

	Test	Test Name	Data	Property	Setting	Value
0	Summary	Statistics	Transformed	Length		120.0
1	Summary	Statistics	Transformed	# Missing Values		0.0
2	Summary	Statistics	Transformed	Mean		6.225
3	Summary	Statistics	Transformed	Median		5.6
4	Summary	Statistics	Transformed	Standard Deviation		2.10223
5	Summary	Statistics	Transformed	Variance		4.41937
6	Summary	Statistics	Transformed	Kurtosis		-1.232708
7	Summary	Statistics	Transformed	Skewness		0.345242
8	Summary	Statistics	Transformed	# Distinct Values		59.0
9	White Noise	Ljung-Box	Transformed	Test Statictic	{'alpha': 0.05, 'K': 24}	1610.583379
10	White Noise	Ljung-Box	Transformed	Test Statictic	{'alpha': 0.05, 'K': 48}	1778.242684
11	White Noise	Ljung-Box	Transformed	p-value	{'alpha': 0.05, 'K': 24}	0.0
12	White Noise	Ljung-Box	Transformed	p-value	{'alpha': 0.05, 'K': 48}	0.0
13	White Noise	Ljung-Box	Transformed	White Noise	{'alpha': 0.05, 'K': 24}	False
14	White Noise	Ljung-Box	Transformed	White Noise	{'alpha': 0.05, 'K': 48}	False
15	Stationarity	ADF	Transformed	Stationarity	{'alpha': 0.05}	False
16	Stationarity	ADF	Transformed	p-value	{'alpha': 0.05}	0.263656
17	Stationarity	ADF	Transformed	Test Statistic	{'alpha': 0.05}	-2.053411
18	Stationarity	ADF	Transformed	Critical Value 1%	{'alpha': 0.05}	-3.492996
19	Stationarity	ADF	Transformed	Critical Value 5%	{'alpha': 0.05}	-2.888955
20	Stationarity	ADF	Transformed	Critical Value 10%	{'alpha': 0.05}	-2.581393
21	Stationarity	KPSS	Transformed	Trend Stationarity	{'alpha': 0.05}	False
22	Stationarity	KPSS	Transformed	p-value	{'alpha': 0.05}	0.01
23	Stationarity	KPSS	Transformed	Test Statistic	{'alpha': 0.05}	0.44361
24	Stationarity	KPSS	Transformed	Critical Value 10%	{'alpha': 0.05}	0.119
25	Stationarity	KPSS	Transformed	Critical Value 5%	{'alpha': 0.05}	0.146
26	Stationarity	KPSS	Transformed	Critical Value 2.5%	{'alpha': 0.05}	0.176
27	Stationarity	KPSS	Transformed	Critical Value 1%	{'alpha': 0.05}	0.216
28	Normality	Shapiro	Transformed	Normality	{'alpha': 0.05}	False
29	Normality	Shapiro	Transformed	p-value	{'alpha': 0.05}	0.000005

	Model	MASE	RMSSE	MAE	RMSE	MAPE	SMAPE	R2	TT (Sec)
bats	BATS	0.1222	0.1364	0.0911	0.1105	0.0225	0.0227	0.8702	2.0060
tbats	TBATS	0.1308	0.1410	0.0976	0.1142	0.0239	0.0242	0.8641	4.8580
auto_arima	Auto ARIMA	0.1487	0.1626	0.1110	0.1319	0.0280	0.0287	0.7229	2.7660
prophet	Prophet	0.1599	0.1675	0.1201	0.1364	0.0293	0.0294	0.8053	0.8600
theta	Theta Forecaster	0.1802	0.1906	0.1348	0.1547	0.0332	0.0332	0.7221	0.0120
ets	ETS	0.1976	0.2108	0.1474	0.1708	0.0358	0.0364	0.6639	0.0200
exp_smooth	Exponential Smoothing	0.2074	0.2256	0.1547	0.1828	0.0371	0.0381	0.6565	0.0340
xgboost_cds_dt	Extreme Gradient Boosting w/ Cond. Deseasonalize & Detrending	0.2118	0.2510	0.1608	0.2056	0.0390	0.0403	0.4461	0.0280
arima	ARIMA	0.2453	0.2573	0.1833	0.2088	0.0462	0.0477	0.4979	0.0460
lr_cds_dt	Linear w/ Cond. Deseasonalize & Detrending	0.2516	0.2635	0.1907	0.2163	0.0465	0.0481	0.4679	0.0580
huber_cds_dt	Huber w/ Cond. Deseasonalize & Detrending	0.2524	0.2662	0.1914	0.2185	0.0466	0.0482	0.4544	0.0140
et_cds_dt	Extra Trees w/ Cond. Deseasonalize & Detrending	0.2726	0.2918	0.2087	0.2411	0.0497	0.0519	0.2802	0.0360
br_cds_dt	Bayesian Ridge w/ Cond. Deseasonalize & Detrending	0.2715	0.2828	0.2056	0.2319	0.0501	0.0519	0.3964	0.0160
ridge_cds_dt	Ridge w/ Cond. Deseasonalize & Detrending	0.2915	0.3005	0.2202	0.2460	0.0540	0.0560	0.3315	0.0140
rf_cds_dt	Random Forest w/ Cond. Deseasonalize & Detrending	0.3052	0.3161	0.2322	0.2603	0.0558	0.0582	0.2598	0.0380
ada_cds_dt	AdaBoost w/ Cond. Deseasonalize & Detrending	0.3063	0.3214	0.2333	0.2647	0.0566	0.0590	0.1843	0.0180
dt_cds_dt	Decision Tree w/ Cond. Deseasonalize & Detrending	0.3072	0.3163	0.2326	0.2593	0.0567	0.0584	0.2933	0.0120
lar_cds_dt	Least Angular Regressor w/ Cond. Deseasonalize & Detrending	0.3288	0.3381	0.2503	0.2786	0.0607	0.0634	0.0918	0.0540
knn_cds_dt	K Neighbors w/ Cond. Deseasonalize & Detrending	0.3390	0.3410	0.2562	0.2792	0.0630	0.0656	0.1838	0.0160
gbr_cds_dt	Gradient Boosting w/ Cond. Deseasonalize & Detrending	0.3448	0.3642	0.2596	0.2972	0.0640	0.0670	0.0070	0.0180
omp_cds_dt	Orthogonal Matching Pursuit w/ Cond. Deseasonalize & Detrending	0.3563	0.3756	0.2700	0.3082	0.0657	0.0688	-0.0960	0.0120
lightgbm_cds_dt	Light Gradient Boosting w/ Cond. Deseasonalize & Detrending	0.3603	0.3727	0.2692	0.3028	0.0667	0.0698	0.0176	0.1020
catboost_cds_dt	CatBoost Regressor w/ Cond. Deseasonalize & Detrending	0.3825	0.3896	0.2912	0.3208	0.0703	0.0740	-0.2316	0.2860
naive	Naive Forecaster	0.5032	0.5268	0.3767	0.4284	0.0949	0.0926	-1.3404	0.6280
snaive	Seasonal Naive Forecaster	0.5834	0.5586	0.4400	0.4570	0.1094	0.1030	-1.5401	0.0180
croston	Croston	0.6327	0.6794	0.4762	0.5550	0.1232	0.1136	-2.7134	0.0120
en_cds_dt	Elastic Net w/ Cond. Deseasonalize & Detrending	0.7809	0.7544	0.5822	0.6118	0.1451	0.1586	-3.1322	0.0180
lasso_cds_dt	Lasso w/ Cond. Deseasonalize & Detrending	0.7809	0.7544	0.5822	0.6118	0.1451	0.1586	-3.1322	0.0140
llar_cds_dt	Lasso Least Angular Regressor w/ Cond. Deseasonalize & Detrending	0.7809	0.7544	0.5822	0.6118	0.1451	0.1586	-3.1322	0.0280
polytrend	Polynomial Trend Forecaster	0.8269	0.8207	0.6164	0.6650	0.1499	0.1651	-3.5825	0.0100
par_cds_dt	Passive Aggressive w/ Cond. Deseasonalize & Detrending	1.3195	1.3532	0.9712	1.0828	0.2564	0.2742	-25.5411	0.0120
grand_means	Grand Means Forecaster	3.7084	3.4400	2.7813	2.8005	0.6998	0.5138	-89.1440	0.3120

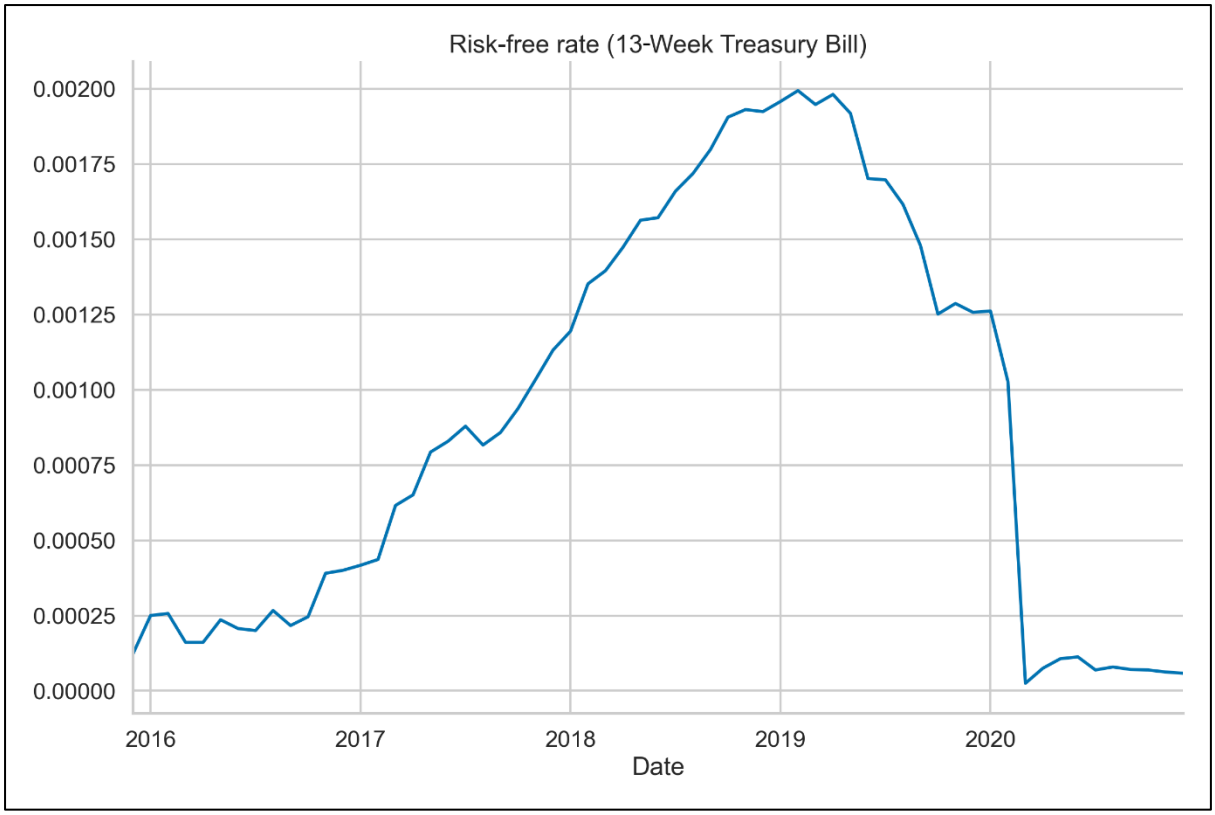
	Model	MASE	RMSSE	MAE	RMSE	MAPE	SMAPE	R2
0	EnsembleForecaster	0.1707	0.1685	0.1174	0.1281	0.0328	0.0333	0.7898

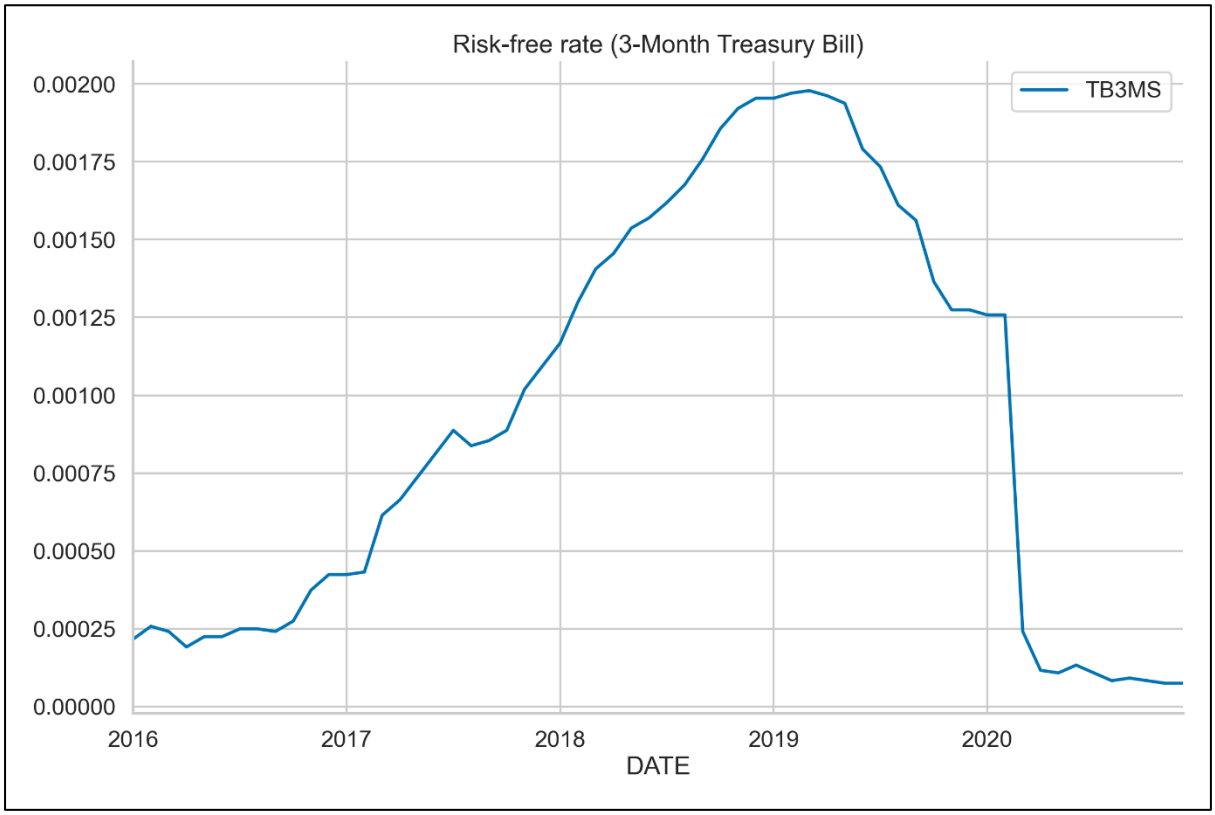



Actual vs. Forecast (Out-of-Sample)
unemp_rate
EnsembleForecaster
10
8
6
4
2010
2012
2014
2016
2018
2020

Chapter 8: Multi-Factor Models

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                  asset   R-squared:                       0.408
Model:                            OLS   Adj. R-squared:                  0.398
Method:                 Least Squares   F-statistic:                     40.05
Date:                Wed, 02 Mar 2022   Prob (F-statistic):           3.89e-08
Time:                        23:28:10   Log-Likelihood:                 80.639
No. Observations:                  60   AIC:                            -157.3
Df Residuals:                      58   BIC:                            -153.1
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.0167      0.009      1.953      0.056      -0.000       0.034
market         1.2035      0.190      6.329      0.000       0.823       1.584
==============================================================================
Omnibus:                        2.202   Durbin-Watson:                   1.783
Prob(Omnibus):                  0.333   Jarque-Bera (JB):                1.814
Skew:                           0.426   Prob(JB):                        0.404
Kurtosis:                       2.989   Cond. No.                         23.0
==============================================================================
```


Risk-free rate (13-Week Treasury Bill)
0.00200
0.00175
0.00150
0.00125
0.00100
0.00075
0.00050
0.00025
0.00000
2016
2017
2018
2019
2020
Date


Risk-free rate (3-Month Treasury Bill)
TB3MS
0.00200
0.00175
0.00150
0.00125
0.00100
0.00075
0.00050
0.00025
0.00000
2016
2017
2018
2019
2020
DATE

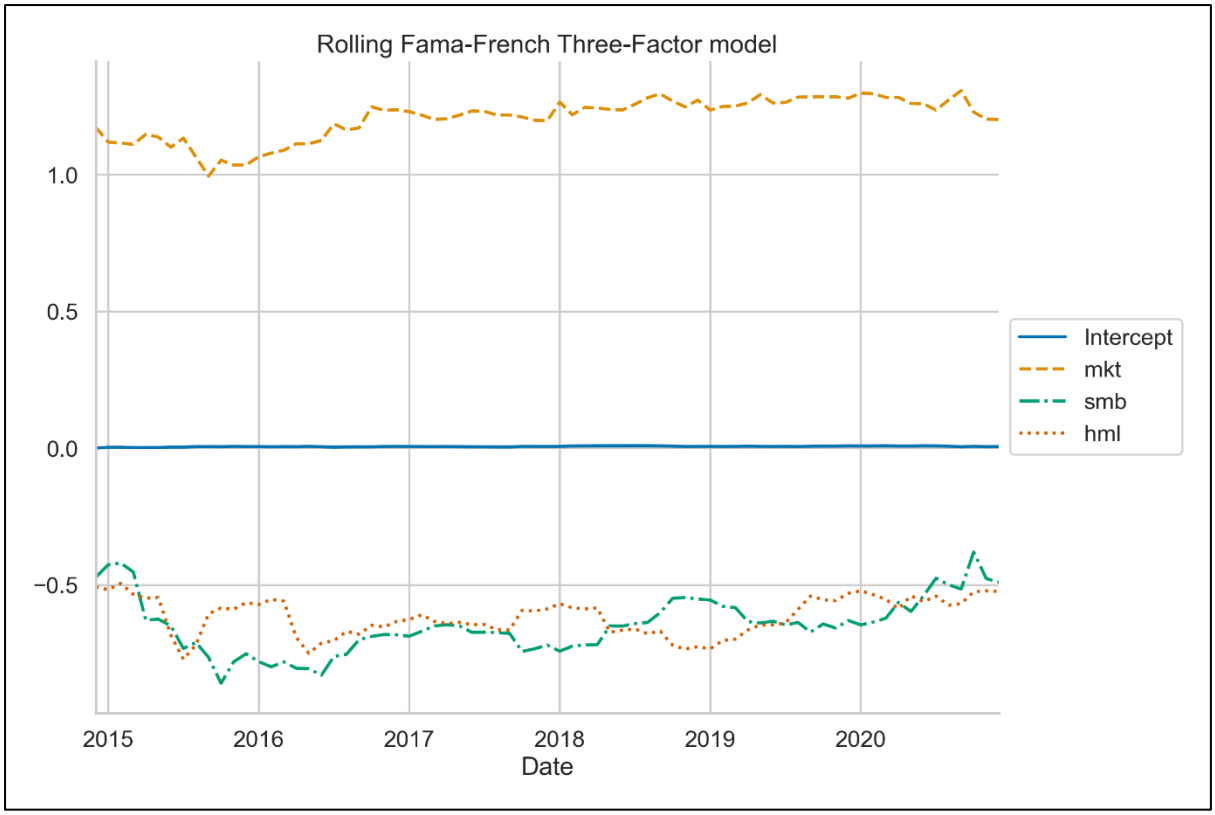
Date	MKT	SMB	HML	RF
2016-01	-0.0577	-0.0339	0.0207	0.0001
2016-02	-0.0008	0.0081	-0.0057	0.0002
2016-03	0.0696	0.0075	0.0110	0.0002
2016-04	0.0092	0.0067	0.0321	0.0001
2016-05	0.0178	-0.0019	-0.0165	0.0001

OLS Regression Results

Dep. Variable:	excess_rtn	R-squared:	0.504
Model:	OLS	Adj. R-squared:	0.477
Method:	Least Squares	F-statistic:	18.94
Date:	Wed, 02 Mar 2022	Prob (F-statistic):	1.32e-08
Time:	23:48:12	Log-Likelihood:	82.679
No. Observations:	60	AIC:	-157.4
Df Residuals:	56	BIC:	-149.0
Df Model:	3		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0084	0.009	0.954	0.344	-0.009	0.026
MKT	1.4264	0.198	7.213	0.000	1.030	1.823
SMB	-0.4590	0.359	-1.280	0.206	-1.177	0.259
HML	-0.7186	0.260	-2.759	0.008	-1.240	-0.197

Omnibus:	8.642	Durbin-Watson:	2.458
Prob(Omnibus):	0.013	Jarque-Bera (JB):	8.952
Skew:	-0.652	Prob(JB):	0.0114
Kurtosis:	4.371	Cond. No.	45.8


Rolling Fama-French Three-Factor model
1.0
0.5
0.0
−0.5
2015
2016
2017
2018
2019
2020
Date
Intercept
mkt
smb
hml

OLS Regression Results

Dep. Variable:	excess_rtn	R-squared:	0.563
Model:	OLS	Adj. R-squared:	0.532
Method:	Least Squares	F-statistic:	17.74
Date:	Thu, 03 Mar 2022	Prob (F-statistic):	2.10e-09
Time:	00:07:34	Log-Likelihood:	89.673
No. Observations:	60	AIC:	-169.3
Df Residuals:	55	BIC:	-158.9
Df Model:	4		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0054	0.008	0.676	0.502	-0.011	0.021
mkt	1.4461	0.188	7.709	0.000	1.070	1.822
smb	-0.4336	0.340	-1.276	0.207	-1.115	0.247
hml	-0.7914	0.274	-2.888	0.006	-1.341	-0.242
mom	0.2220	0.269	0.826	0.412	-0.316	0.760

Omnibus:	0.390	Durbin-Watson:	2.032
Prob(Omnibus):	0.823	Jarque-Bera (JB):	0.276
Skew:	0.163	Prob(JB):	0.871
Kurtosis:	2.933	Cond. No.	50.8

OLS Regression Results

Dep. Variable:	excess_rtn	R-squared:	0.612
Model:	OLS	Adj. R-squared:	0.576
Method:	Least Squares	F-statistic:	17.01
Date:	Thu, 03 Mar 2022	Prob (F-statistic):	4.54e-10
Time:	00:07:35	Log-Likelihood:	93.191
No. Observations:	60	AIC:	-174.4
Df Residuals:	54	BIC:	-161.8
Df Model:	5		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	0.0059	0.008	0.772	0.444	-0.009	0.021
mkt	1.5117	0.193	7.851	0.000	1.126	1.898
smb	-0.9411	0.335	-2.807	0.007	-1.613	-0.269
hml	-0.5433	0.281	-1.936	0.058	-1.106	0.019
rmw	-1.1628	0.513	-2.266	0.027	-2.191	-0.134
cma	-0.5153	0.509	-1.012	0.316	-1.536	0.505

Omnibus:	0.073	Durbin-Watson:	2.074
Prob(Omnibus):	0.964	Jarque-Bera (JB):	0.181
Skew:	-0.077	Prob(JB):	0.913
Kurtosis:	2.779	Cond. No.	79.4

LinearFactorModel Estimation Summary

No. Test Portfolios:	12	R-squared:	0.7906
No. Factors:	5	J-statistic:	9.9132
No. Observations:	132	P-value	0.1935
Date:	Thu, Mar 03 2022	Distribution:	chi2(7)
Time:	00:14:16		
Cov. Estimator:	robust		

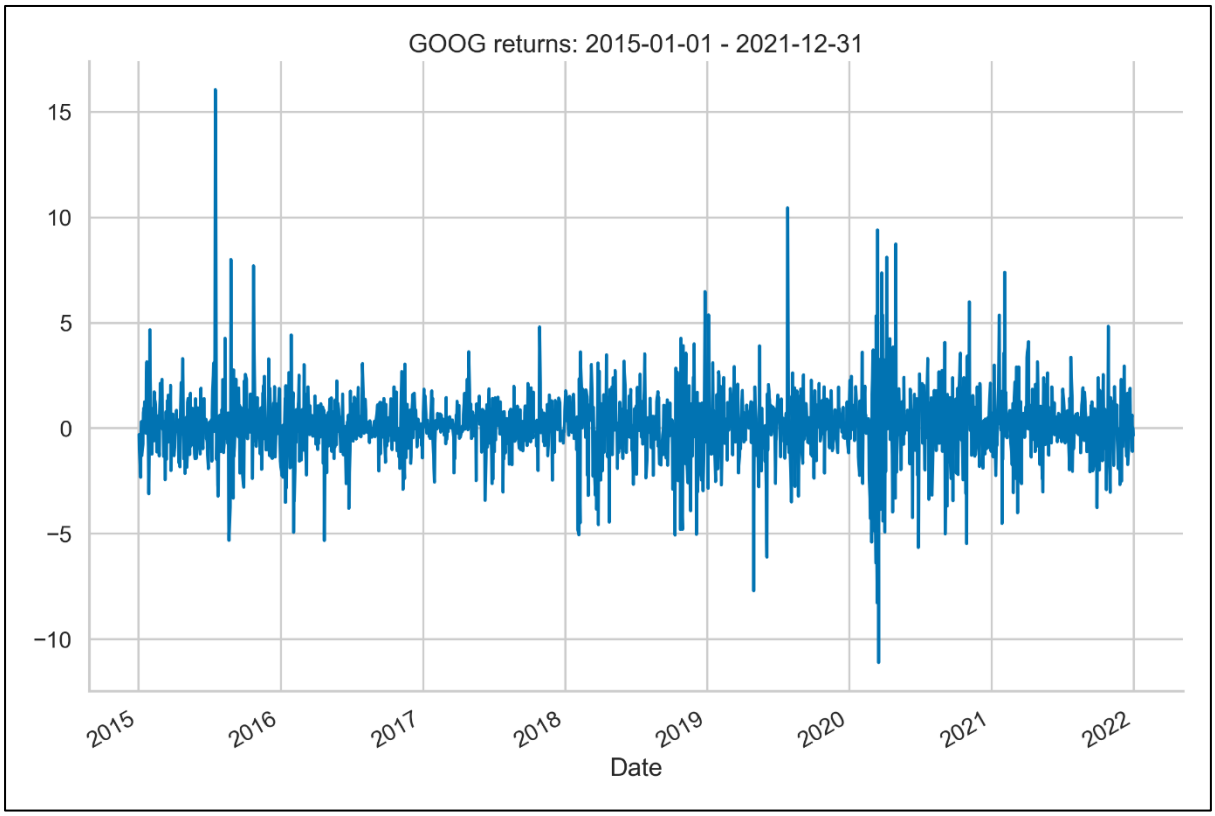
Risk Premia Estimates

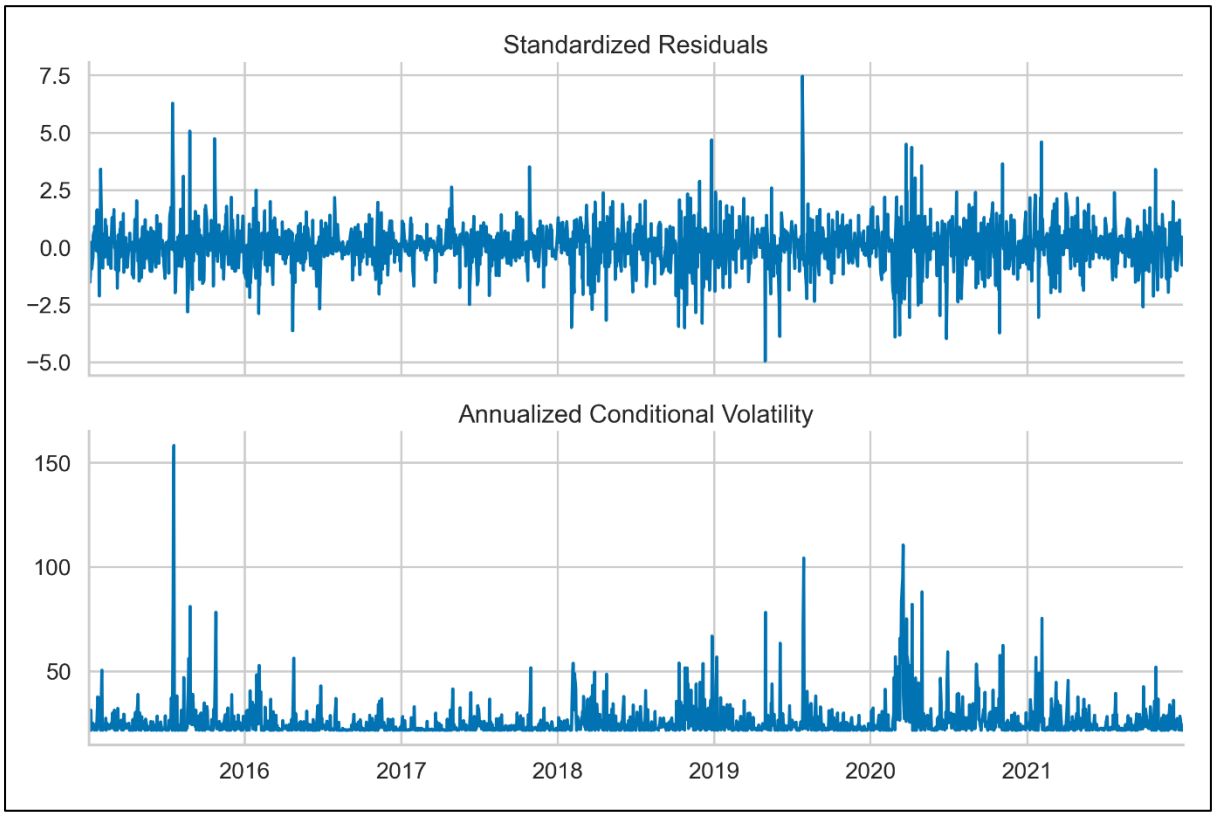
	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
Mkt-RF	0.0123	0.0038	3.2629	0.0011	0.0049	0.0198
SMB	-0.0063	0.0052	-1.2085	0.2269	-0.0165	0.0039
HML	-0.0089	0.0032	-2.7764	0.0055	-0.0152	-0.0026
RMW	-0.0009	0.0046	-0.1953	0.8451	-0.0099	0.0081
CMA	-0.0025	0.0039	-0.6467	0.5178	-0.0100	0.0051

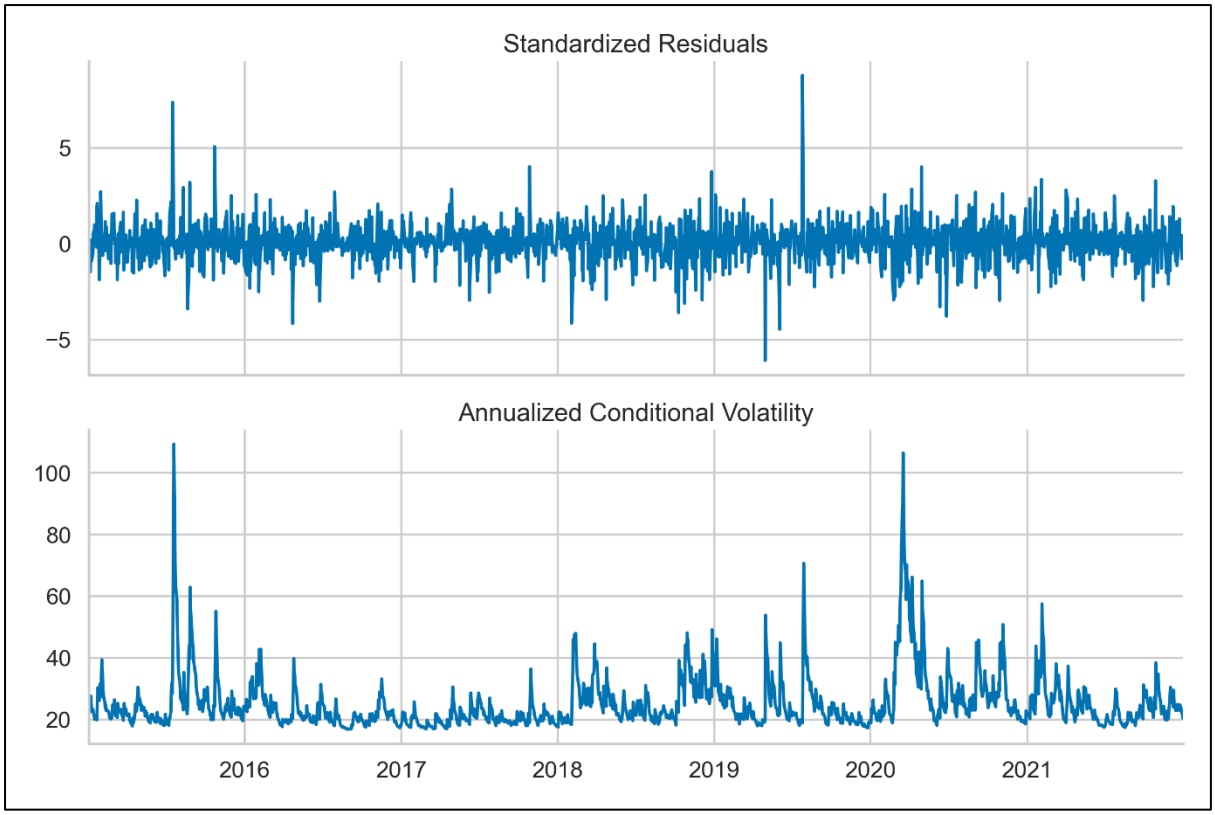
	Mkt-RF	SMB	HML	RMW	CMA
NoDur	0.786087	-0.215818	-0.083847	0.468129	0.338823
Durbl	1.548809	0.580849	-0.168357	0.294196	0.299400
Manuf	1.094951	0.291003	0.146831	0.086695	-0.010987
Enrgy	1.248025	0.487285	0.630805	0.243854	0.404512
Chems	0.885184	-0.089296	-0.018501	0.171997	0.210732

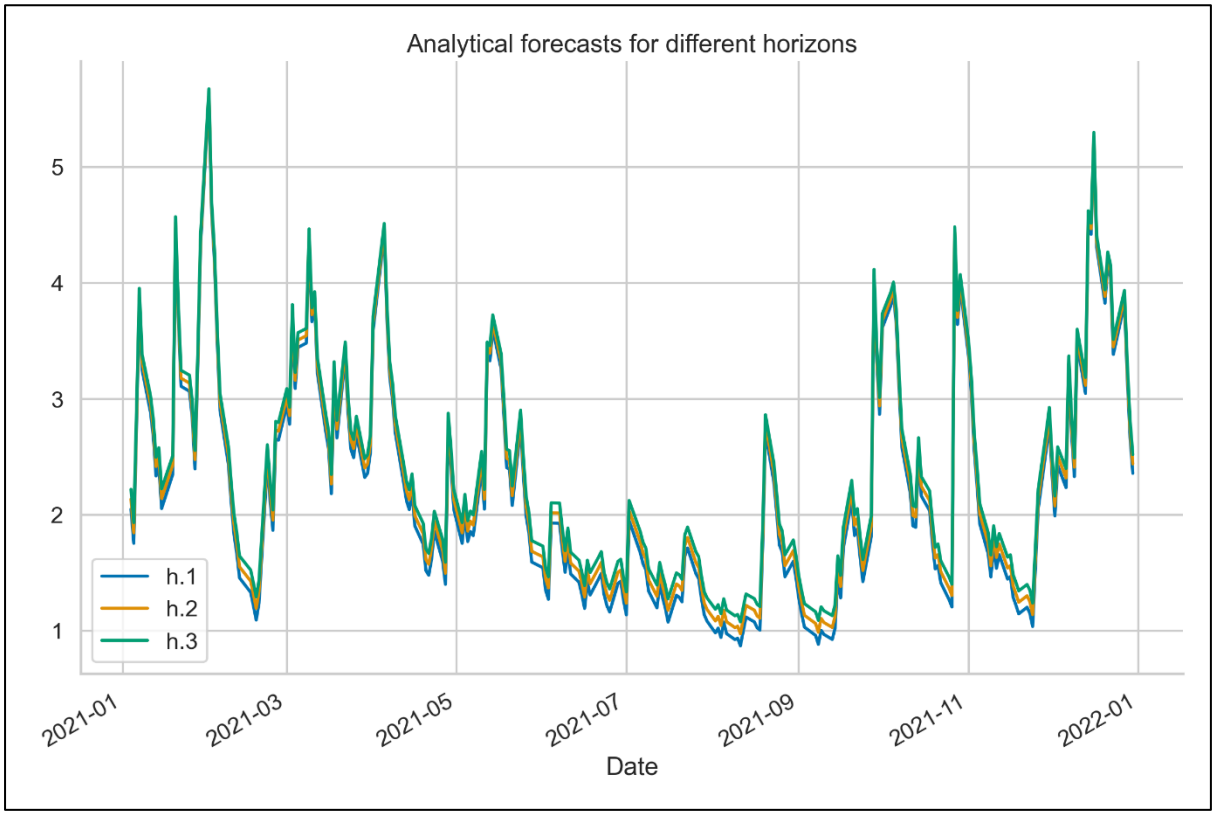
Date	Mkt-RF	SMB	HML	RMW	CMA
2010-01	-0.032631	0.051998	-0.023749	-0.039525	0.015071
2010-02	0.036662	0.020982	-0.014351	0.027181	-0.029331
2010-03	0.065954	-0.031731	-0.003074	-0.001531	-0.001160
2010-04	0.019455	0.048860	0.009688	0.040766	-0.014576
2010-05	-0.076882	0.024591	-0.021421	0.021403	-0.014296

Chapter 9: Modeling Volatility with GARCH Class Models

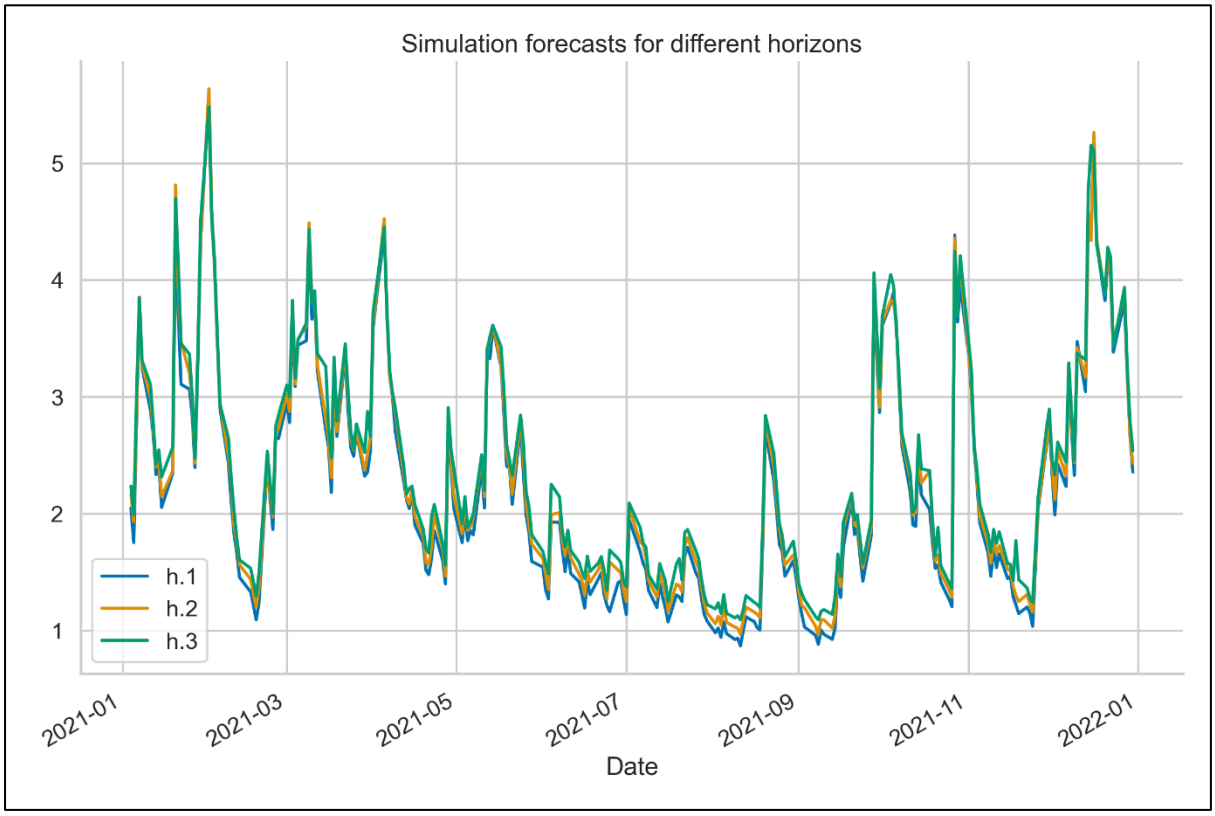


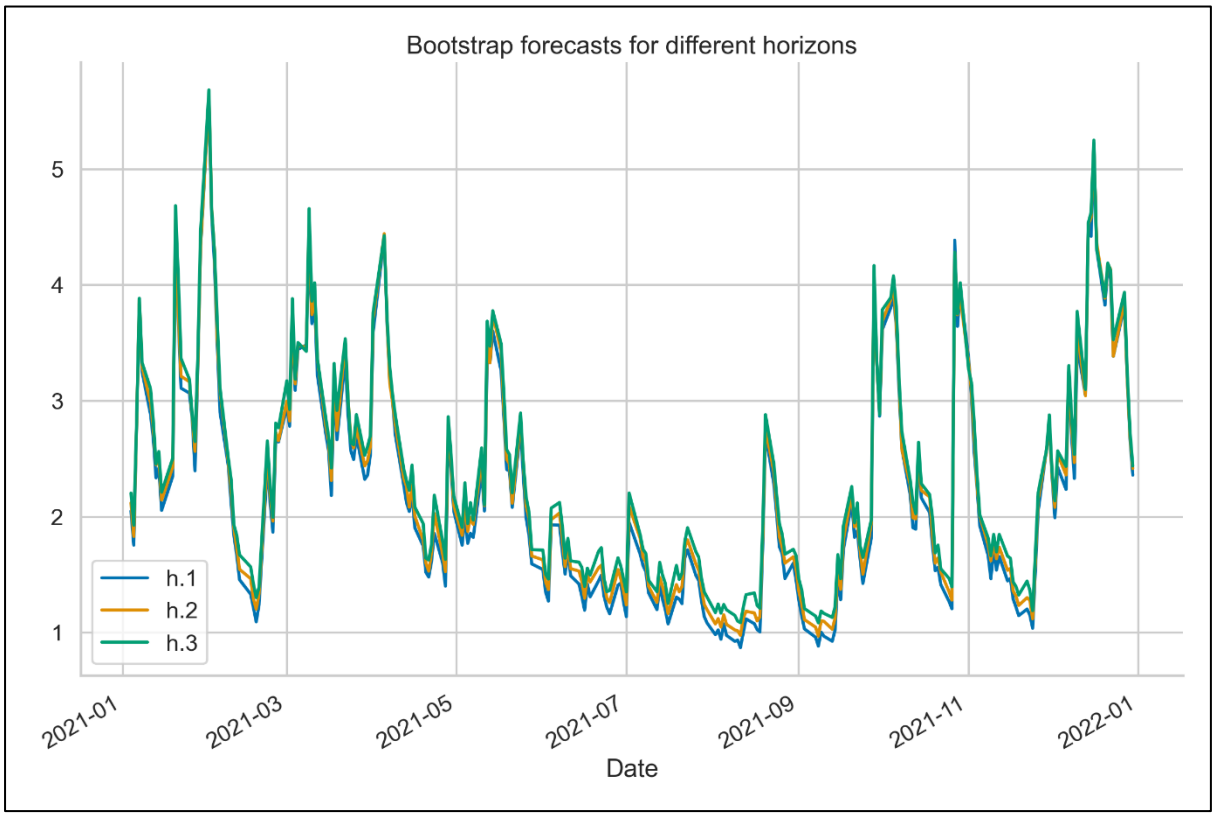


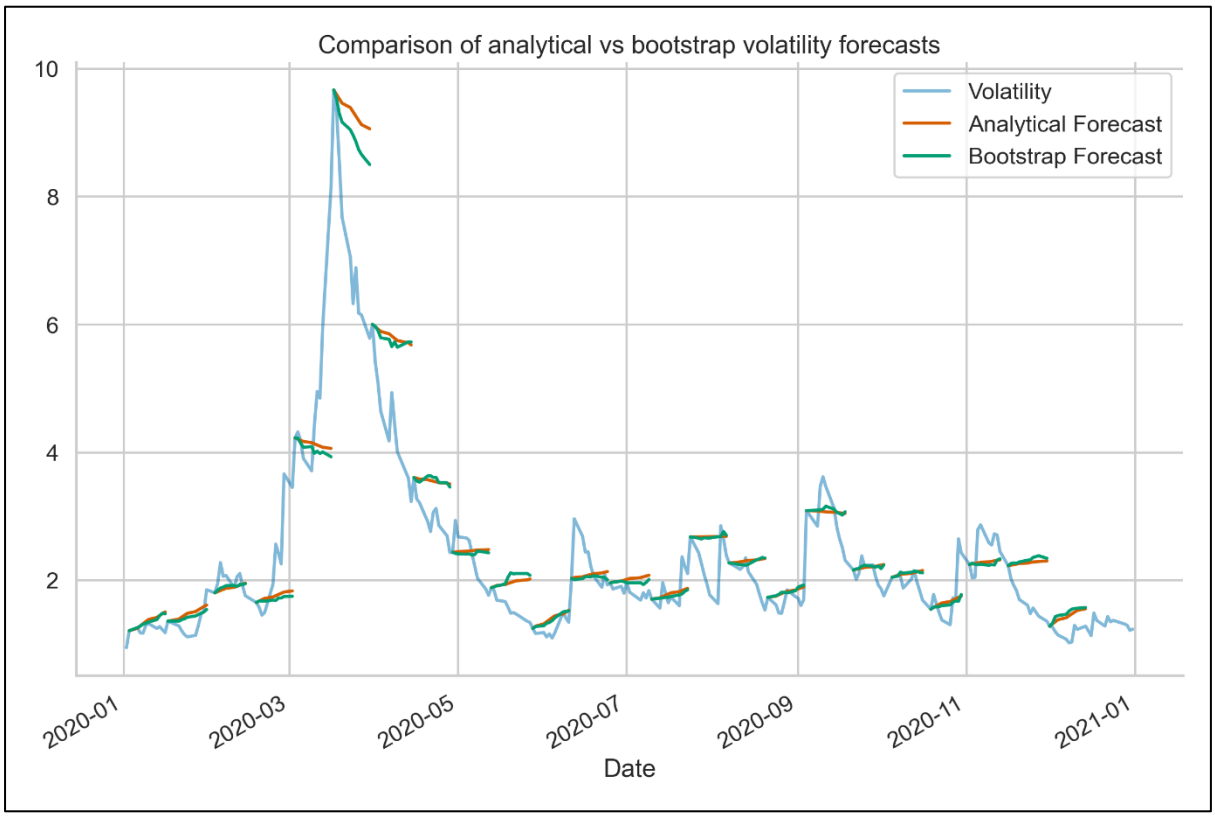

Standardized Residuals
5
0
−5
Annualized Conditional Volatility
100
80
60
40
20
2016
2017
2018
2019
2020
2021

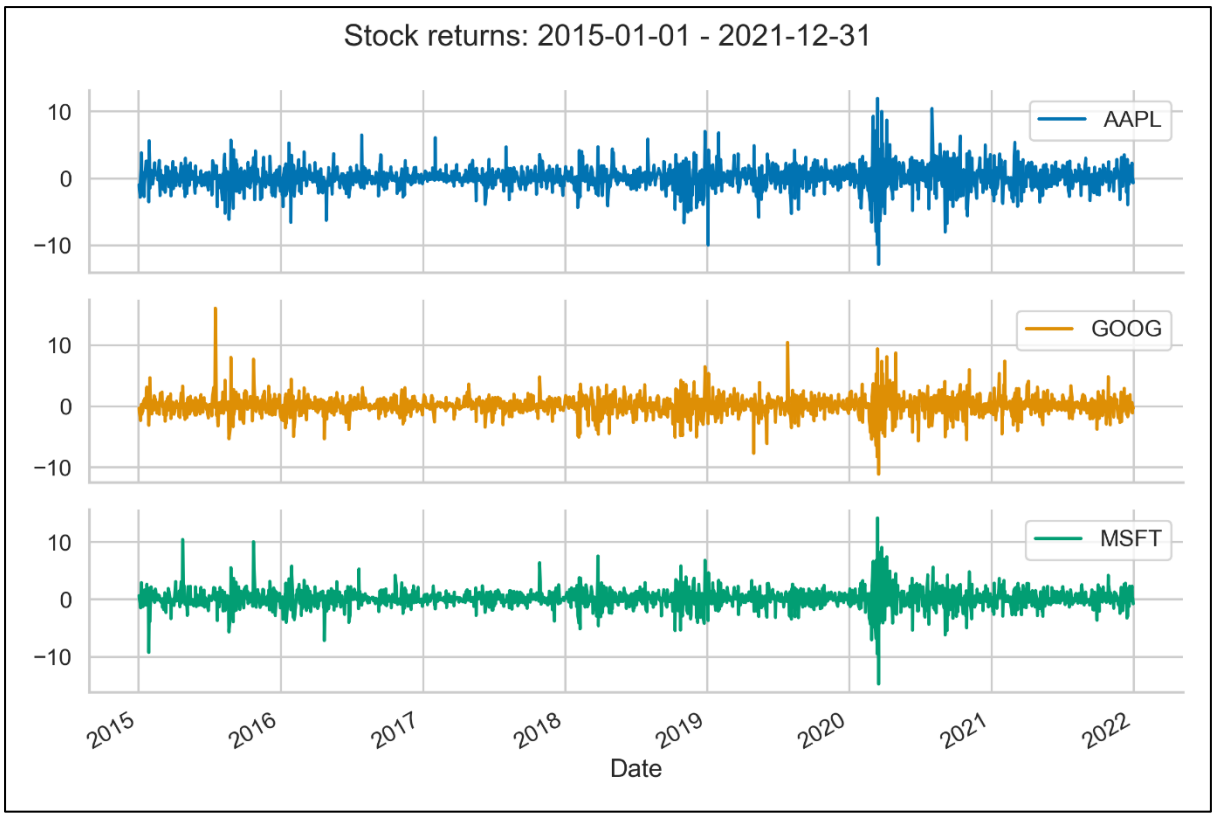

Analytical forecasts for different horizons
5
4
3
2
1
h.1
h.2
h.3
2021-01
2021-03
2021-05
2021-07
2021-09
2021-11
2022-01
Date

Date	h.1	h.2	h.3
2021-01-04	2.050335	2.136144	2.220612
2021-01-05	1.755680	1.846097	1.935101
2021-01-06	2.772100	2.846622	2.919980
2021-01-07	3.839409	3.897241	3.954169
2021-01-08	3.250745	3.317782	3.383772
...	...	...	...
2021-12-23	3.385120	3.450056	3.513977
2021-12-27	3.821128	3.879246	3.936455
2021-12-28	3.189848	3.257838	3.324764
2021-12-29	2.671069	2.747172	2.822084
2021-12-30	2.359531	2.440505	2.520213



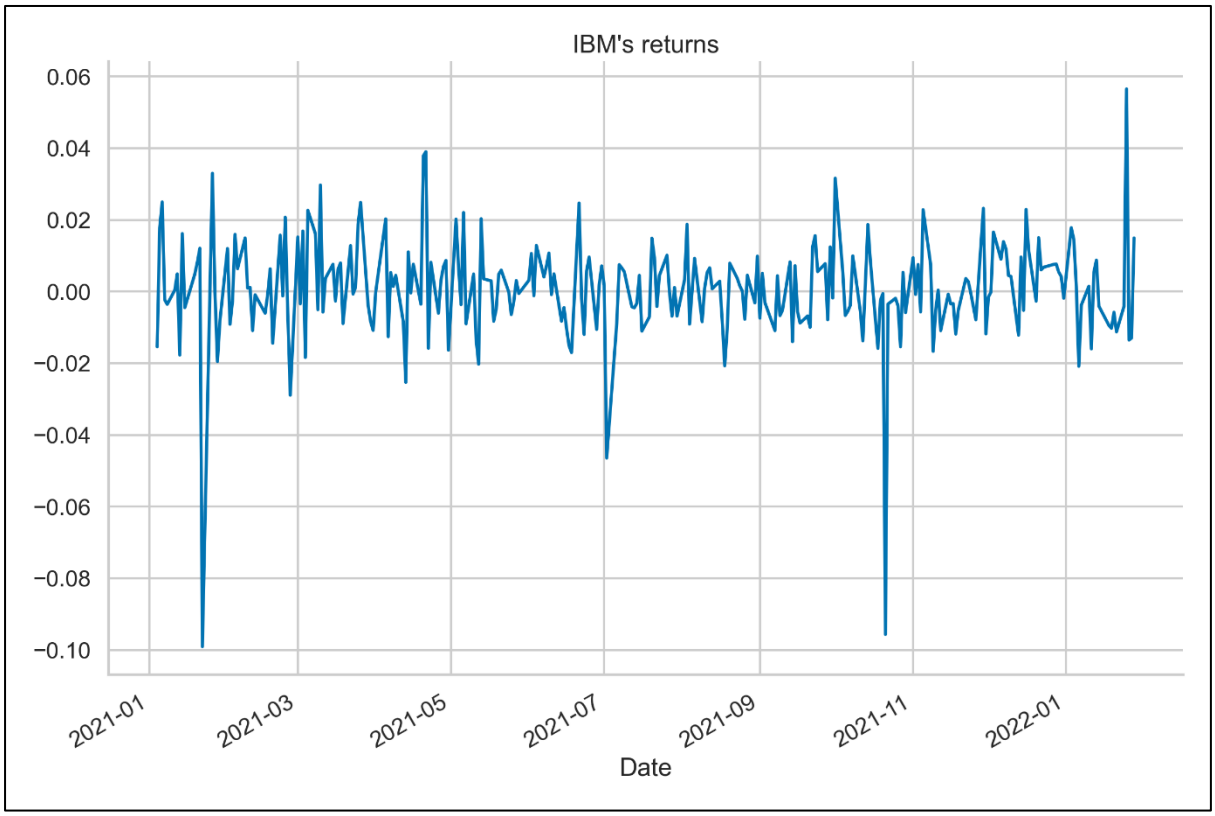

Bootstrap forecasts for different horizons
5
4
3
2
1
h.1
h.2
h.3
2021-01
2021-03
2021-05
2021-07
2021-09
2021-11
2022-01
Date

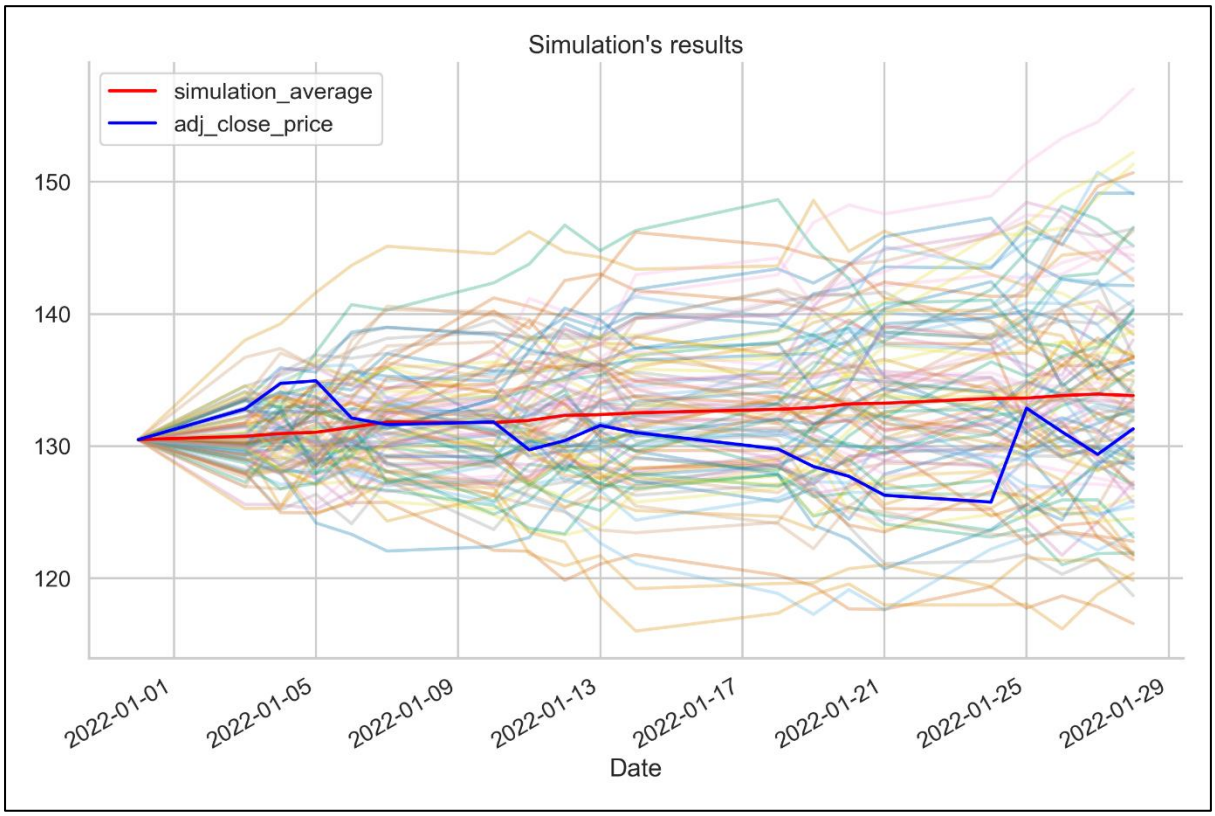

Comparison of analytical vs bootstrap volatility forecasts
10
8
6
4
2
Volatility
Analytical Forecast
Bootstrap Forecast
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01
Date

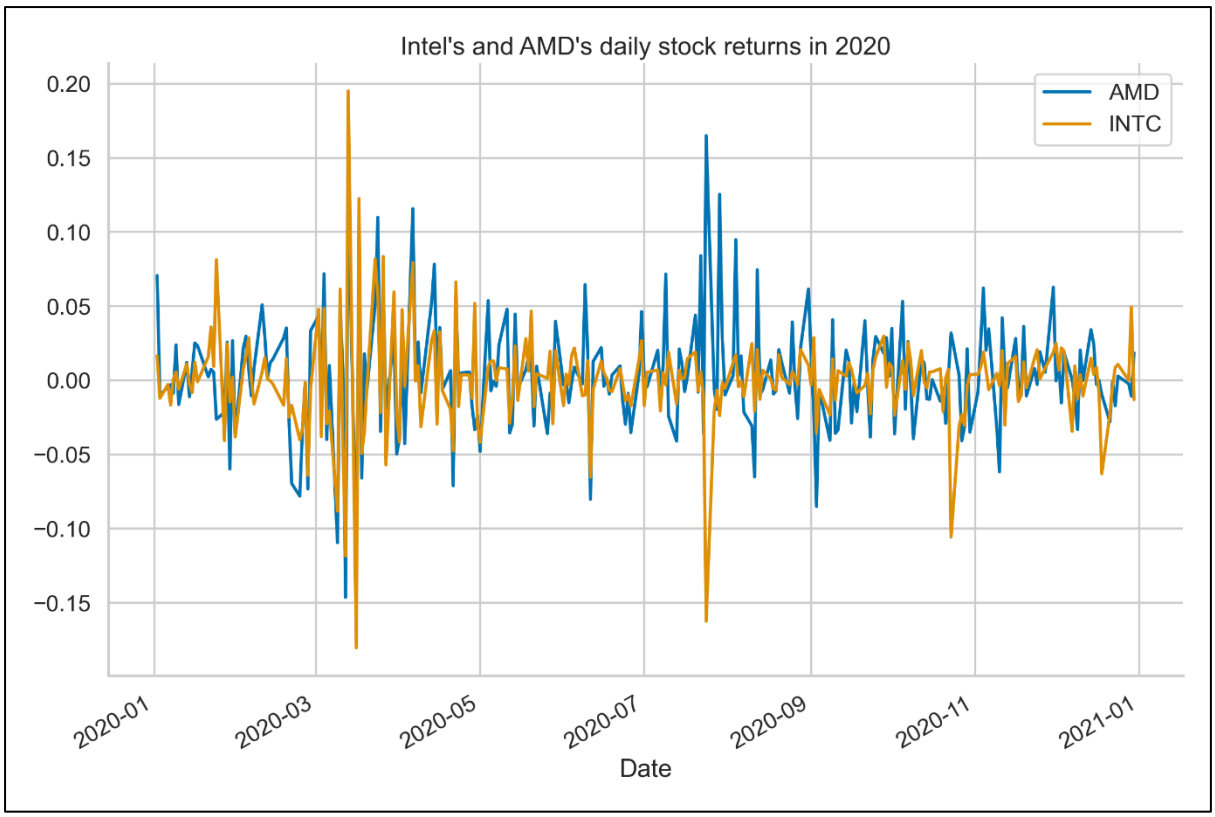


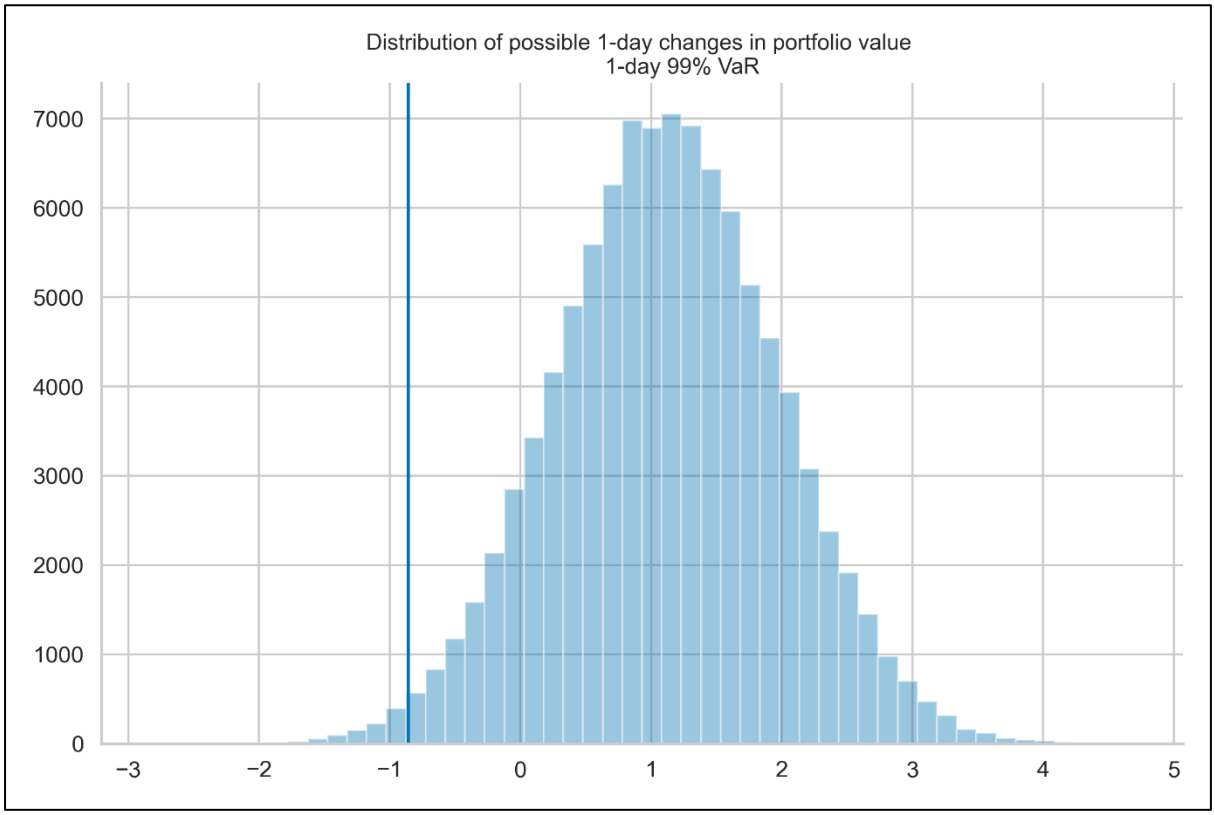
	mu	omega	alpha[1]	beta[1]
AAPL	0.189287	0.176098	0.134563	0.811815
GOOG	0.124954	0.304484	0.183056	0.716245
MSFT	0.149370	0.268674	0.213800	0.699576

Chapter 10: Monte Carlo Simulations in Finance

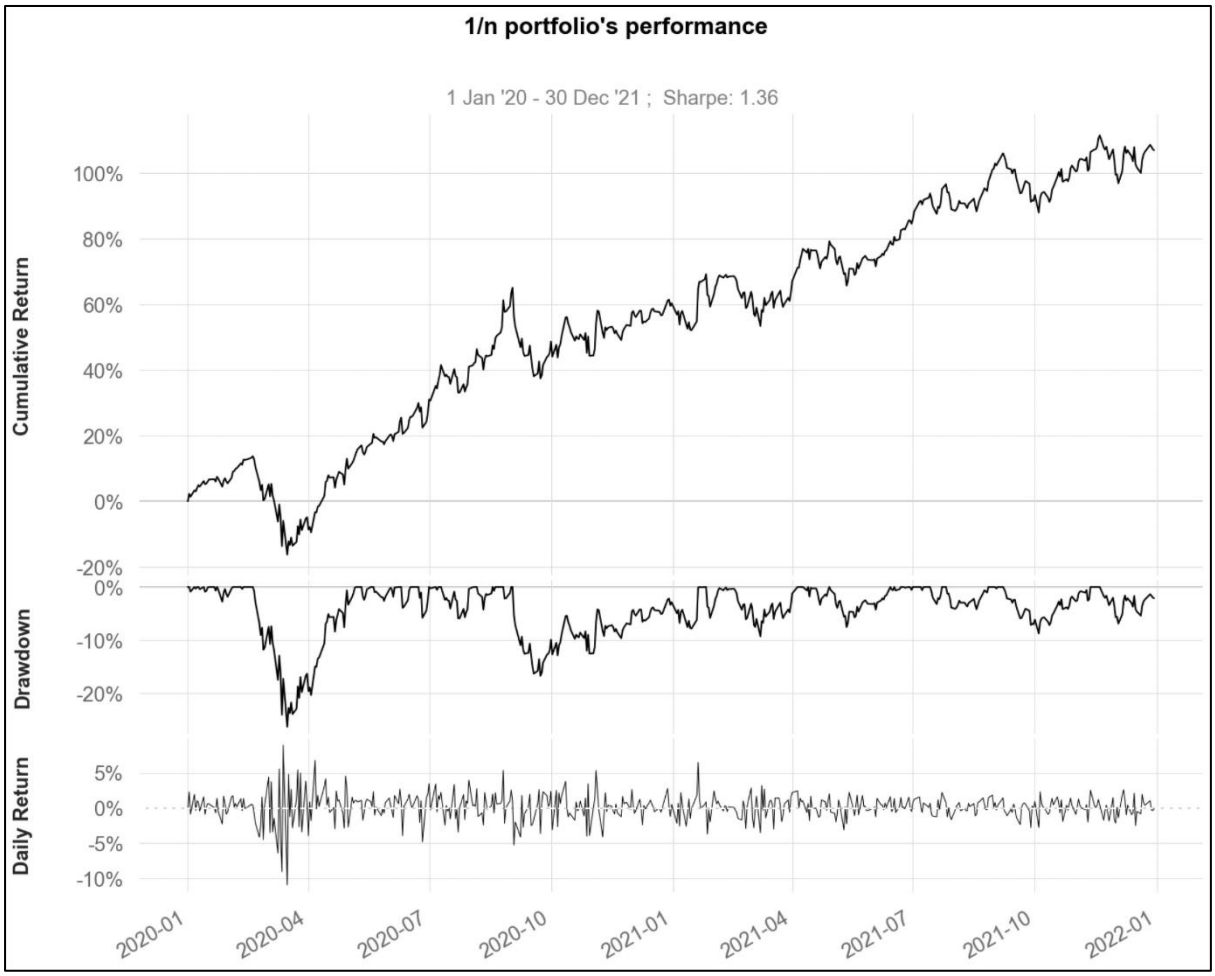





Intel's and AMD's daily stock returns in 2020
AMD
INTC
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
2020-01
2020-03
2020-05
2020-07
2020-09
2020-11
2021-01
Date


Distribution of possible 1-day changes in portfolio value
1-day 99% VaR
7000
6000
5000
4000
3000
2000
1000
0
−3
−2
−1
0
1
2
3
4
5

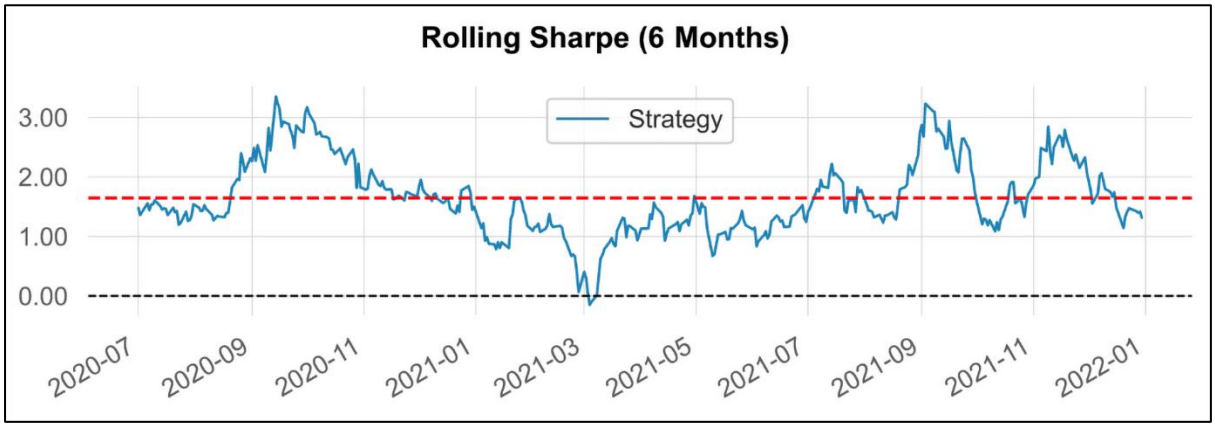
Chapter 11: Asset Allocation



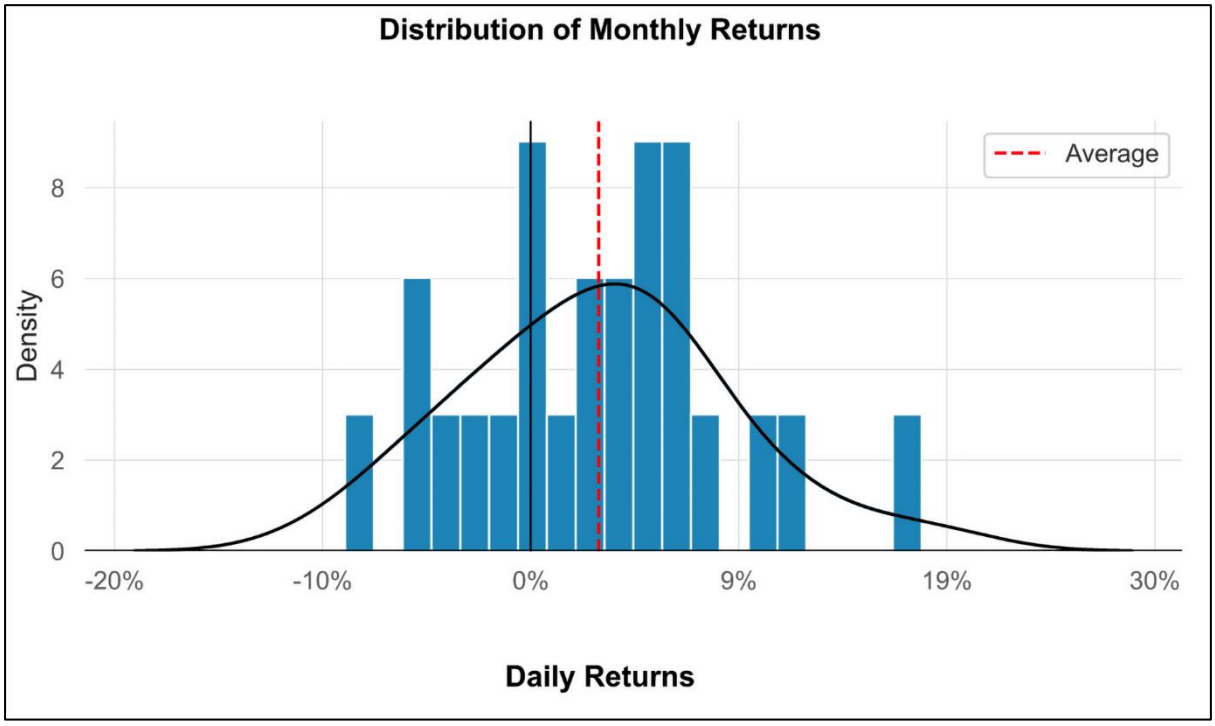
	Strategy	Benchmark
Start Period	2020-01-02	2020-01-02
End Period	2021-12-30	2021-12-30
Risk-Free Rate	0.0%	0.0%
Time in Market	100.0%	100.0%
Cumulative Return	107.0%	51.3%
CAGR%	44.02%	23.07%
Sharpe	1.36	0.94
Sortino	1.96	1.3
Sortino/√2	1.39	0.92
Omega	1.28	1.28
Max Drawdown	-26.35%	-33.72%
Longest DD Days	140	172
Gain/Pain Ratio	0.28	0.22
Gain/Pain (1M)	3.48	1.54
Payoff Ratio	0.84	0.8
Profit Factor	1.28	1.22
Common Sense Ratio	1.21	0.97
CPC Index	0.63	0.57
Tail Ratio	0.94	0.8
Outlier Win Ratio	4.13	5.68
Outlier Loss Ratio	3.3	4.46
MTD	1.56%	4.89%
3M	8.24%	10.17%
6M	11.59%	12.08%
YTD	29.09%	29.05%
1Y	28.21%	29.89%
3Y (ann.)	44.02%	23.07%
5Y (ann.)	44.02%	23.07%
10Y (ann.)	44.02%	23.07%
All-time (ann.)	44.02%	23.07%
Avg. Drawdown	-3.55%	-1.78%
Avg. Drawdown Days	18	10
Recovery Factor	4.06	1.52
Ulcer Index	0.06	0.07
Serenity Index	2.54	0.8

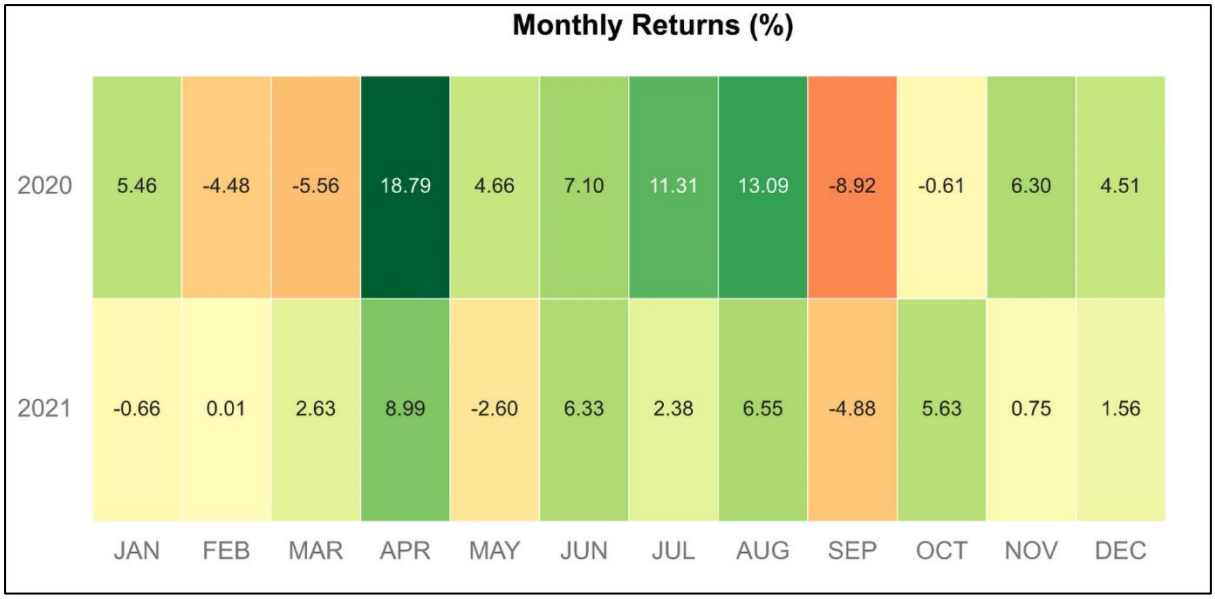
Worst 10 Drawdowns

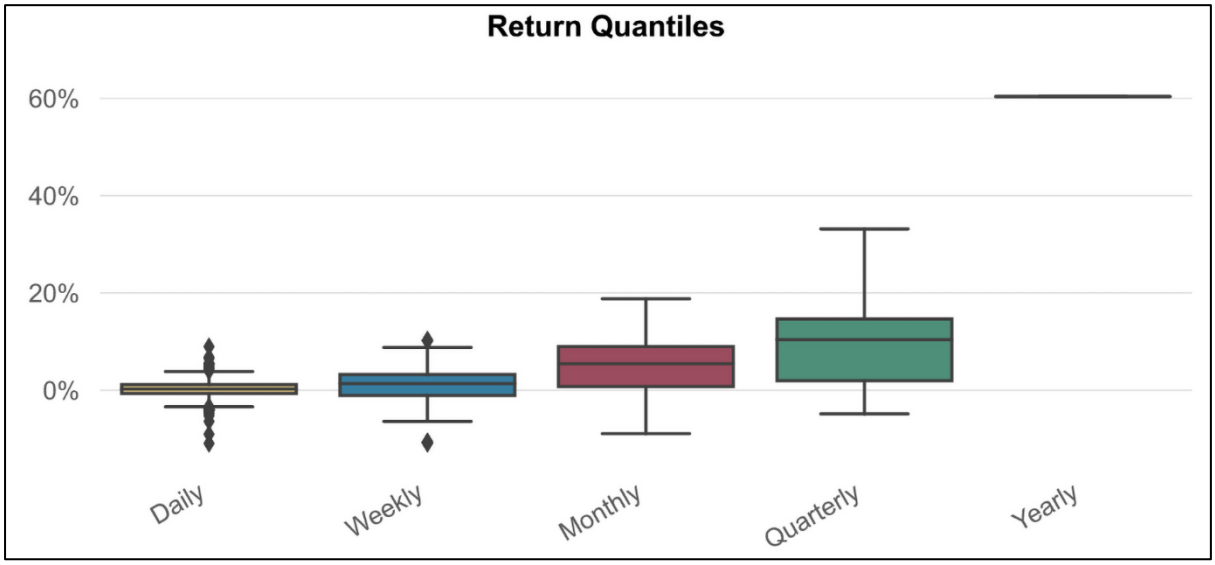
Started	Recovered	Drawdown	Days
2020-02-20	2020-05-07	-26.35%	77
2020-09-03	2021-01-21	-16.75%	140
2021-01-27	2021-04-05	-9.33%	68
2021-09-08	2021-11-12	-8.75%	65
2021-04-30	2021-06-14	-7.55%	45
2021-11-22	2021-12-30	-6.91%	38
2020-07-13	2020-08-04	-5.93%	22
2020-06-24	2020-07-01	-5.81%	7
2020-08-07	2020-08-18	-4.27%	11
2021-07-27	2021-08-27	-4.21%	31



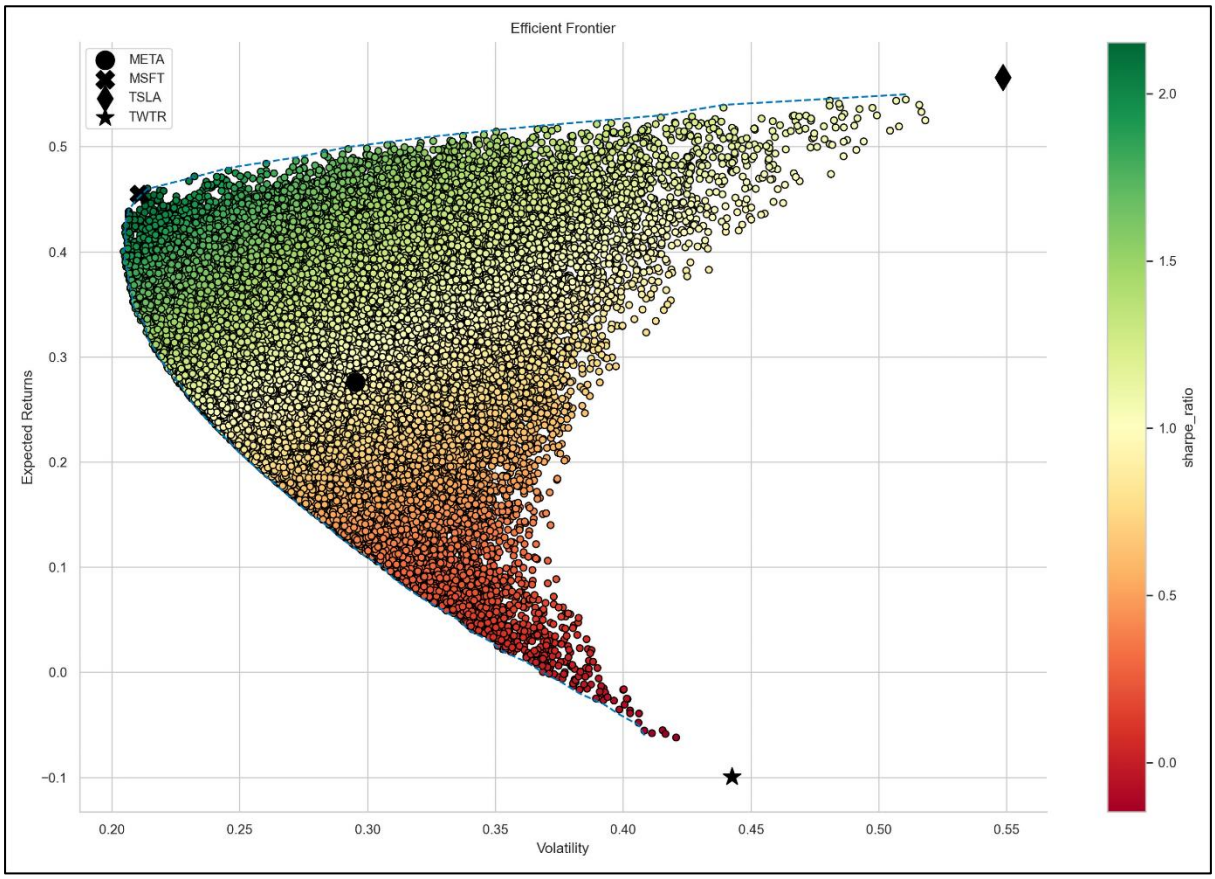

Worst 5 Drawdown Periods
100%
75%
50%
25%
0%
2020-01
2020-04
2020-07
2020-10
2021-01
2021-04
2021-07
2021-10
2022-01

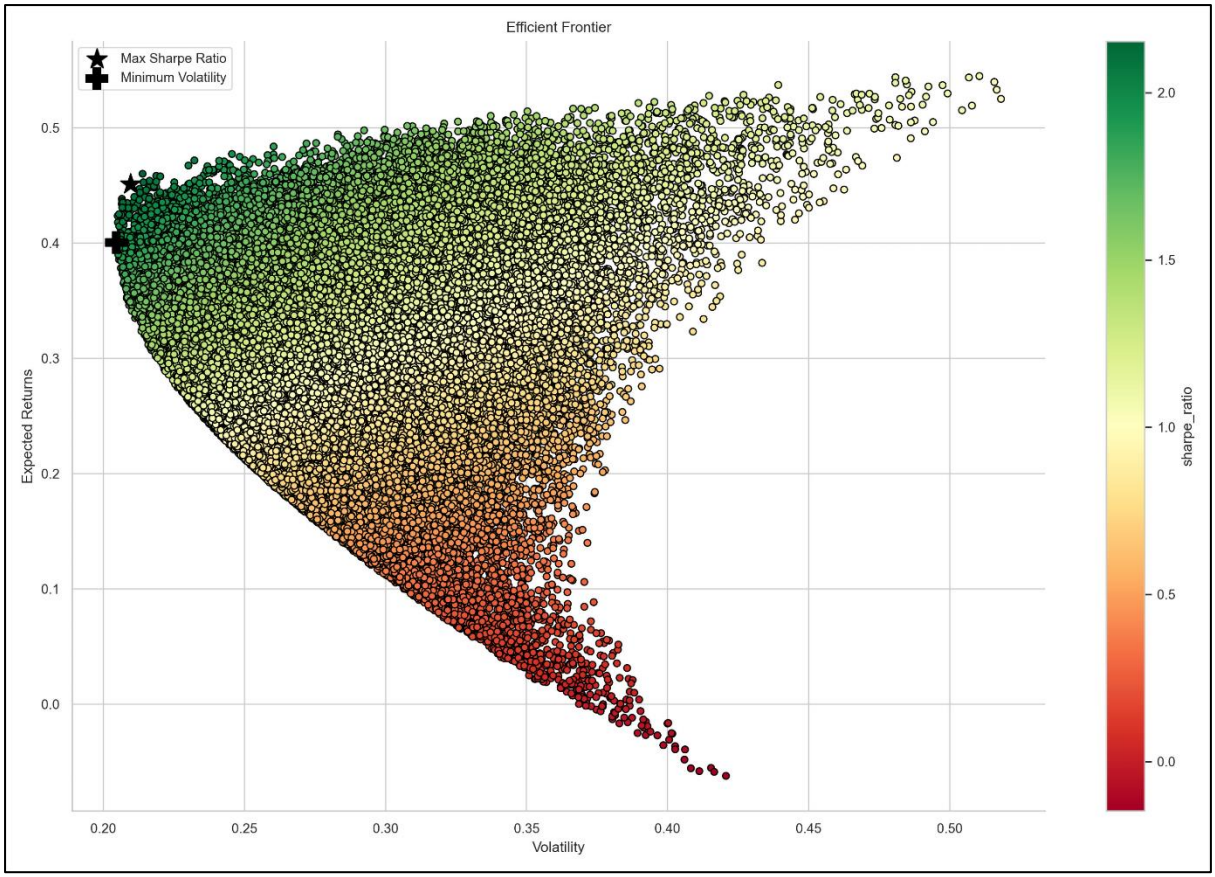

Distribution of Monthly Returns
Average
Density
8
6
4
2
0
-20%
-10%
0%
9%
19%
30%
Daily Returns

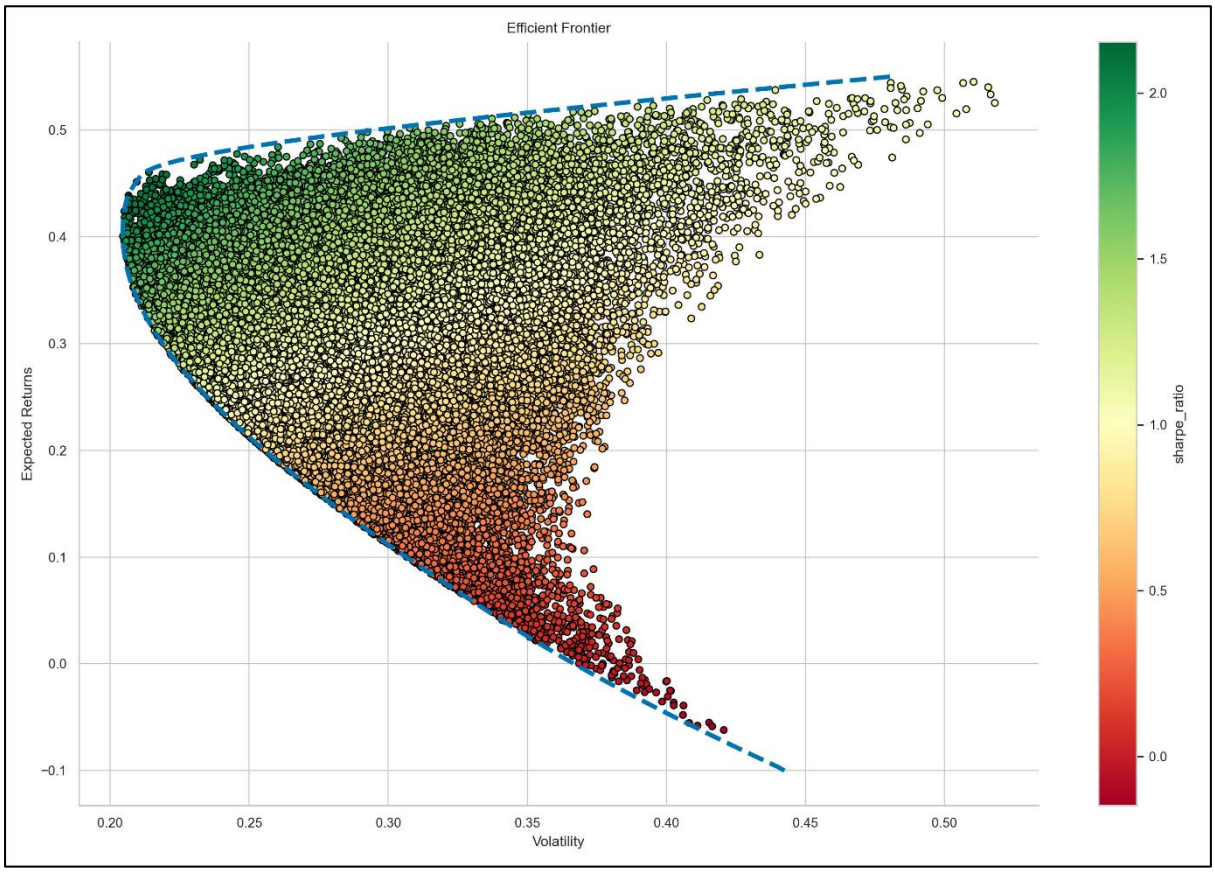

Monthly Returns (%)
2020
5.46
-4.48
-5.56
18.79
4.66
7.10
11.31
13.09
-8.92
-0.61
6.30
4.51
2021
-0.66
0.01
2.63
8.99
-2.60
6.33
2.38
6.55
-4.88
5.63
0.75
1.56
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

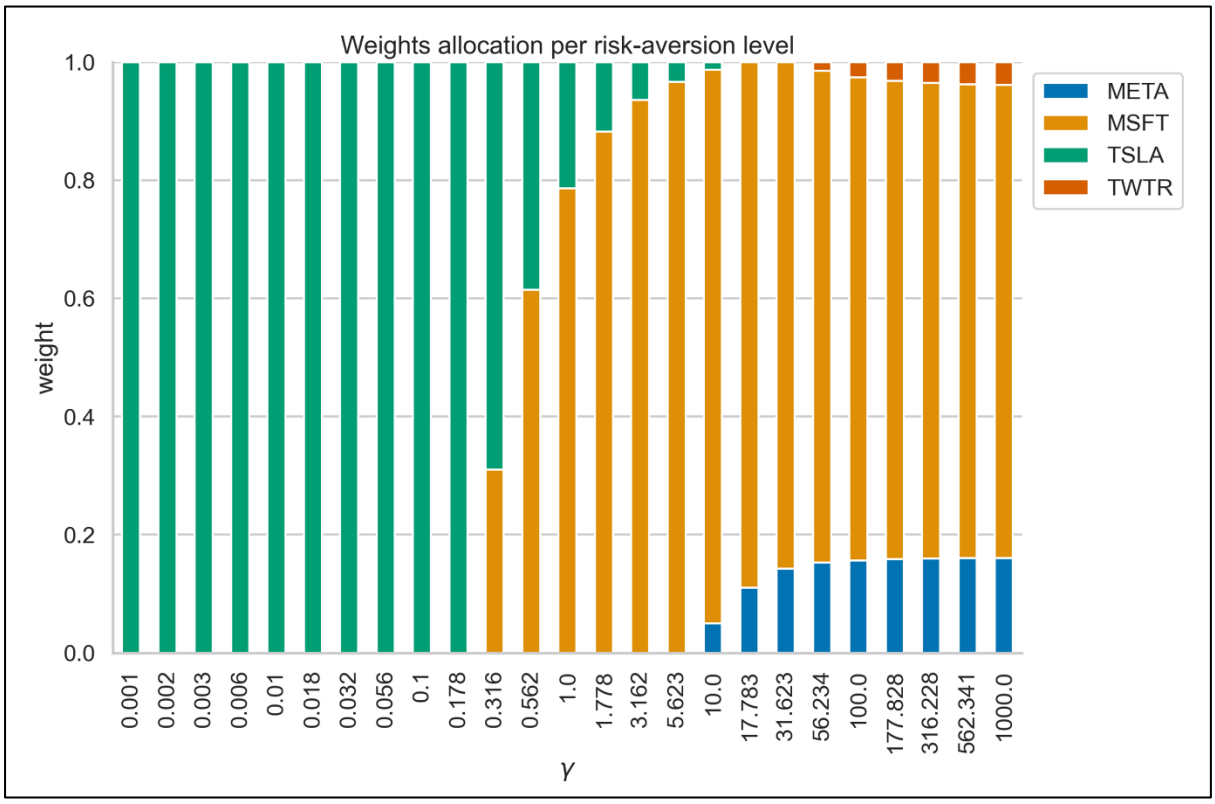

Return Quantiles
60%
40%
20%
0%
Daily
Weekly
Monthly
Quarterly
Yearly

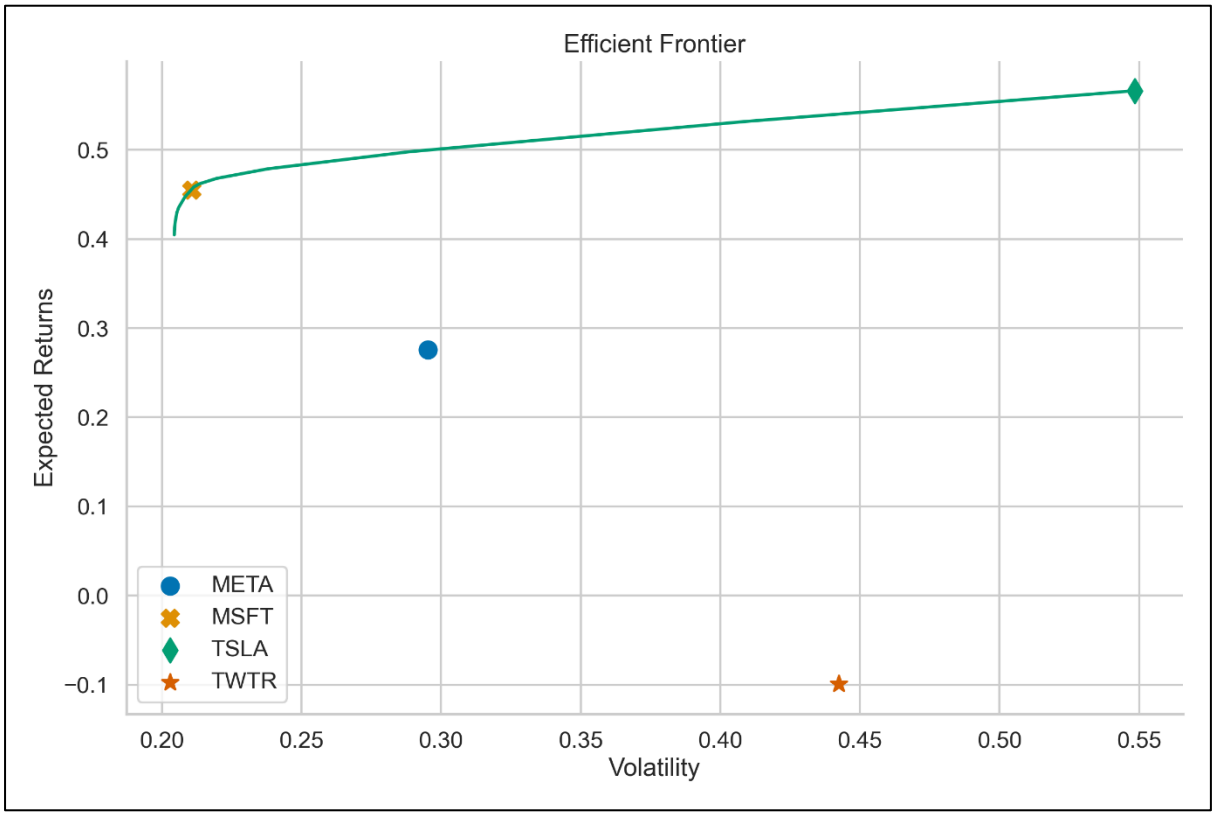
	returns	volatility	sharpe_ratio
0	0.335464	0.266351	1.259480
1	0.049227	0.346262	0.142167
2	0.175372	0.267961	0.654471
3	0.291582	0.257783	1.131113
4	0.346867	0.264669	1.310569
...	...	...	...
99995	0.442953	0.279346	1.585678
99996	0.145918	0.304849	0.478655
99997	0.419965	0.278450	1.508224
99998	0.277796	0.288633	0.962455
99999	0.353457	0.305080	1.158572

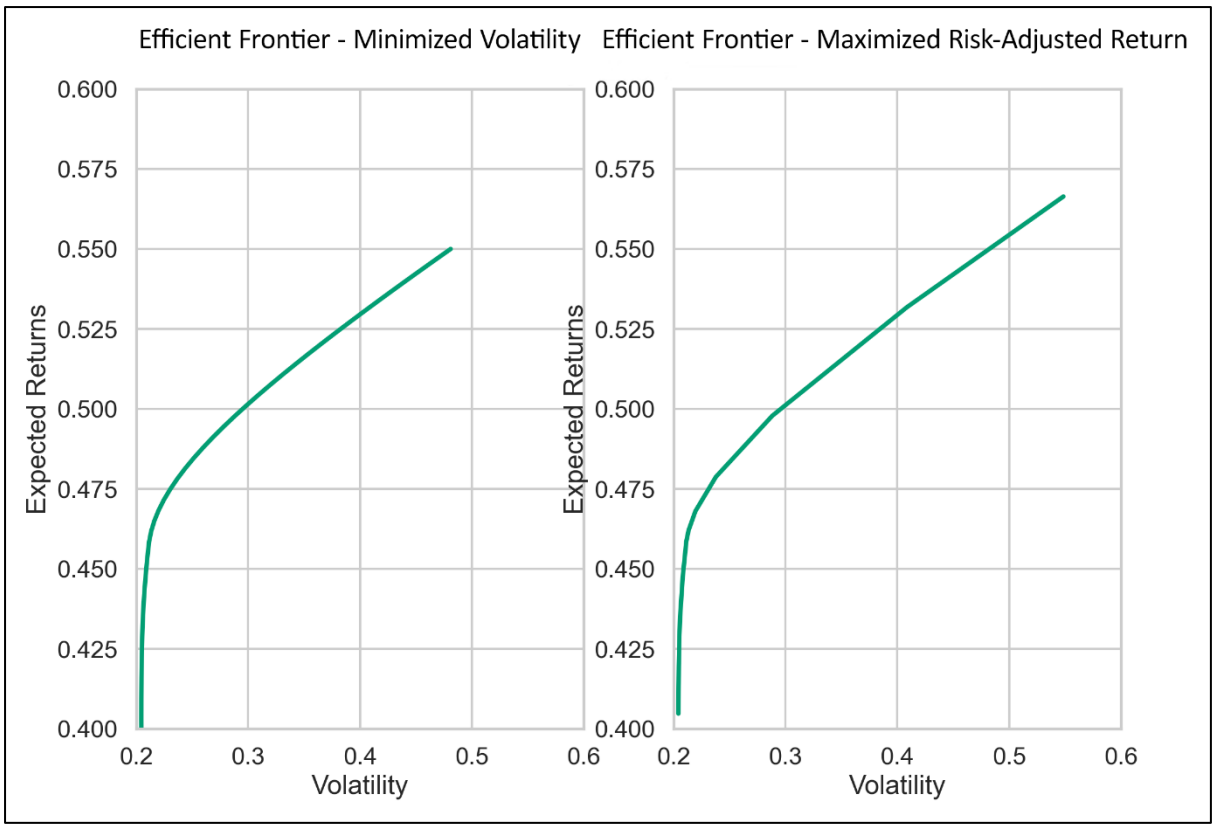


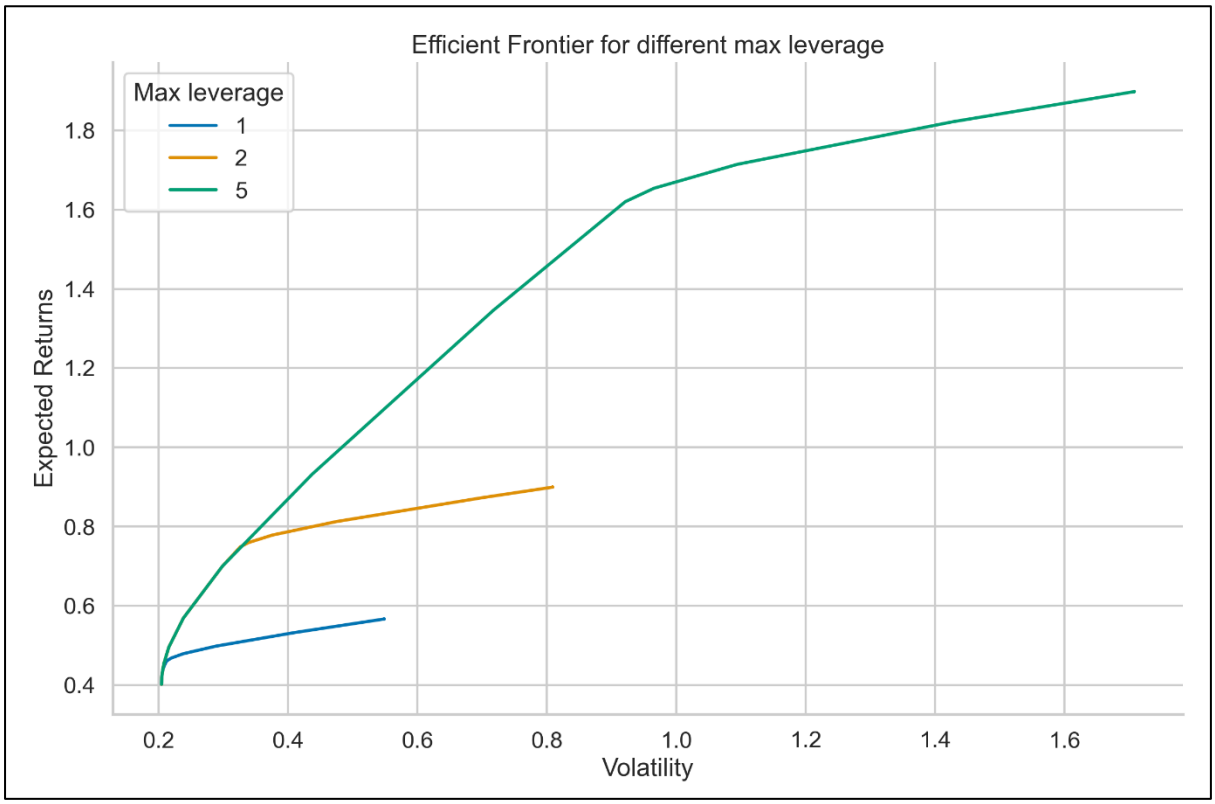

Efficient Frontier
Max Sharpe Ratio
Minimum Volatility
Expected Returns
Volatility
sharpe_ratio
0.0
0.1
0.2
0.3
0.4
0.5
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.0
0.5
1.0
1.5
2.0

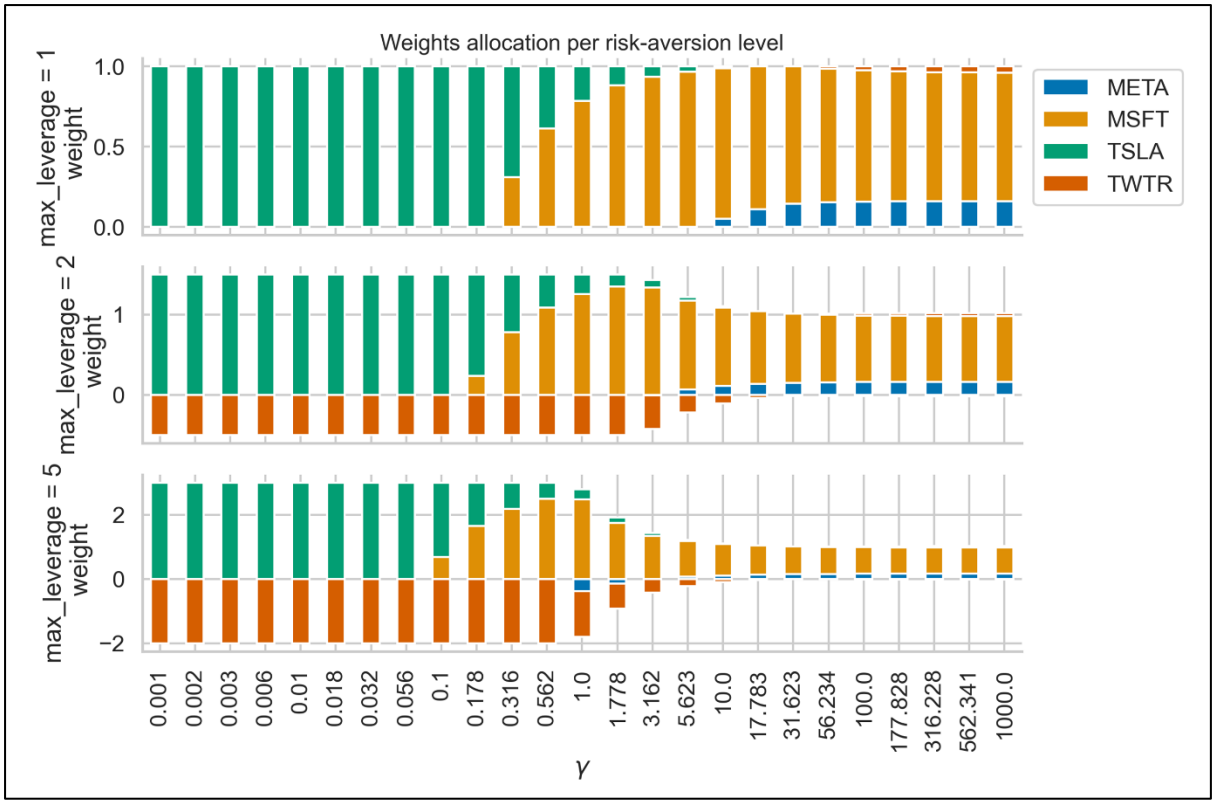

Efficient Frontier
Expected Returns
Volatility
sharpe_ratio
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.0
0.5
1.0
1.5
2.0

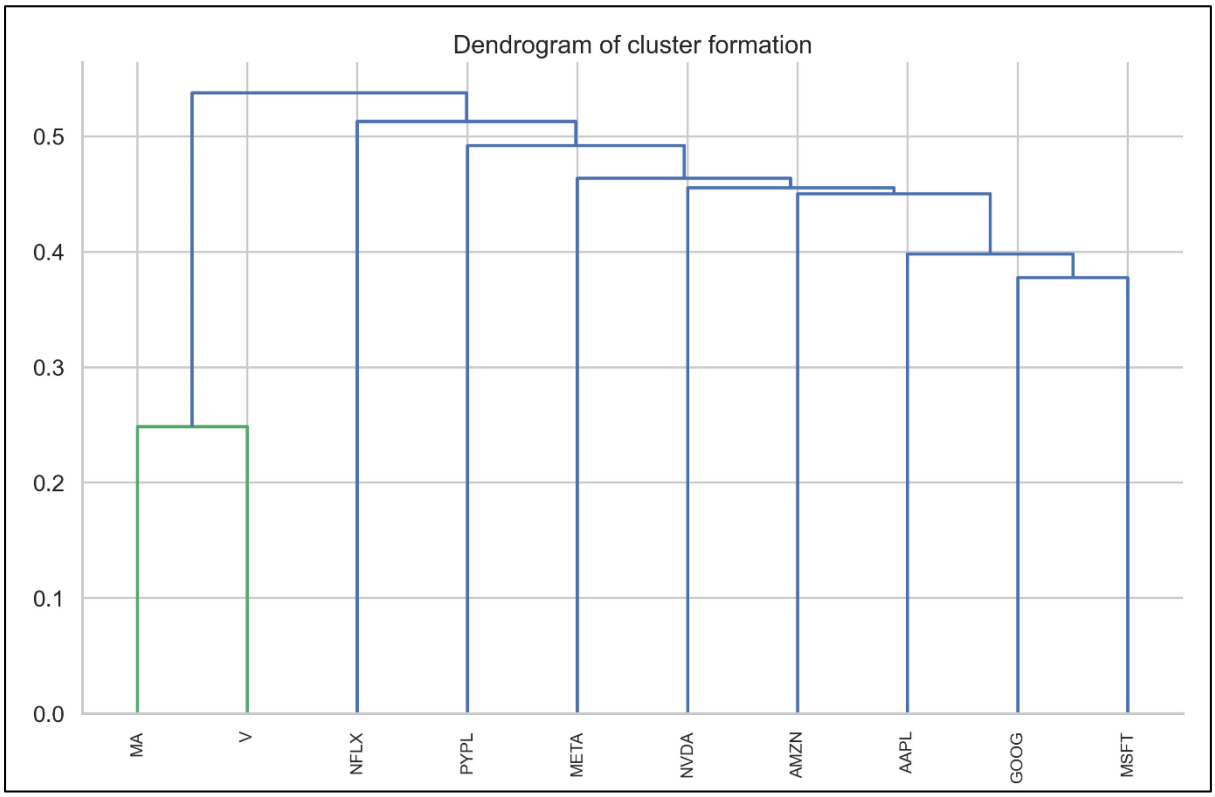

Weights allocation per risk-aversion level
weight
1.0
0.8
0.6
0.4
0.2
0.0
0.001
0.002
0.003
0.006
0.01
0.018
0.032
0.056
0.1
0.178
0.316
0.562
1.0
1.778
3.162
5.623
10.0
17.783
31.623
56.234
100.0
177.828
316.228
562.341
1000.0
γ
META
MSFT
TSLA
TWTR

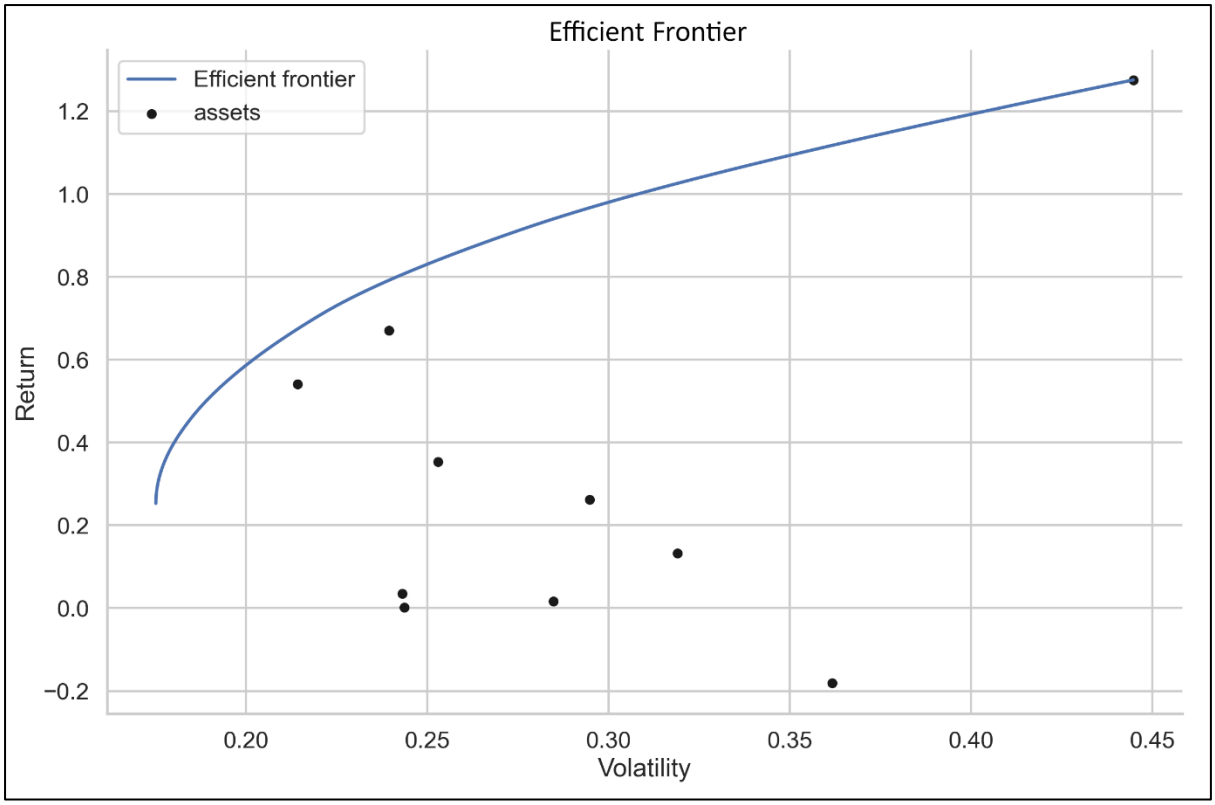

Efficient Frontier
Expected Returns
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
Volatility
META
MSFT
TSLA
TWTR


Efficient Frontier - Minimized Volatility
Efficient Frontier - Maximized Risk-Adjusted Return
Expected Returns
Volatility
0.600
0.575
0.550
0.525
0.500
0.475
0.450
0.425
0.400
0.2
0.3
0.4
0.5
0.6

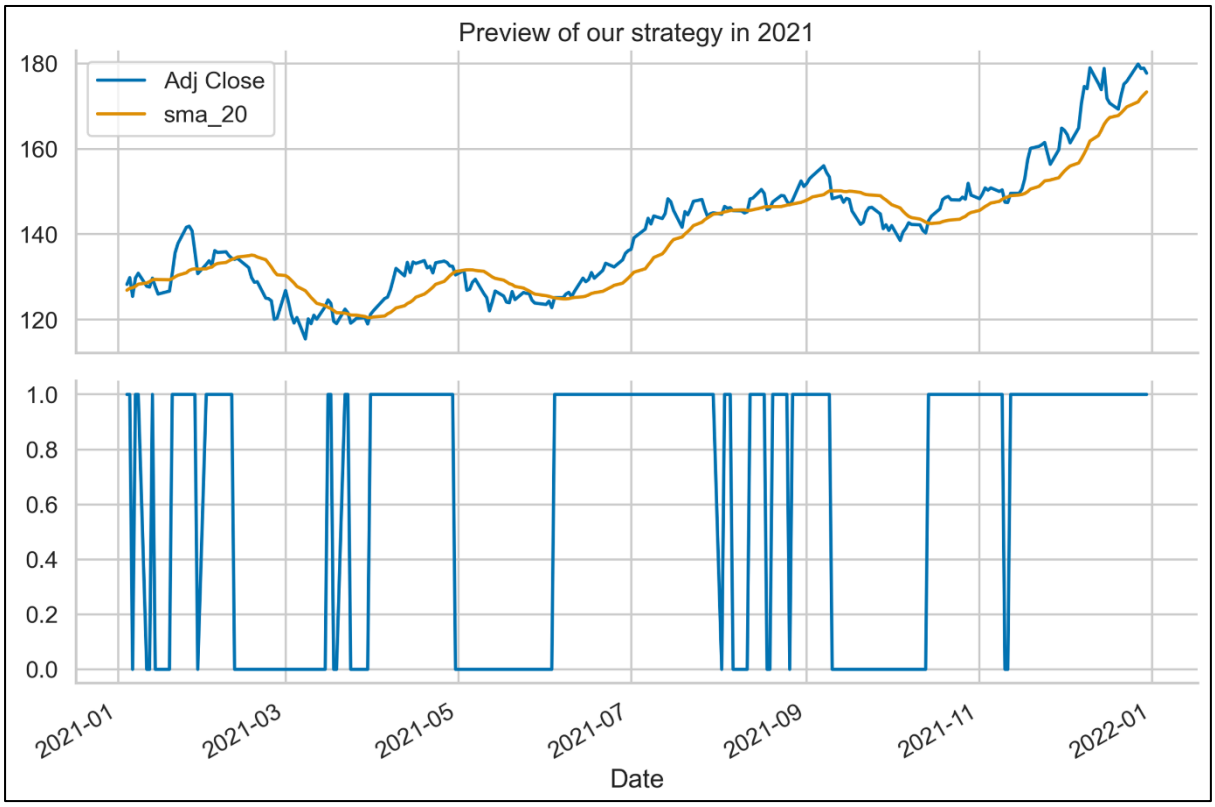

Efficient Frontier for different max leverage
Max leverage
1
2
5
Expected Returns
Volatility
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

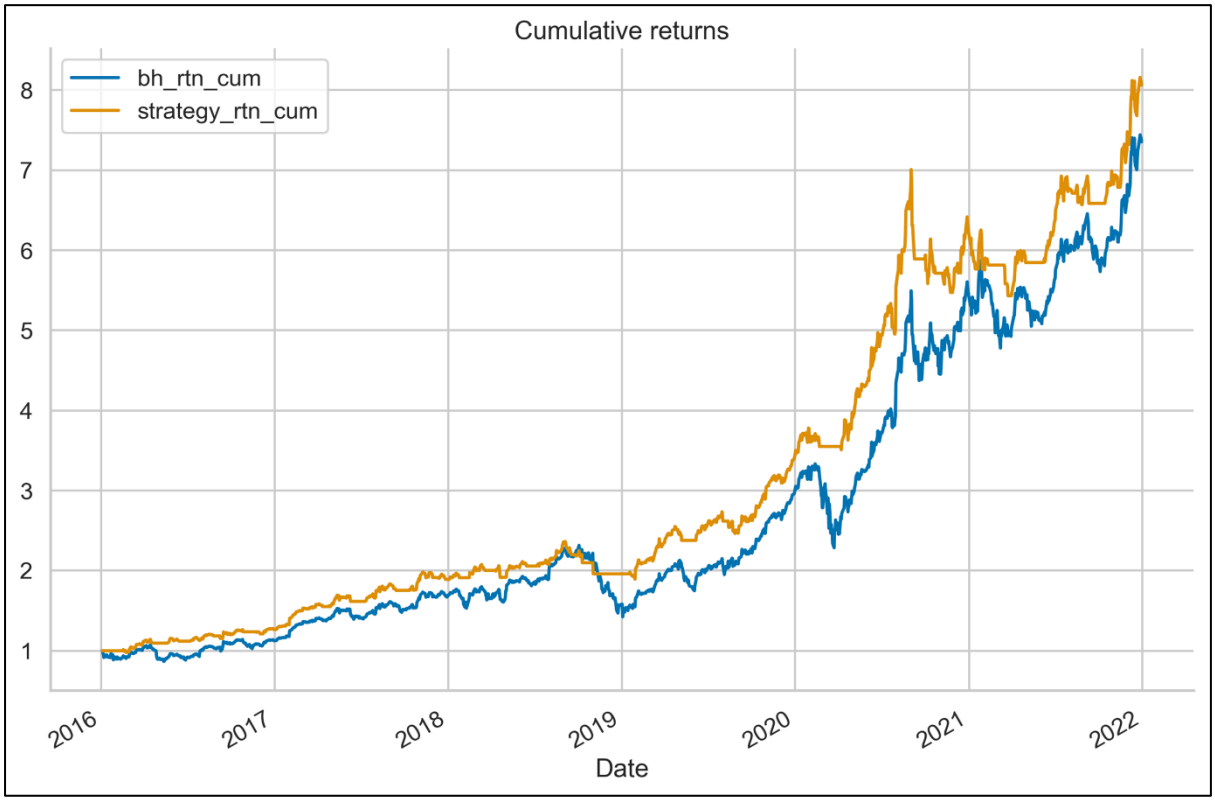

Weights allocation per risk-aversion level
max_leverage = 1
weight
max_leverage = 2
weight
max_leverage = 5
weight
META
MSFT
TSLA
TWTR
1.0
0.5
0.0
1
0
2
0
−2
0.001
0.002
0.003
0.006
0.01
0.018
0.032
0.056
0.1
0.178
0.316
0.562
1.0
1.778
3.162
5.623
10.0
17.783
31.623
56.234
100.0
177.828
316.228
562.341
1000.0
γ

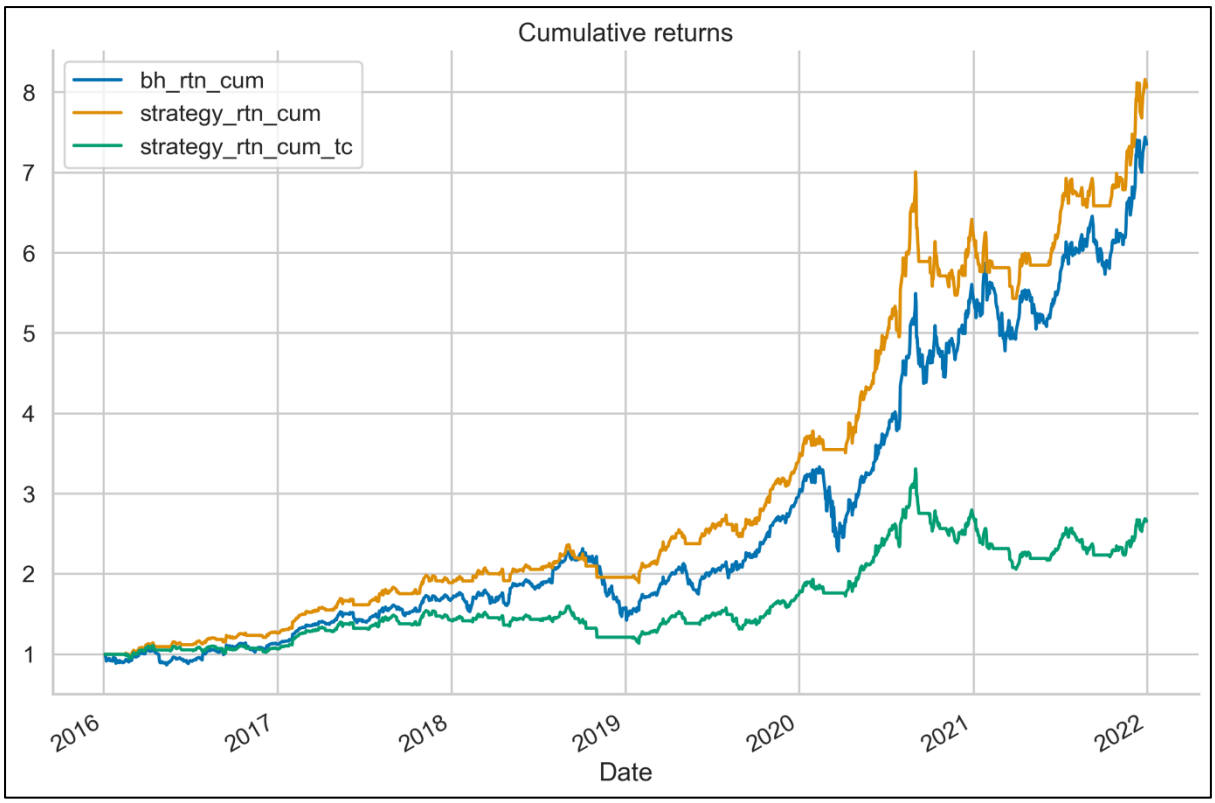

Dendrogram of cluster formation
0.5
0.4
0.3
0.2
0.1
0.0
MA
V
NFLX
PYPL
META
NVDA
AMZN
AAPL
GOOG
MSFT

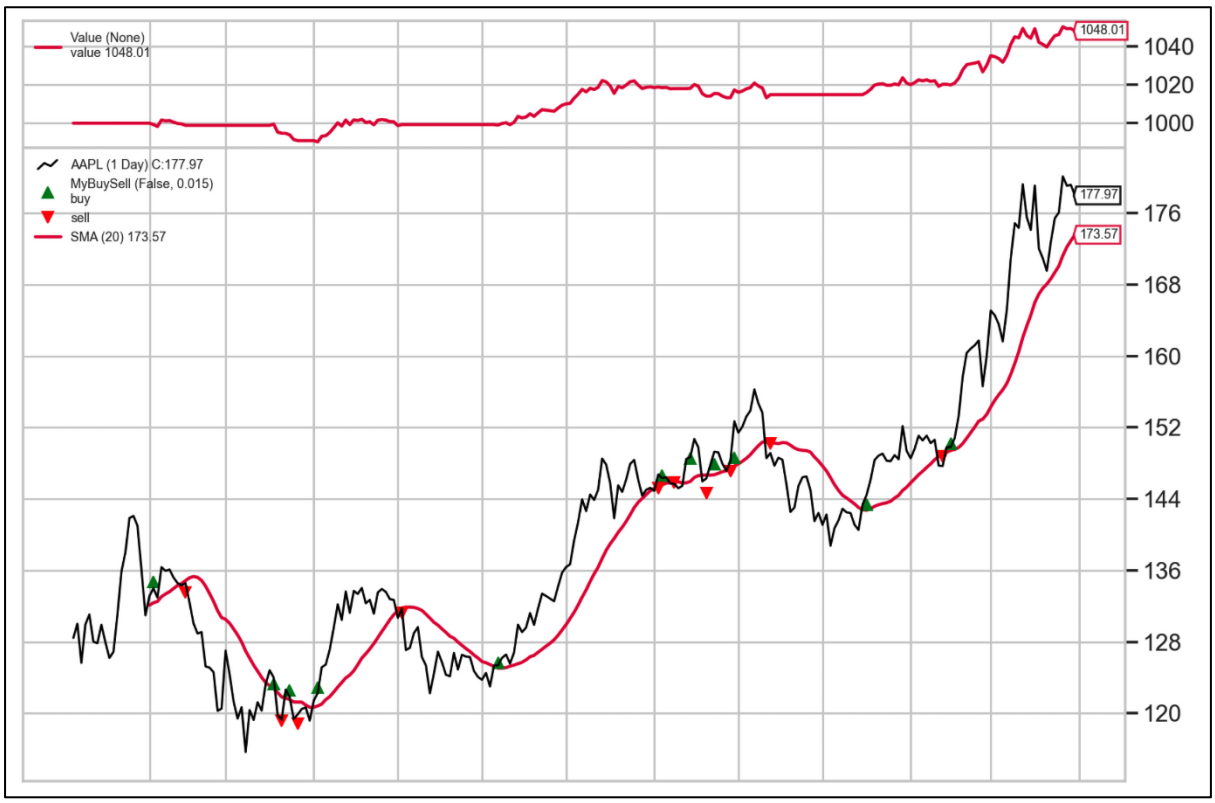

Efficient Frontier
Efficient frontier
assets
Return
Volatility
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0.20
0.25
0.30
0.35
0.40
0.45

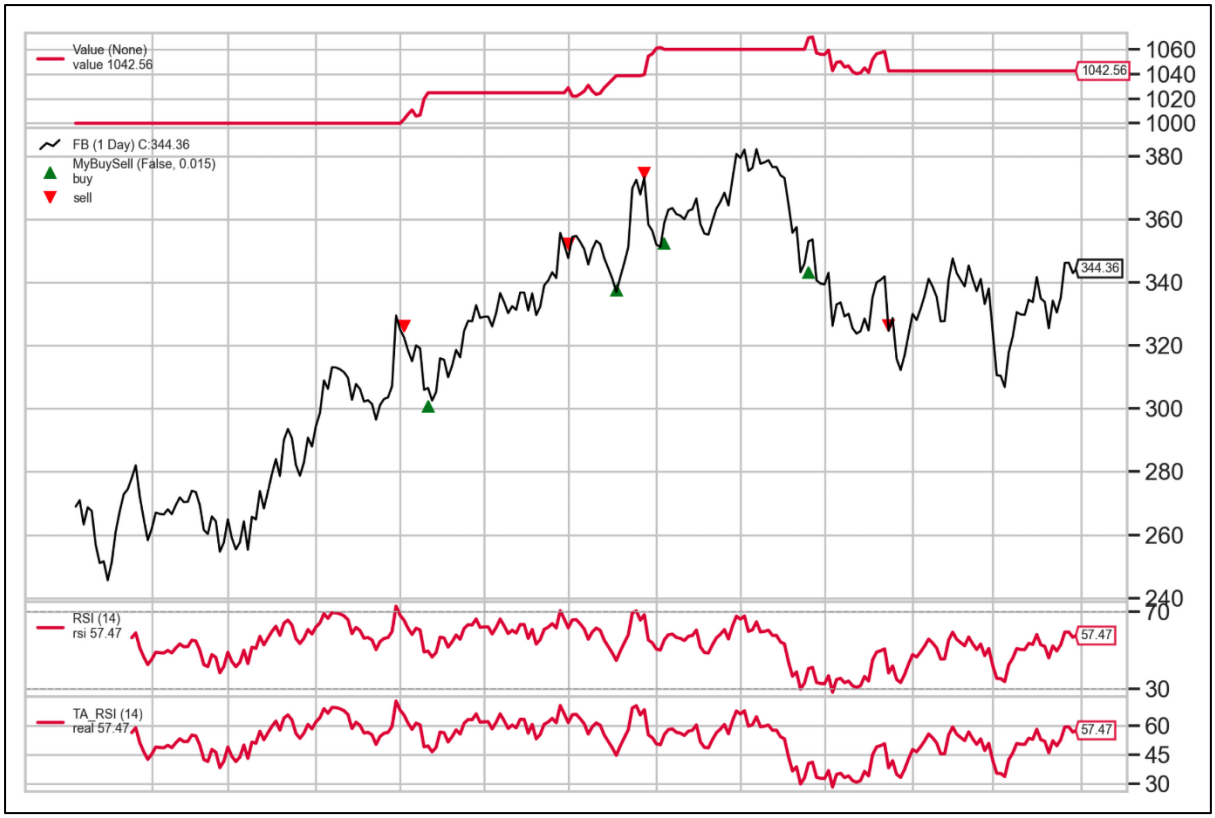
Chapter 12: Backtesting Trading Strategies

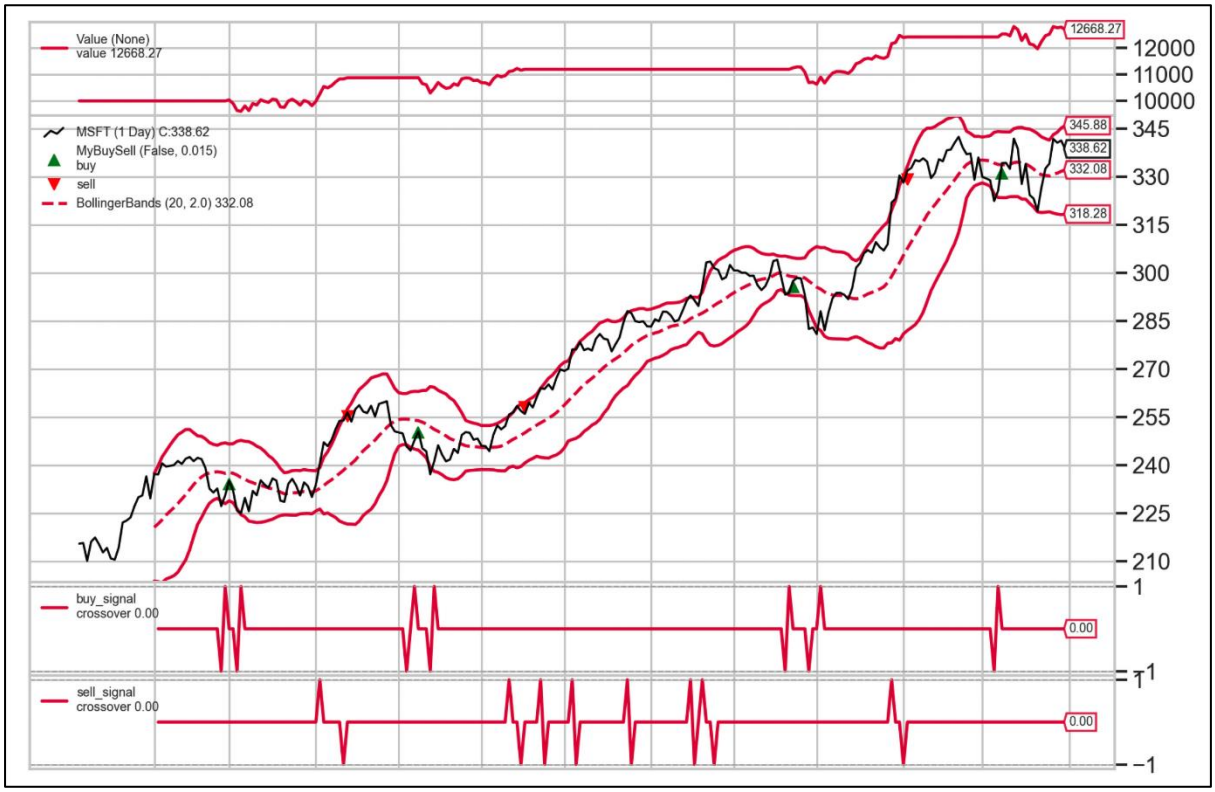


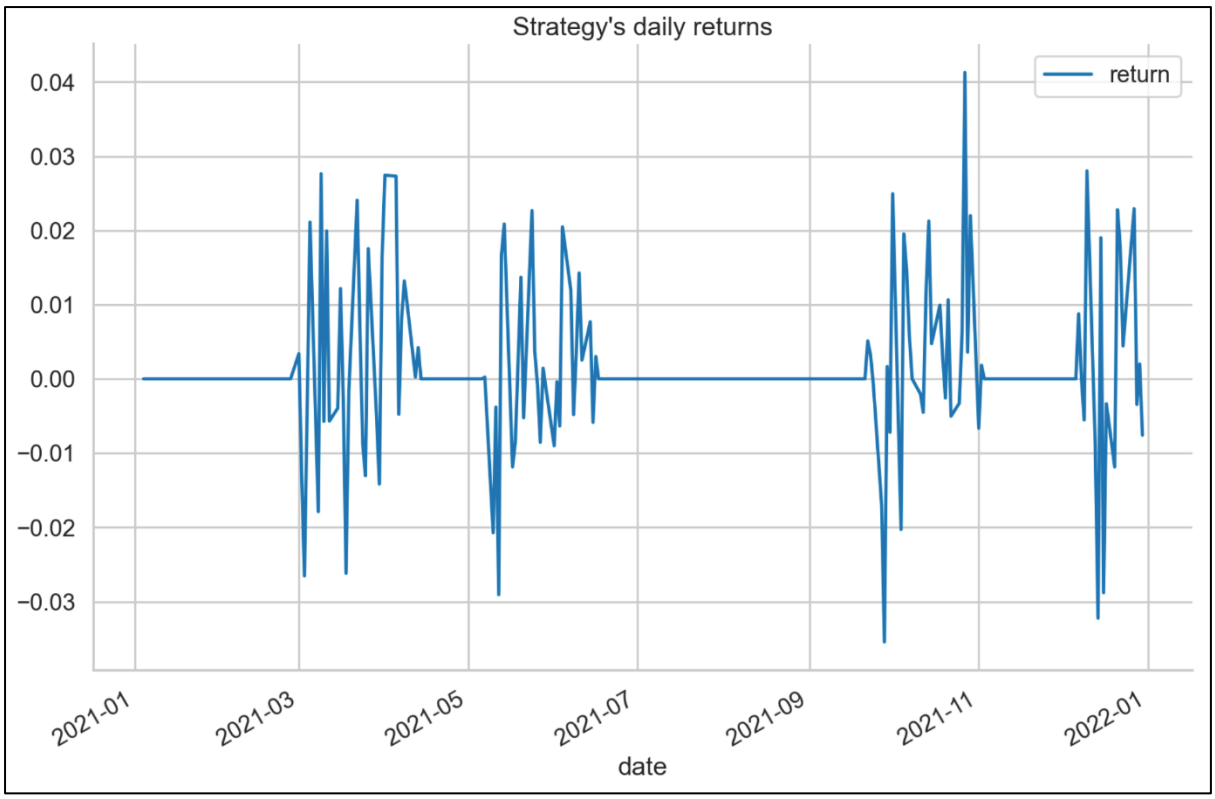


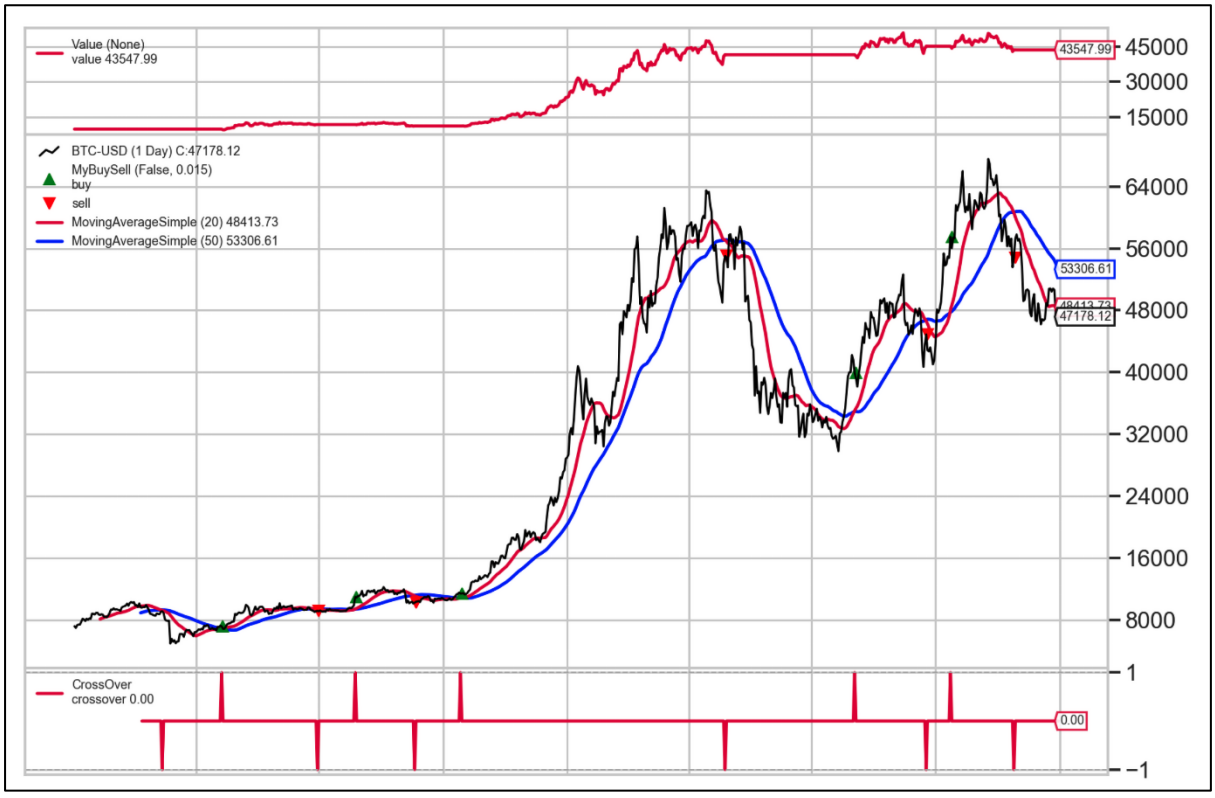

Cumulative returns
bh_rtn_cum
strategy_rtn_cum
strategy_rtn_cum_tc
8
7
6
5
4
3
2
1
2016
2017
2018
2019
2020
2021
2022
Date


Value (None)
value 1048.01
1048.01
AAPL (1 Day) C:177.97
MyBuySell (False, 0.015)
buy
sell
SMA (20) 173.57
177.97
173.57
1040
1020
1000
176
168
160
152
144
136
128
120


Value (None)
value 1042.56
1042.56
1060
1040
1020
1000
FB (1 Day) C:344.36
MyBuySell (False, 0.015)
buy
sell
380
360
344.36
340
320
300
280
260
240
RSI (14)
rsi 57.47
57.47
70
30
TA_RSI (14)
real 57.47
57.47
60
45
30


Value (None)
value 12668.27
12668.27
12000
11000
10000
MSFT (1 Day) C:338.62
MyBuySell (False, 0.015)
buy
sell
BollingerBands (20, 2.0) 332.08
345.88
345
338.62
332.08
330
318.28
315
300
285
270
255
240
225
210
buy_signal
crossover 0.00
1
0.00
−1
sell_signal
crossover 0.00
0.00
−1


Strategy's daily returns
return
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
2021-01
2021-03
2021-05
2021-07
2021-09
2021-11
2022-01
date

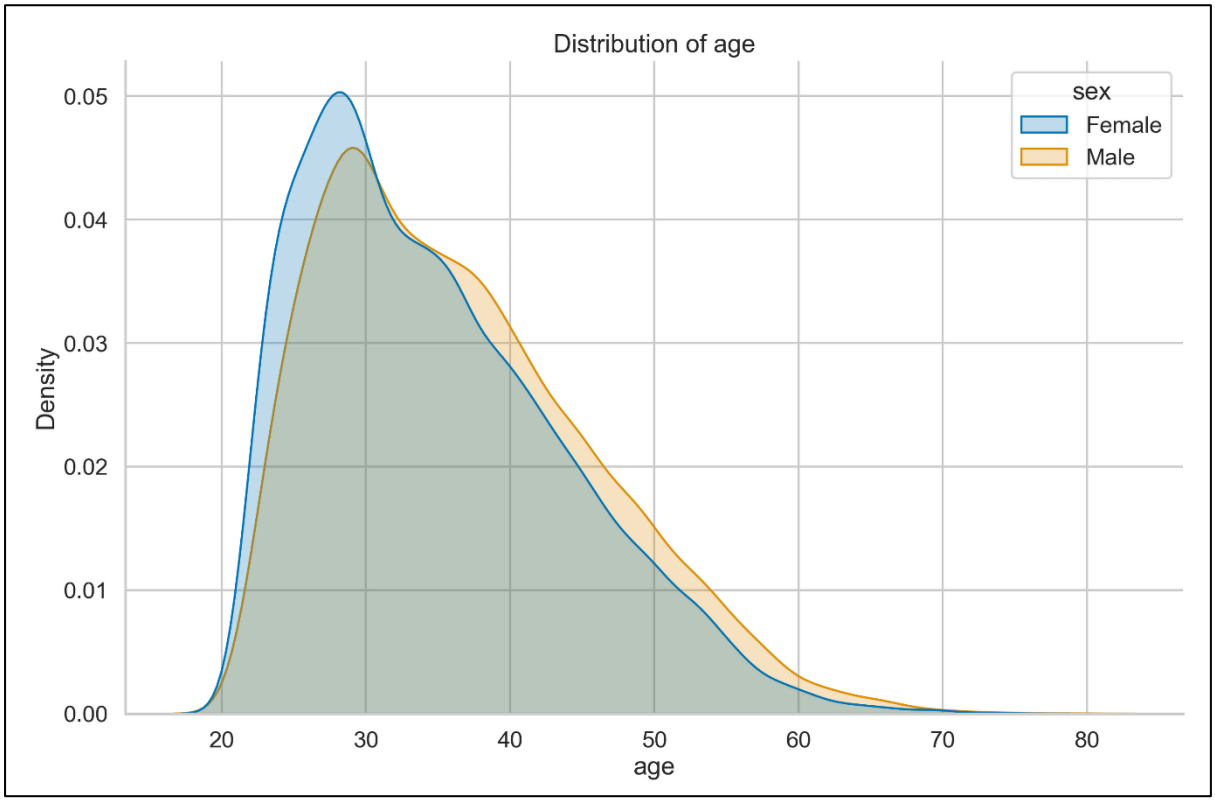

Value (None)
value 43547.99
43547.99
45000
30000
15000
BTC-USD (1 Day) C:47178.12
MyBuySell (False, 0.015)
buy
sell
MovingAverageSimple (20) 48413.73
MovingAverageSimple (50) 53306.61
64000
56000
53306.61
48000
48413.73
47178.12
40000
32000
24000
16000
8000
1
CrossOver
crossover 0.00
0.00
−1

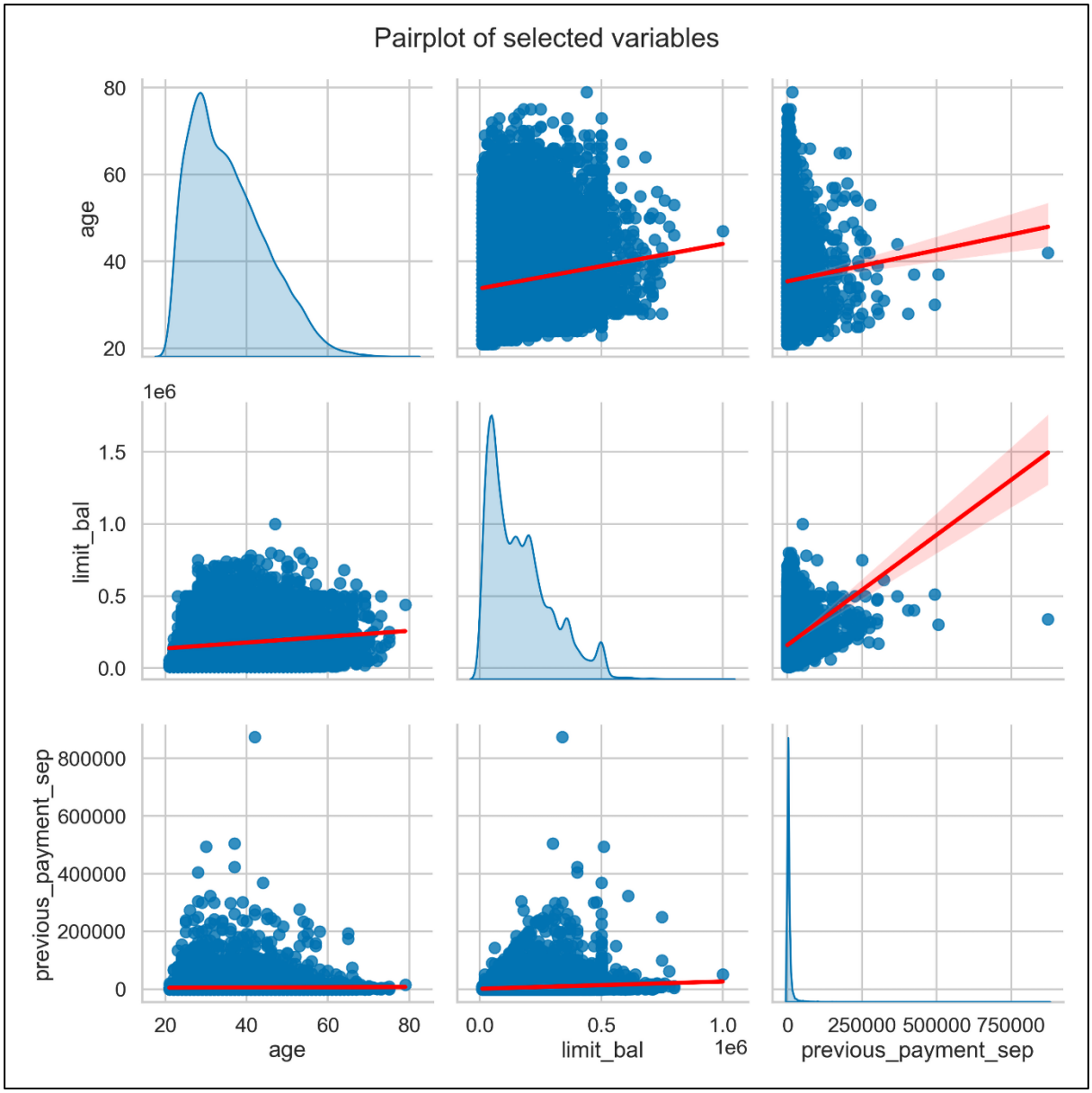
Chapter 13: Applied Machine Learning: Identifying Credit Default

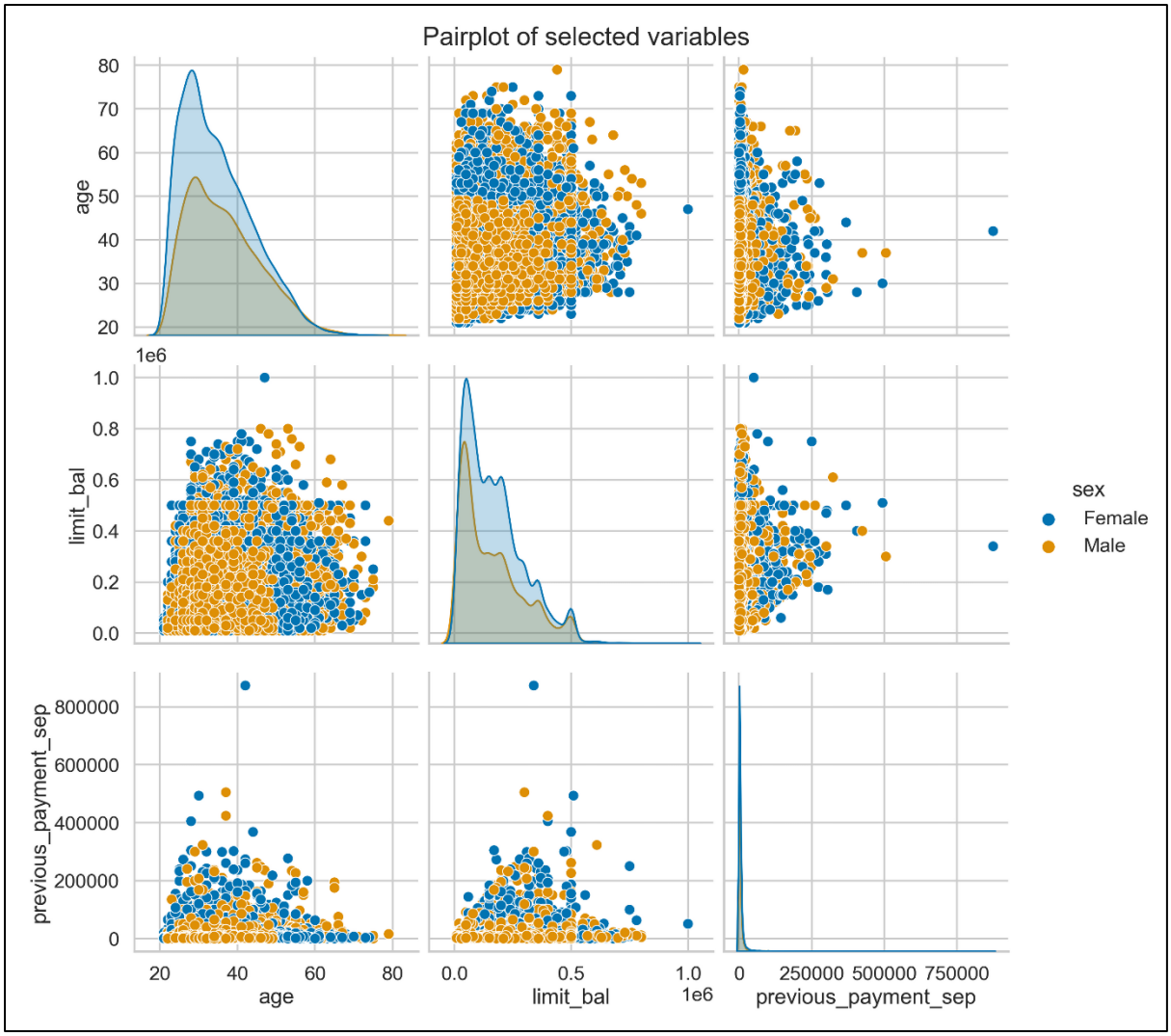
	limit_bal	sex	education	marriage	age	payment_status_sep	payment_status_aug
0	20000	Female	University	Married	24.0	Payment delayed 2 months	Payment delayed 2 months
1	120000	Female	University	Single	26.0	Payed duly	Payment delayed 2 months
2	90000	Female	University	Single	34.0	Unknown	Unknown
3	50000	Female	University	Married	37.0	Unknown	Unknown
4	50000	Male	University	Married	57.0	Payed duly	Unknown
...	...	...	...	...	...	...	...
29995	220000	NaN	High school	Married	39.0	Unknown	Unknown
29996	150000	Male	High school	Single	43.0	Payed duly	Payed duly
29997	30000	Male	University	Single	37.0	Payment delayed 4 months	Payment delayed 3 months
29998	80000	Male	High school	Married	41.0	Payment delayed 1 month	Payed duly
29999	50000	Male	University	Married	46.0	Unknown	Unknown

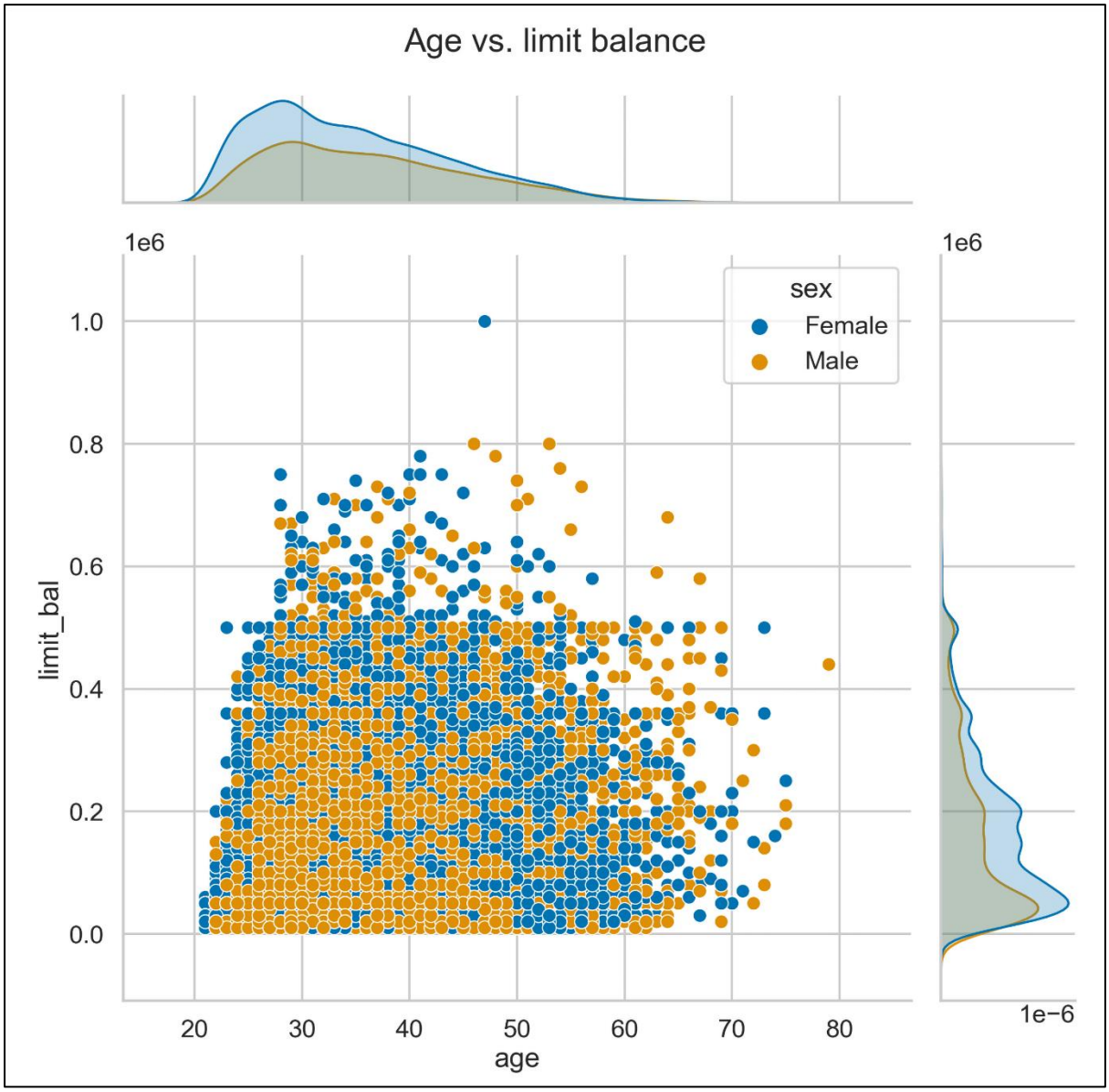
	count	mean	std	min	25%	50%	75%	max
limit_bal	30000.0	167484.32	129747.66	10000.0	50000.00	140000.0	240000.00	1000000.0
age	29850.0	35.49	9.22	21.0	28.00	34.0	41.00	79.0
bill_statement_sep	30000.0	51223.33	73635.86	-165580.0	3558.75	22381.5	67091.00	964511.0
bill_statement_aug	30000.0	49179.08	71173.77	-69777.0	2984.75	21200.0	64006.25	983931.0
bill_statement_jul	30000.0	47013.15	69349.39	-157264.0	2666.25	20088.5	60164.75	1664089.0
bill_statement_jun	30000.0	43262.95	64332.86	-170000.0	2326.75	19052.0	54506.00	891586.0
bill_statement_may	30000.0	40311.40	60797.16	-81334.0	1763.00	18104.5	50190.50	927171.0
bill_statement_apr	30000.0	38871.76	59554.11	-339603.0	1256.00	17071.0	49198.25	961664.0
previous_payment_sep	30000.0	5663.58	16563.28	0.0	1000.00	2100.0	5006.00	873552.0
previous_payment_aug	30000.0	5921.16	23040.87	0.0	833.00	2009.0	5000.00	1684259.0
previous_payment_jul	30000.0	5225.68	17606.96	0.0	390.00	1800.0	4505.00	896040.0
previous_payment_jun	30000.0	4826.08	15666.16	0.0	296.00	1500.0	4013.25	621000.0
previous_payment_may	30000.0	4799.39	15278.31	0.0	252.50	1500.0	4031.50	426529.0
previous_payment_apr	30000.0	5215.50	17777.47	0.0	117.75	1500.0	4000.00	528666.0
default_payment_next_month	30000.0	0.22	0.42	0.0	0.00	0.0	0.00	1.0

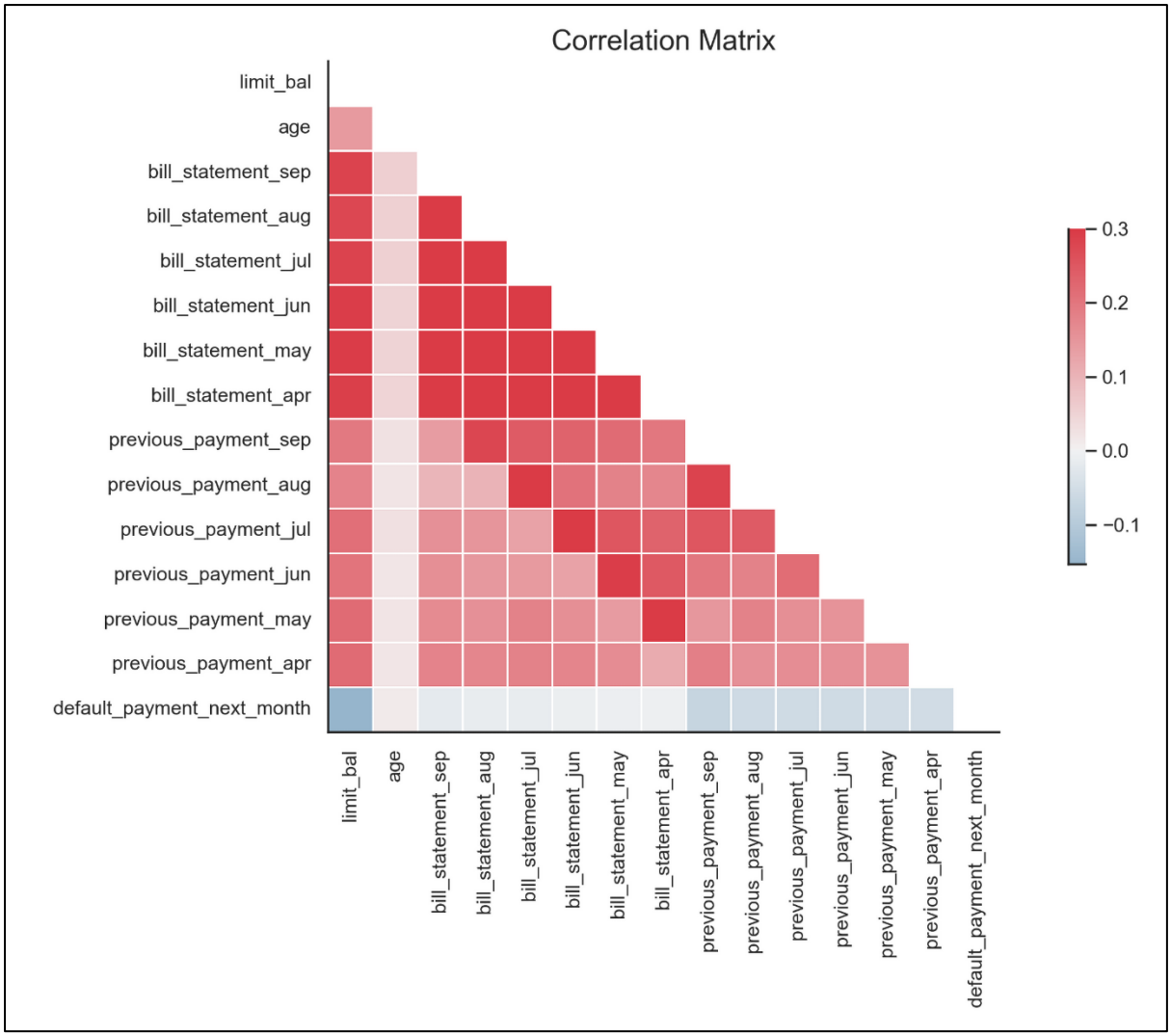
	count	unique	top	freq
sex	29850	2	Female	18027
education	29850	4	University	13960
marriage	29850	3	Single	15891
payment_status_sep	30000	10	Unknown	17496
payment_status_aug	30000	10	Unknown	19512
payment_status_jul	30000	10	Unknown	19849
payment_status_jun	30000	10	Unknown	20803
payment_status_may	30000	9	Unknown	21493
payment_status_apr	30000	9	Unknown	21181

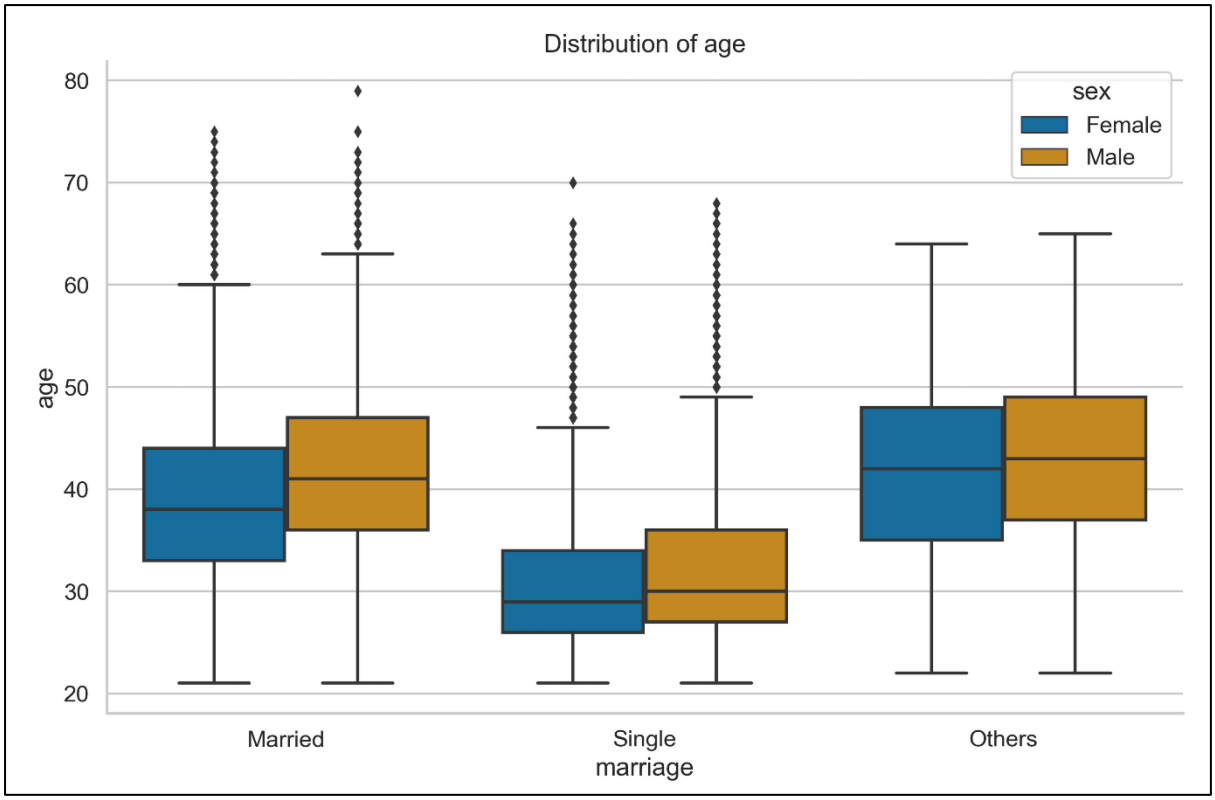


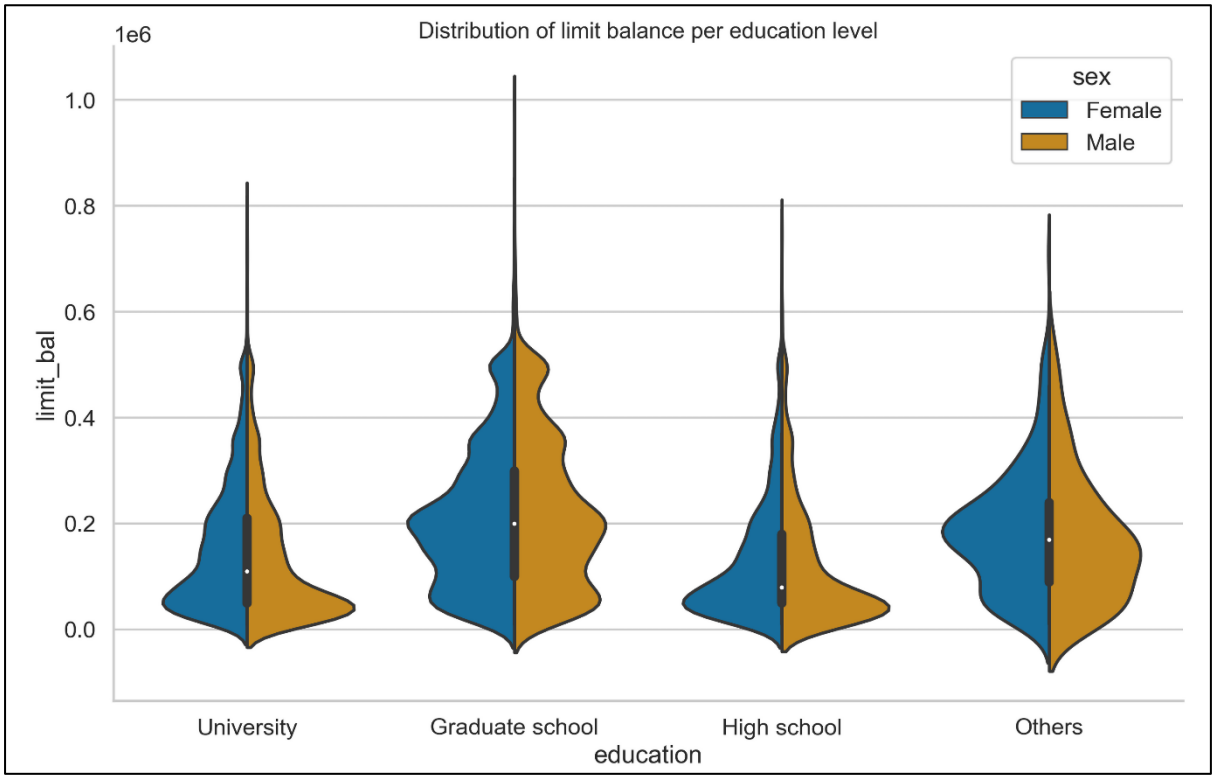

Pairplot of selected variables
age
limit_bal
previous_payment_sep
1e6
1e6

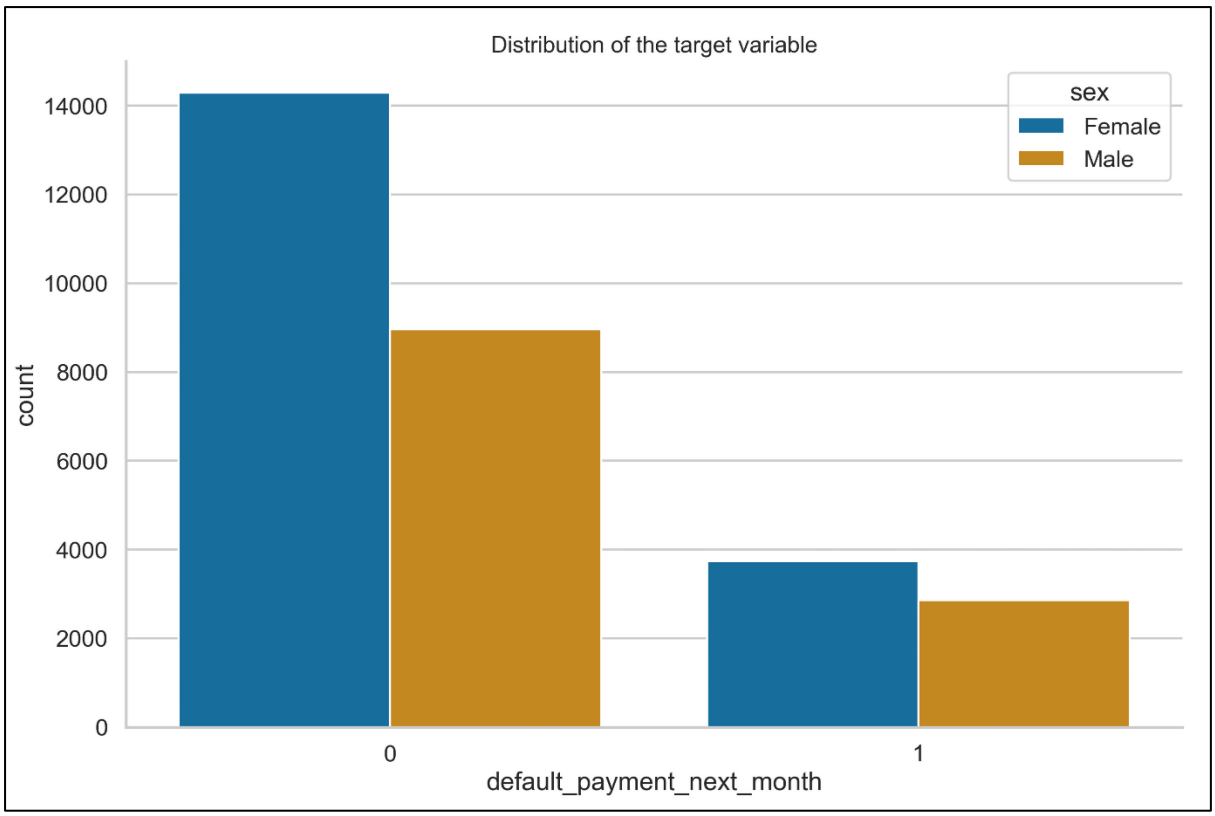

Pairplot of selected variables
age
limit_bal
previous_payment_sep
1e6
sex
Female
Male

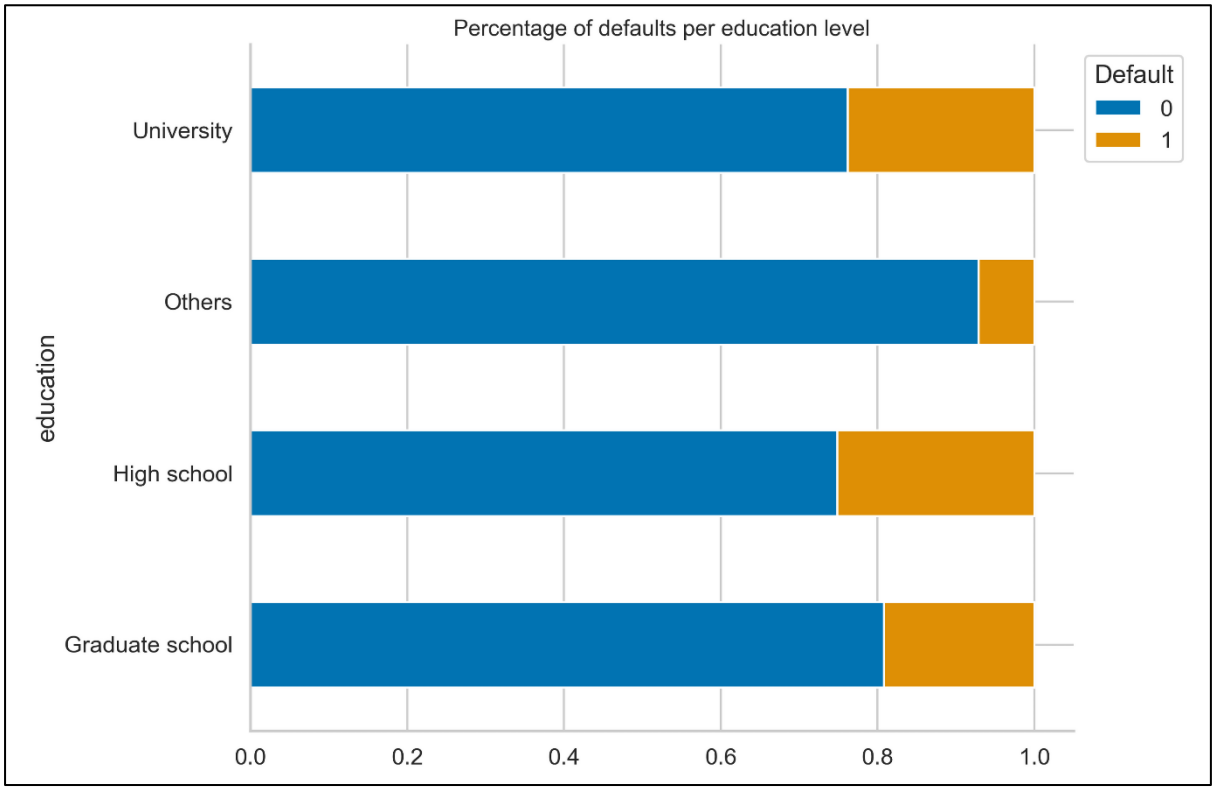

Age vs. limit balance
1e6
1.0
0.8
0.6
0.4
0.2
0.0
limit_bal
sex
Female
Male
20
30
40
50
60
70
80
age
1e6
1e−6

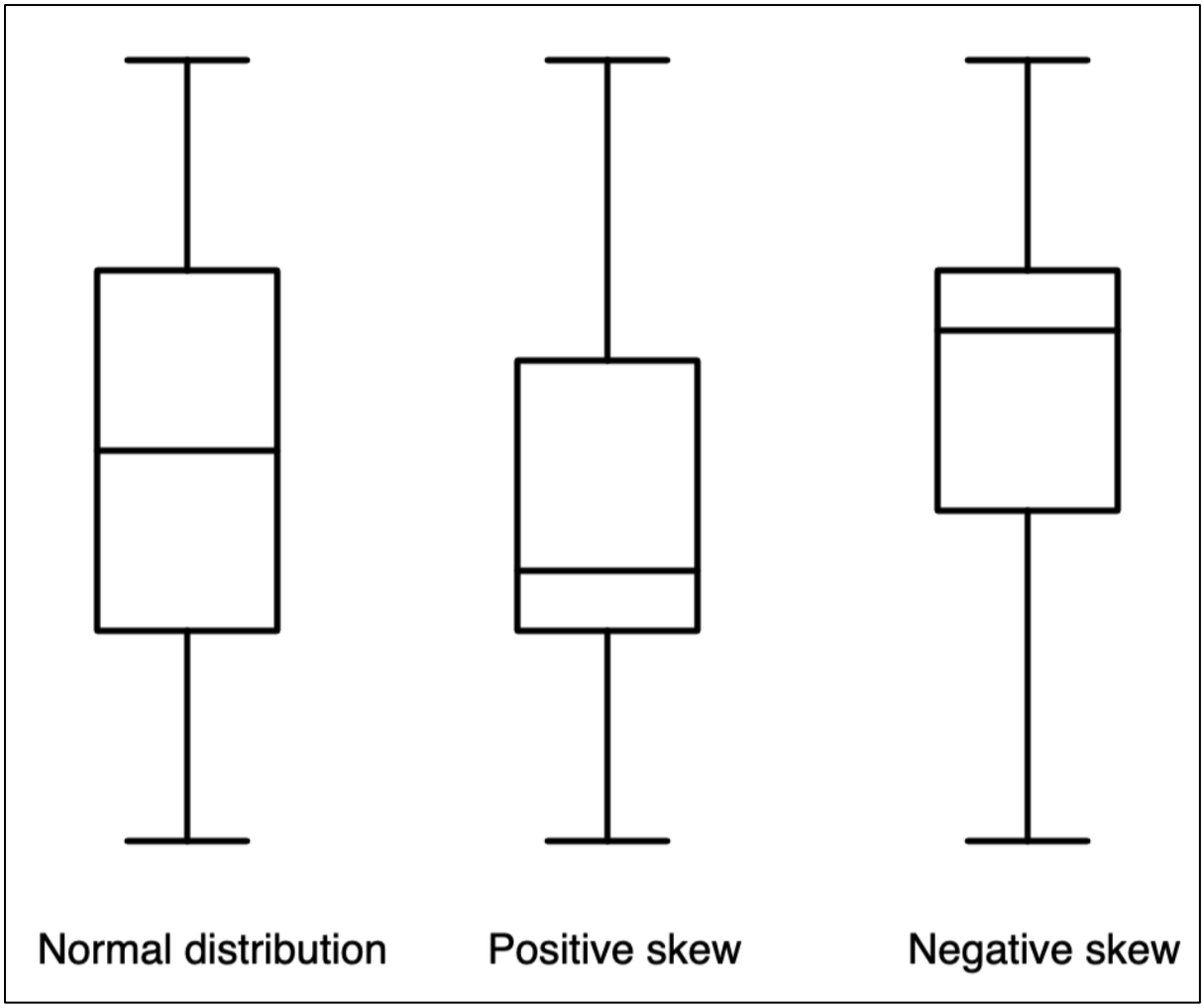

Correlation Matrix
limit_bal
age
bill_statement_sep
bill_statement_aug
bill_statement_jul
bill_statement_jun
bill_statement_may
bill_statement_apr
previous_payment_sep
previous_payment_aug
previous_payment_jul
previous_payment_jun
previous_payment_may
previous_payment_apr
default_payment_next_month
0.3
0.2
0.1
0.0
−0.1


Distribution of age
sex
Female
Male
80
70
60
50
40
30
20
age
Married
Single
Others
marriage


Distribution of limit balance per education level
1e6
sex
Female
Male
1.0
0.8
0.6
0.4
0.2
0.0
limit_bal
University
Graduate school
High school
Others
education


Distribution of the target variable
sex
Female
Male
14000
12000
10000
8000
6000
4000
2000
0
count
0
1
default_payment_next_month


Percentage of defaults per education level
Default
0
1
University
Others
High school
Graduate school
education
0.0
0.2
0.4
0.6
0.8
1.0



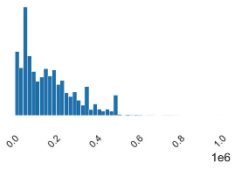
Variables

limit_bal
Real number ($\mathbb{R}_{\geq 0}$)

HIGH CORRELATION

Distinct	81
Distinct (%)	0.3%
Missing	0
Missing (%)	0.0%
Infinite	0
Infinite (%)	0.0%
Mean	167484.3227

Minimum	10000
Maximum	1000000
Zeros	0
Zeros (%)	0.0%
Negative	0
Negative (%)	0.0%
Memory size	234.5 KiB



Toggle details

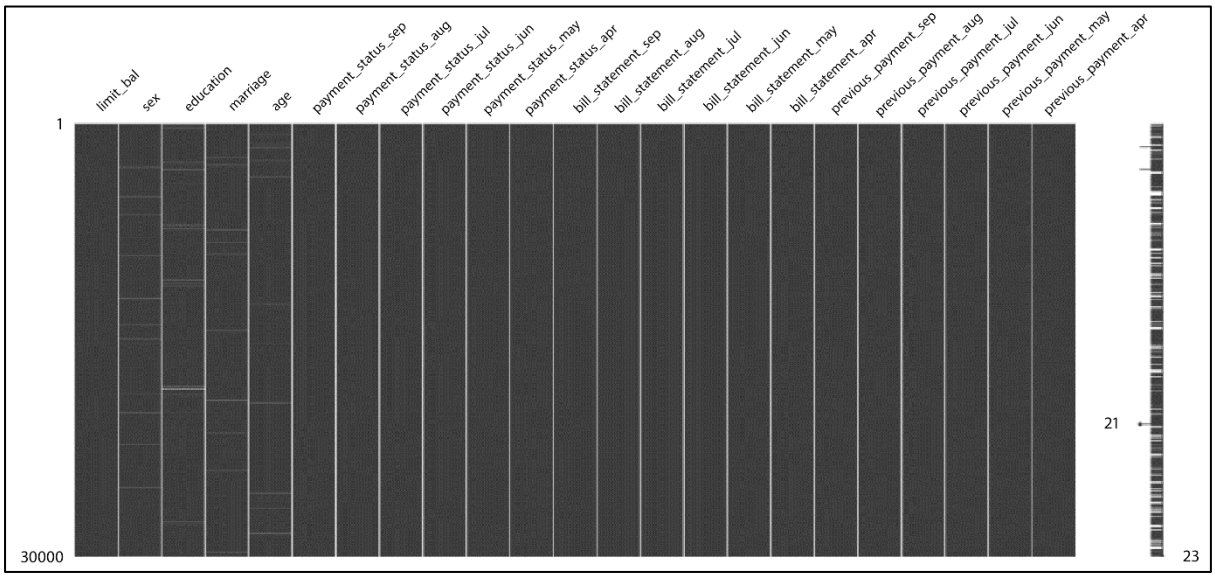
Statistics | Histogram | Common values | Extreme values

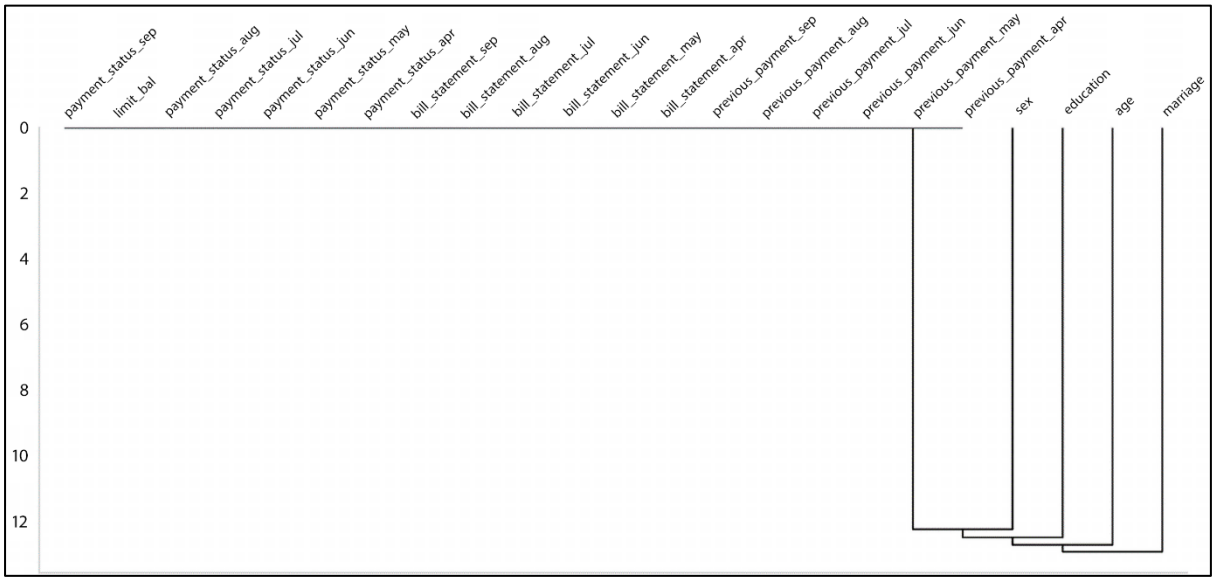
Quantile statistics

Minimum	10000
5-th percentile	20000
Q1	50000
median	140000
Q3	240000
95-th percentile	430000
Maximum	1000000
Range	990000
Interquartile range (IQR)	190000

Descriptive statistics

Standard deviation	129747.6616
Coefficient of variation (CV)	0.7746854124
Kurtosis	0.5362628964
Mean	167484.3227
Median Absolute Deviation (MAD)	90000
Skewness	0.9928669605
Sum	5024529680
Variance	$1.683445568 \times 10^{10}$
Monotonicity	Not monotonic





ColumnTransformer

```
ColumnTransformer(remainder='passthrough',
                  transformers=[('one_hot',
                                 OneHotEncoder(drop='first', sparse=False),
                                 ['sex', 'education', 'marriage',
                                  'payment_status_sep', 'payment_status_aug',
                                  'payment_status_jul', 'payment_status_jun',
                                  'payment_status_may',
                                  'payment_status_apr'])],
                  verbose_feature_names_out=False)
```

one_hot

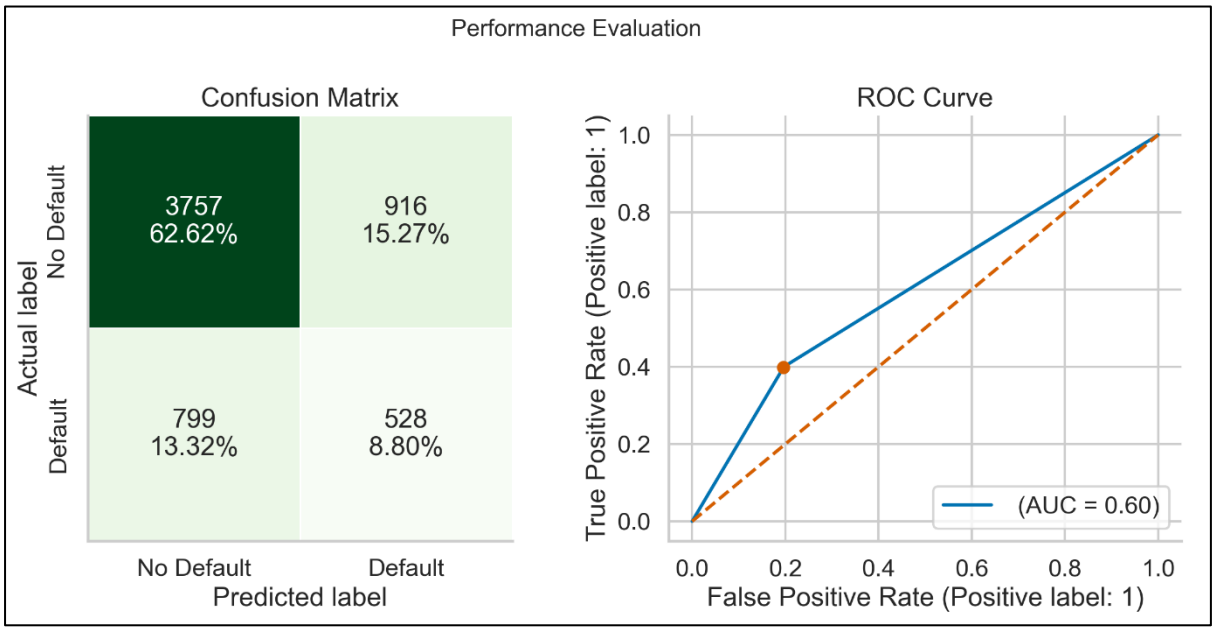
OneHotEncoder

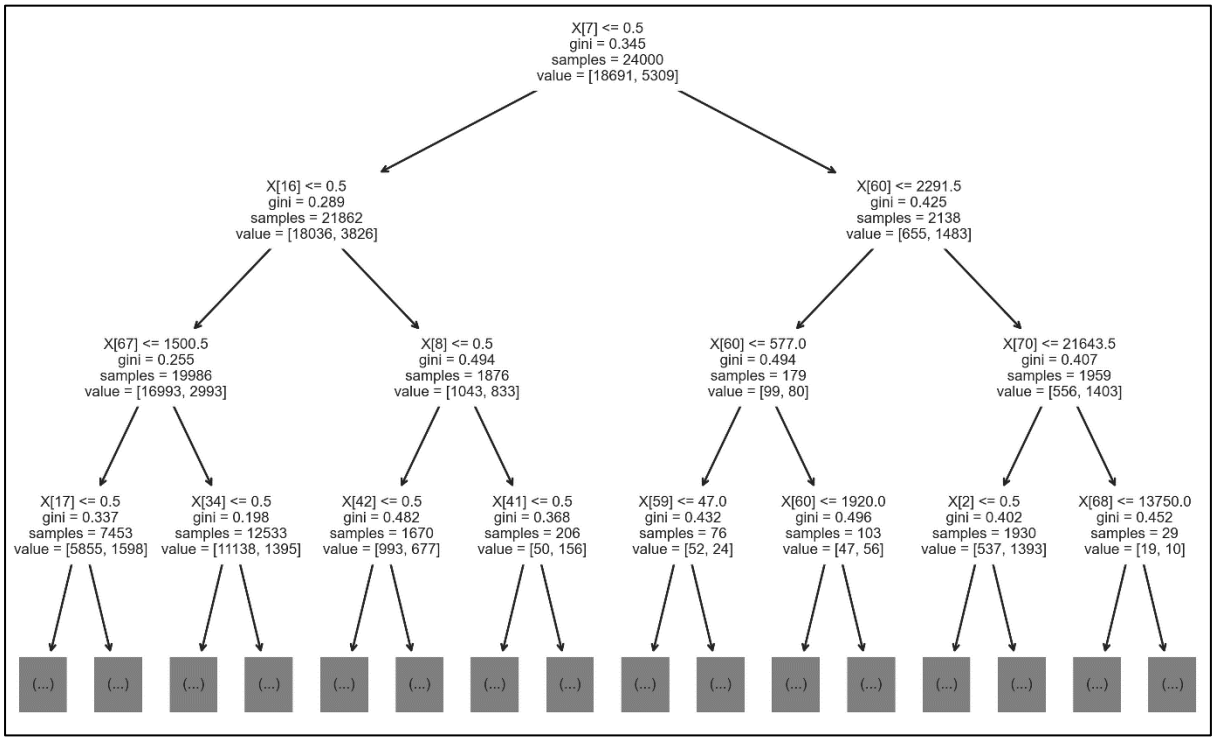
```
OneHotEncoder(drop='first', sparse=False)
```

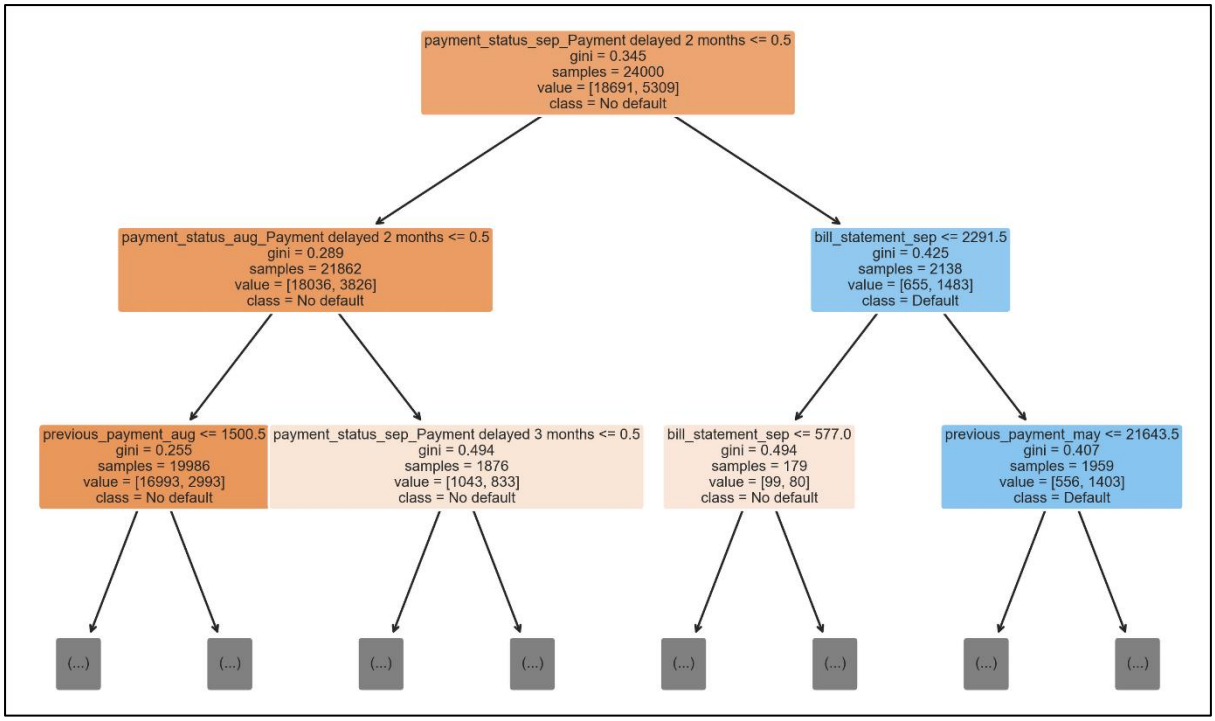
remainder

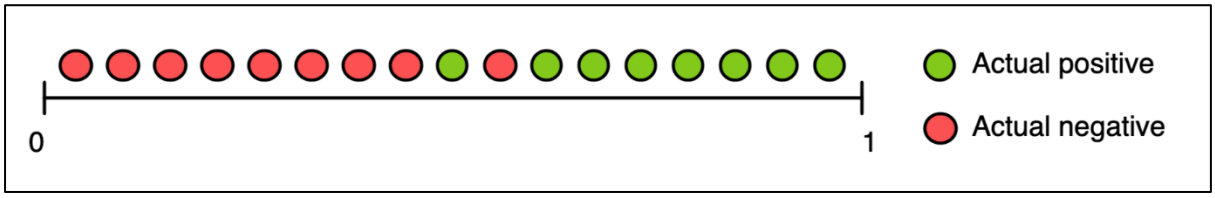
passthrough

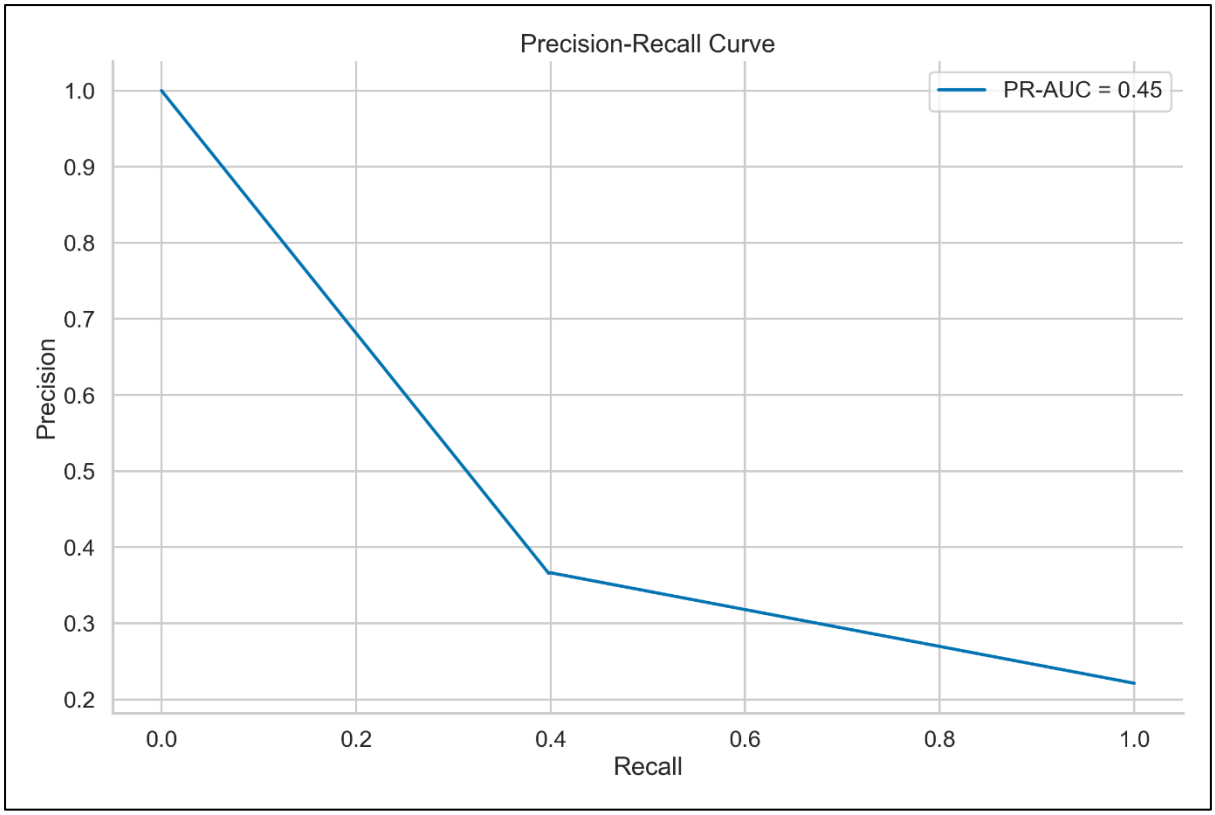
passthrough

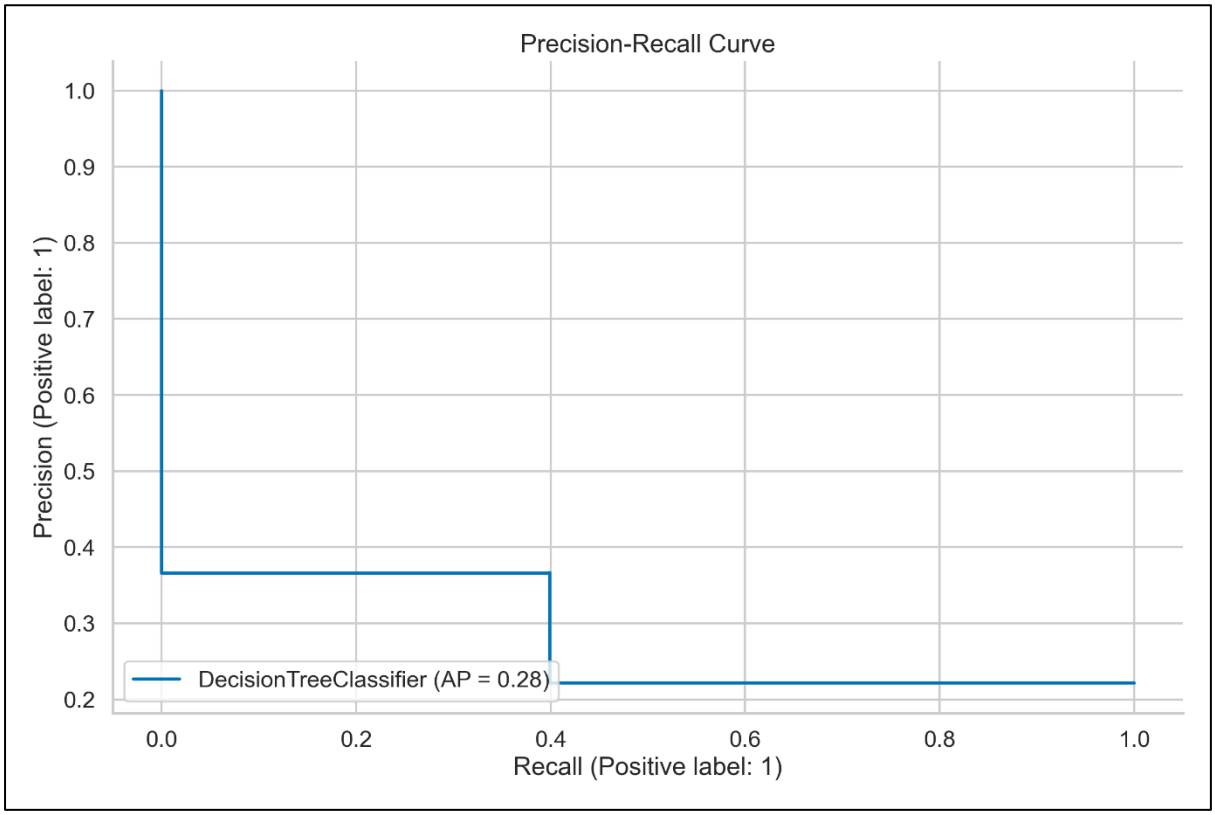

Performance Evaluation
Confusion Matrix
Actual label
No Default
Default
3757
62.62%
916
15.27%
799
13.32%
528
8.80%
No Default
Default
Predicted label
ROC Curve
True Positive Rate (Positive label: 1)
False Positive Rate (Positive label: 1)
(AUC = 0.60)

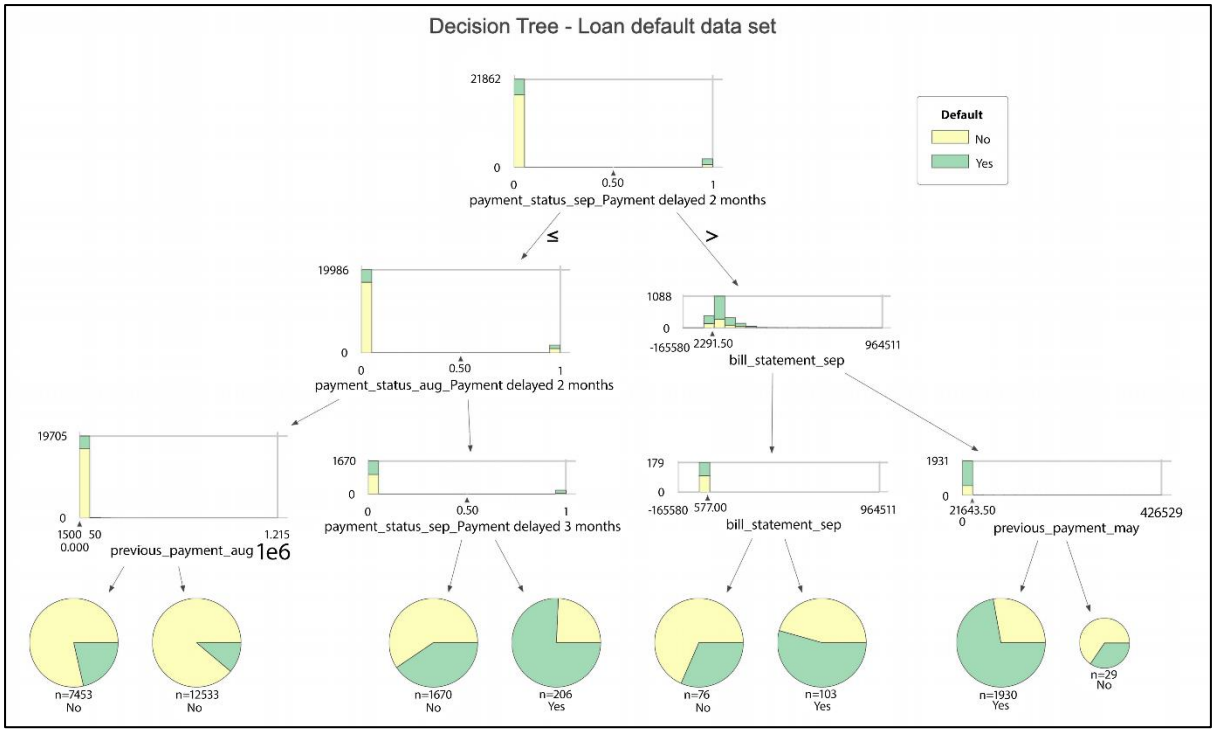

X[7] <= 0.5
gini = 0.345
samples = 24000
value = [18691, 5309]
X[16] <= 0.5
gini = 0.289
samples = 21862
value = [18036, 3826]
X[60] <= 2291.5
gini = 0.425
samples = 2138
value = [655, 1483]
X[67] <= 1500.5
gini = 0.255
samples = 19986
value = [16993, 2993]
X[8] <= 0.5
gini = 0.494
samples = 1876
value = [1043, 833]
X[60] <= 577.0
gini = 0.494
samples = 179
value = [99, 80]
X[70] <= 21643.5
gini = 0.407
samples = 1959
value = [556, 1403]
X[17] <= 0.5
gini = 0.337
samples = 7453
value = [5855, 1598]
X[34] <= 0.5
gini = 0.198
samples = 12533
value = [11138, 1395]
X[42] <= 0.5
gini = 0.482
samples = 1670
value = [993, 677]
X[41] <= 0.5
gini = 0.368
samples = 206
value = [50, 156]
X[59] <= 47.0
gini = 0.432
samples = 76
value = [52, 24]
X[60] <= 1920.0
gini = 0.496
samples = 103
value = [47, 56]
X[2] <= 0.5
gini = 0.402
samples = 1930
value = [537, 1393]
X[68] <= 13750.0
gini = 0.452
samples = 29
value = [19, 10]
(...)

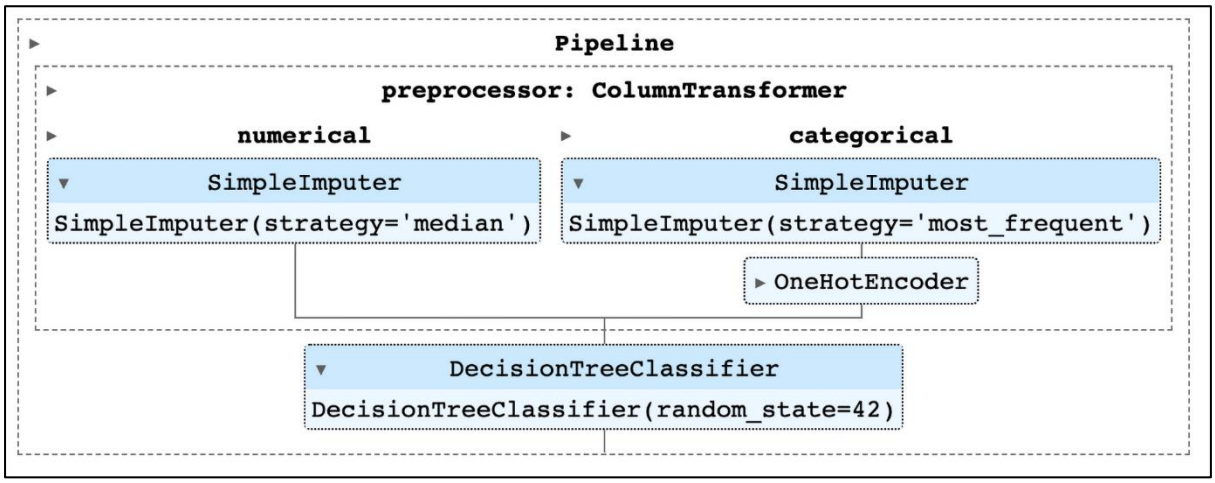

payment_status_sep_Payment delayed 2 months <= 0.5
gini = 0.345
samples = 24000
value = [18691, 5309]
class = No default
payment_status_aug_Payment delayed 2 months <= 0.5
gini = 0.289
samples = 21862
value = [18036, 3826]
class = No default
bill_statement_sep <= 2291.5
gini = 0.425
samples = 2138
value = [655, 1483]
class = Default
previous_payment_aug <= 1500.5
gini = 0.255
samples = 19986
value = [16993, 2993]
class = No default
payment_status_sep_Payment delayed 3 months <= 0.5
gini = 0.494
samples = 1876
value = [1043, 833]
class = No default
bill_statement_sep <= 577.0
gini = 0.494
samples = 179
value = [99, 80]
class = No default
previous_payment_may <= 21643.5
gini = 0.407
samples = 1959
value = [556, 1403]
class = Default
(...)
(...)
(...)
(...)
(...)
(...)
(...)
(...)

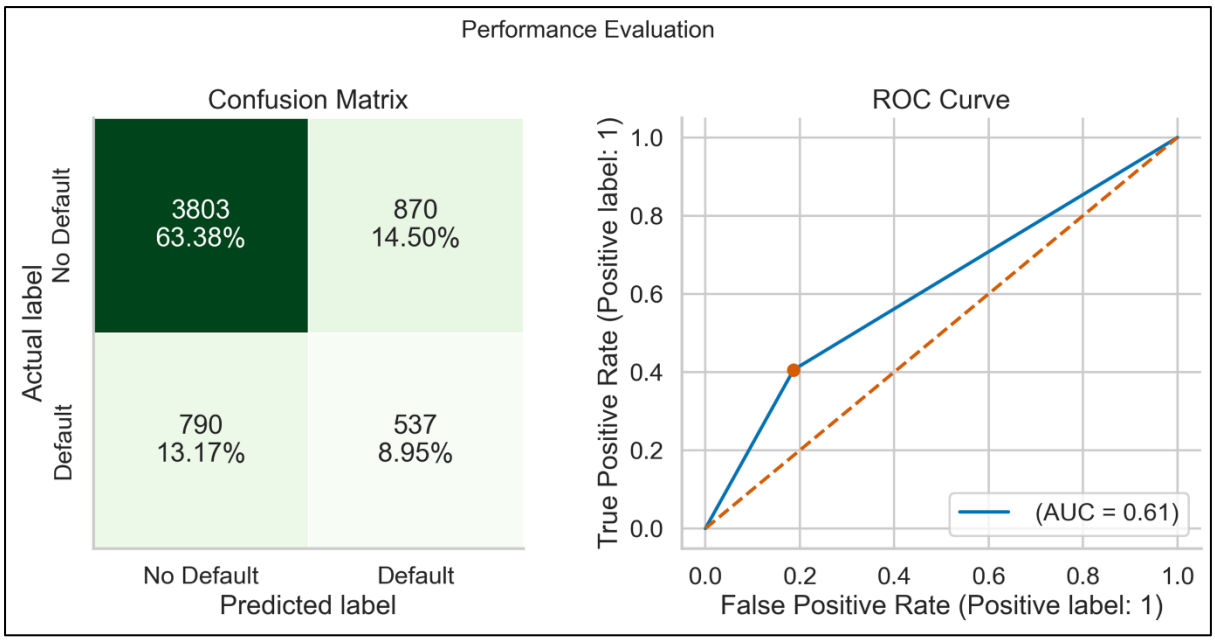

0
1
Actual positive
Actual negative

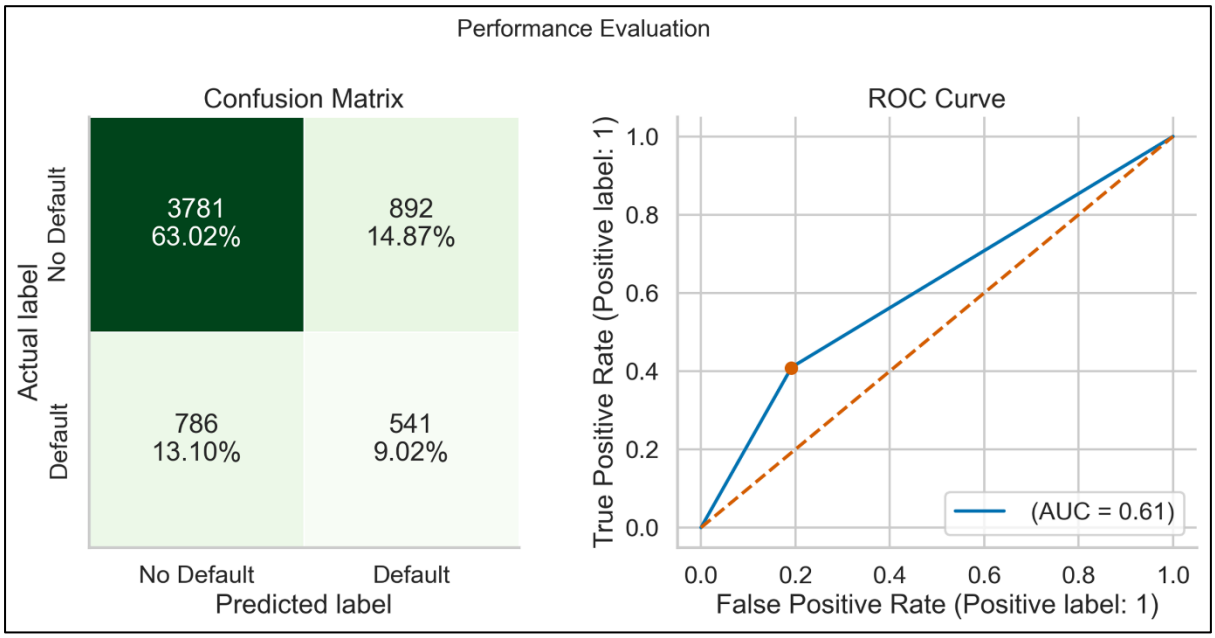

Precision-Recall Curve
PR-AUC = 0.45
Precision
Recall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.0
0.2
0.4
0.6
0.8
1.0


Precision-Recall Curve
DecisionTreeClassifier (AP = 0.28)
Precision (Positive label: 1)
Recall (Positive label: 1)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.0
0.2
0.4
0.6
0.8
1.0


Decision Tree - Loan default data set
Default
No
Yes
payment_status_sep_Payment delayed 2 months
≤
>
payment_status_aug_Payment delayed 2 months
bill_statement_sep
payment_status_sep_Payment delayed 3 months
bill_statement_sep
previous_payment_aug
previous_payment_may
1e6
n=7453
No
n=12533
No
n=1670
No
n=206
Yes
n=76
No
n=103
Yes
n=1930
Yes
n=29
No

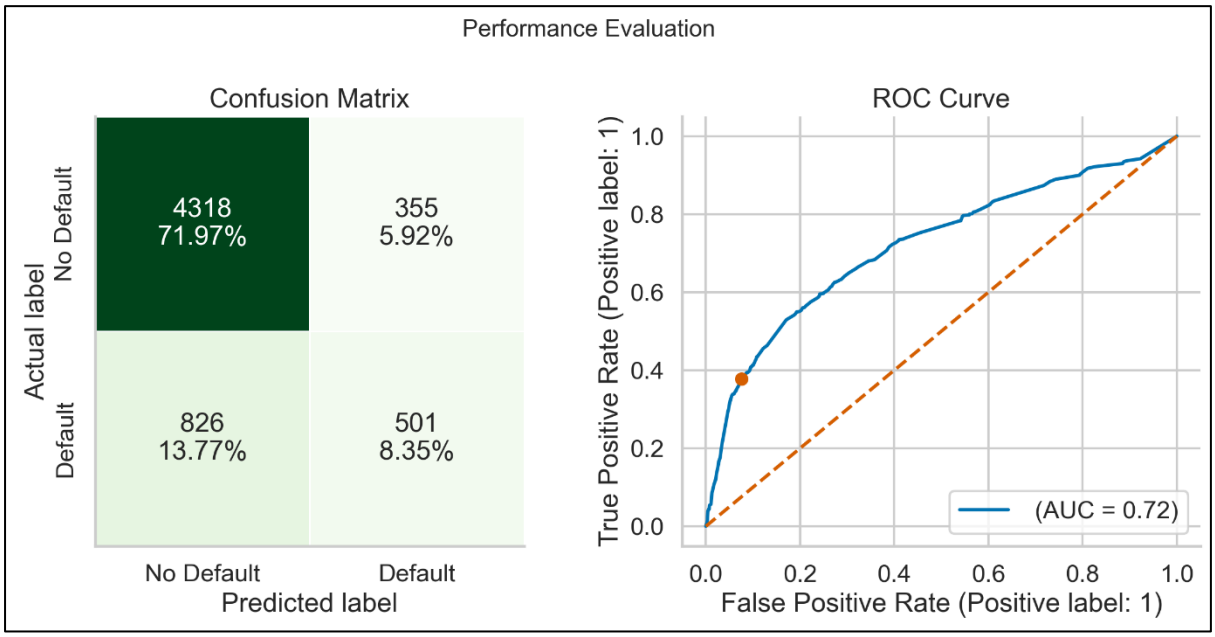

Pipeline
preprocessor: ColumnTransformer
numerical
categorical
SimpleImputer
SimpleImputer(strategy='median')
SimpleImputer
SimpleImputer(strategy='most_frequent')
OneHotEncoder
DecisionTreeClassifier
DecisionTreeClassifier(random_state=42)


Performance Evaluation
Confusion Matrix
3803
63.38%
870
14.50%
790
13.17%
537
8.95%
Actual label
No Default
Default
No Default
Default
Predicted label
ROC Curve
True Positive Rate (Positive label: 1)
False Positive Rate (Positive label: 1)
(AUC = 0.61)
0.0
0.2
0.4
0.6
0.8
1.0


Performance Evaluation
Confusion Matrix
3781
63.02%
892
14.87%
786
13.10%
541
9.02%
Actual label
No Default
Default
No Default
Default
Predicted label
ROC Curve
True Positive Rate (Positive label: 1)
False Positive Rate (Positive label: 1)
(AUC = 0.61)
0.0
0.2
0.4
0.6
0.8
1.0

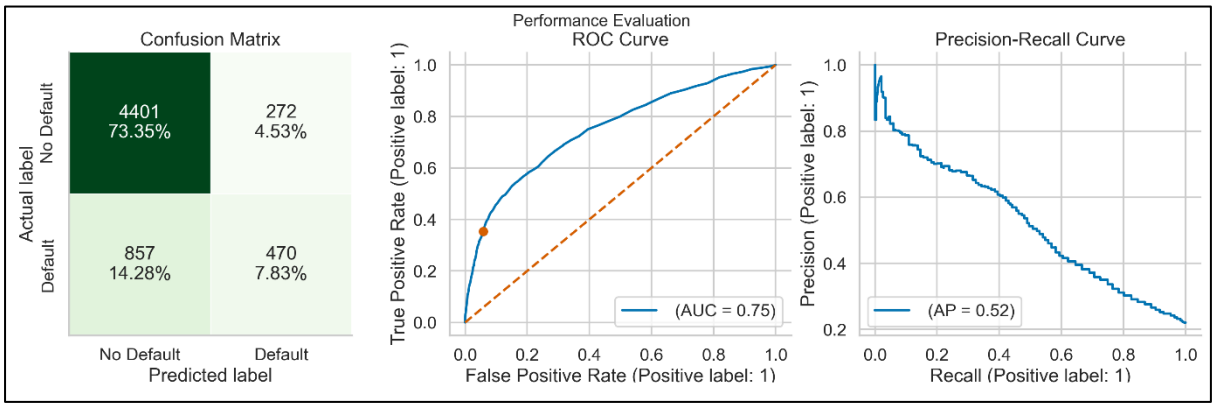


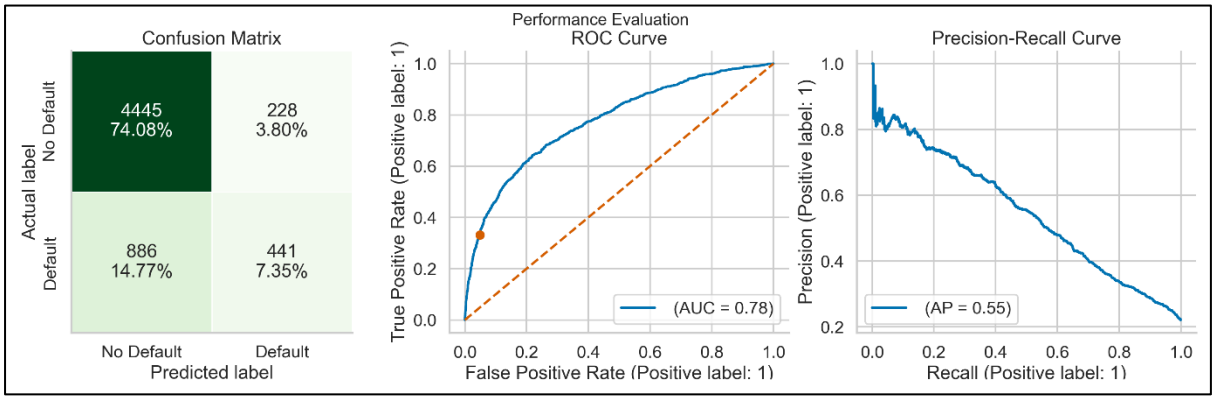
	fit_time	score_time	test_accuracy	test_precision	test_recall	test_roc_auc
0	0.800832	0.218017	0.723333	0.385604	0.424128	0.616333
1	0.746714	0.249949	0.729583	0.395575	0.420904	0.618938
2	0.759059	0.214318	0.713750	0.369783	0.417137	0.607940
3	0.764652	0.249994	0.723125	0.386383	0.427495	0.618066
4	0.717186	0.253843	0.720000	0.376748	0.405838	0.607129

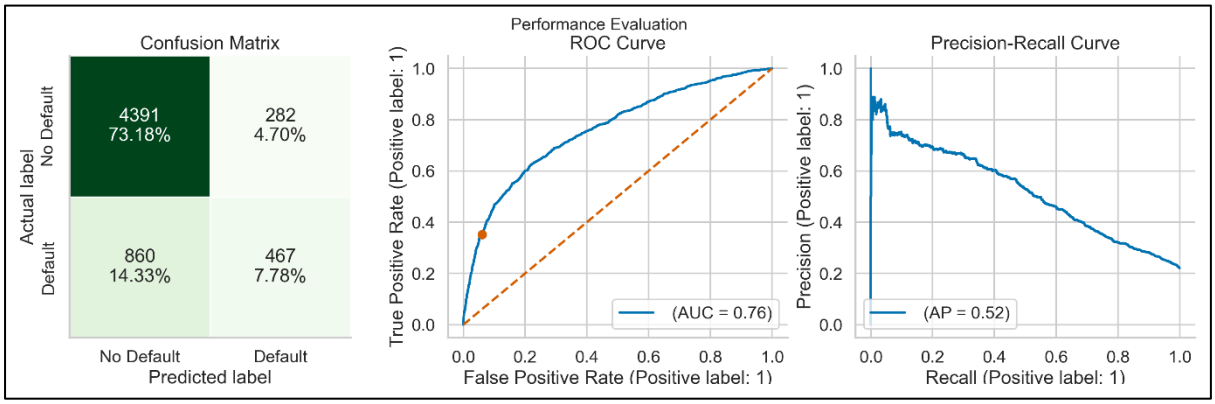


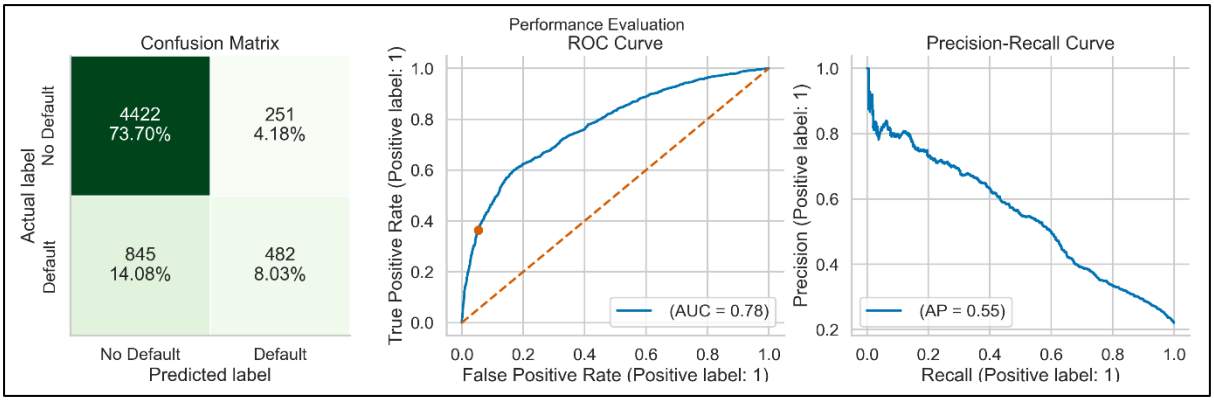
	classifier__criterion	classifier__max_depth	classifier__min_samples_leaf	preprocessor__numerical__outliers__n_std
grid_search	gini	10	7	4
randomized_search	gini	10	7	3
halving_search	gini	10	6	4

Chapter 14: Advanced Concepts for Machine Learning Projects

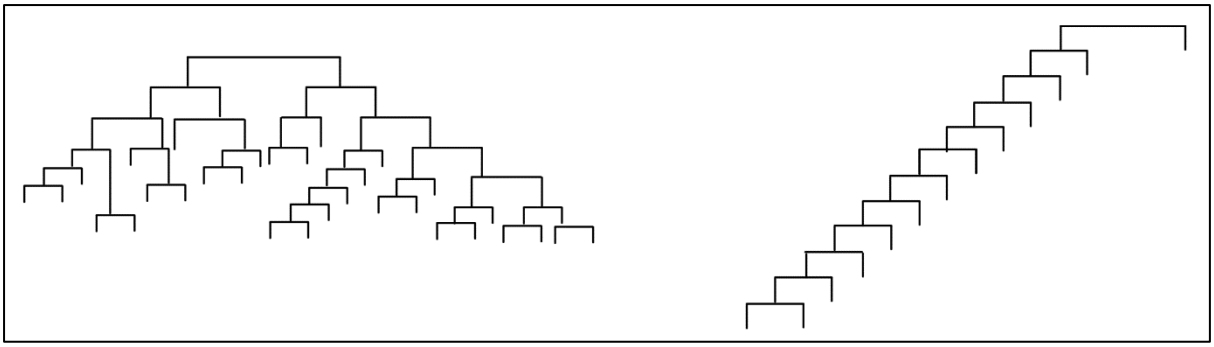








	accuracy	precision	recall	specificity	f1_score	cohens_kappa	matthews_corr_coeff	roc_auc	pr_auc	average_precision
decision_tree_baseline	0.7233	0.3817	0.4047	0.8138	0.3928	0.2139	0.2140	0.6095	0.4589	0.2862
random_forest	0.8118	0.6334	0.3542	0.9418	0.4543	0.3514	0.3731	0.7518	0.5247	0.5207
random_forest_rs	0.8090	0.6116	0.3738	0.9326	0.4640	0.3559	0.3719	0.7352	0.4863	0.4822
gradient_boosted_trees	0.8143	0.6592	0.3323	0.9512	0.4419	0.3447	0.3739	0.7755	0.5475	0.5478
gradient_boosted_trees_rs	0.8060	0.6049	0.3542	0.9343	0.4468	0.3388	0.3566	0.7547	0.5147	0.5152
xgboost	0.8097	0.6235	0.3519	0.9397	0.4499	0.3454	0.3661	0.7613	0.5202	0.5210
xgboost_rs	0.8005	0.5754	0.3738	0.9217	0.4532	0.3378	0.3496	0.7418	0.5015	0.5019
light_gbm	0.8173	0.6576	0.3632	0.9463	0.4680	0.3686	0.3923	0.7754	0.5474	0.5478
light_gbm_rs	0.8017	0.5832	0.3617	0.9266	0.4465	0.3337	0.3478	0.7538	0.5051	0.5057



original data

category	target
a	1
a	0
b	1
b	1
b	0

posterior probabilities

category	target mean
a	0.5
b	0.67

encoded data

category	target encoding	target
a	0.5	1
a	0.5	0
b	0.67	1
b	0.67	1
b	0.67	0

original data

category	target
a	1
a	0
b	1
b	1
b	0

encoded data

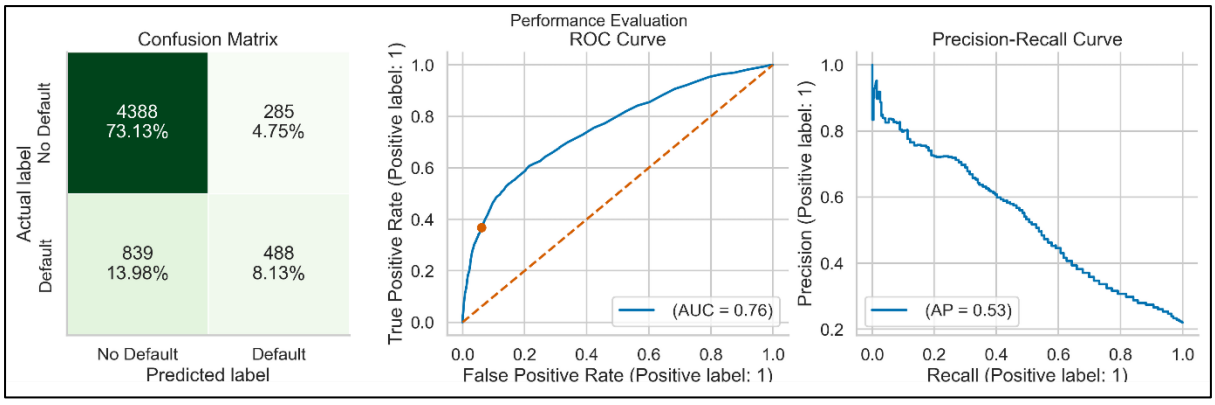
category	leave one out encoding	target
a	0	1
a	1	0
b	0.5	1
b	0.5	1
b	1	0

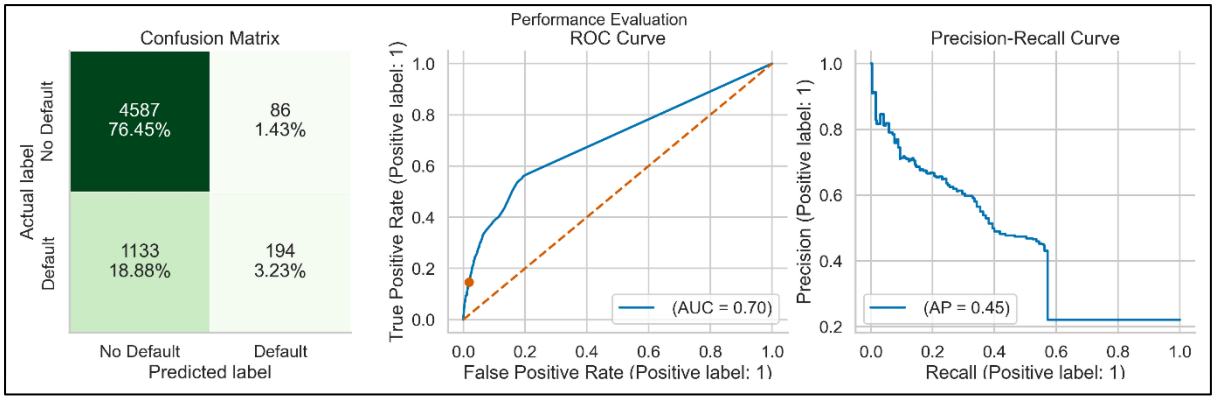
original data

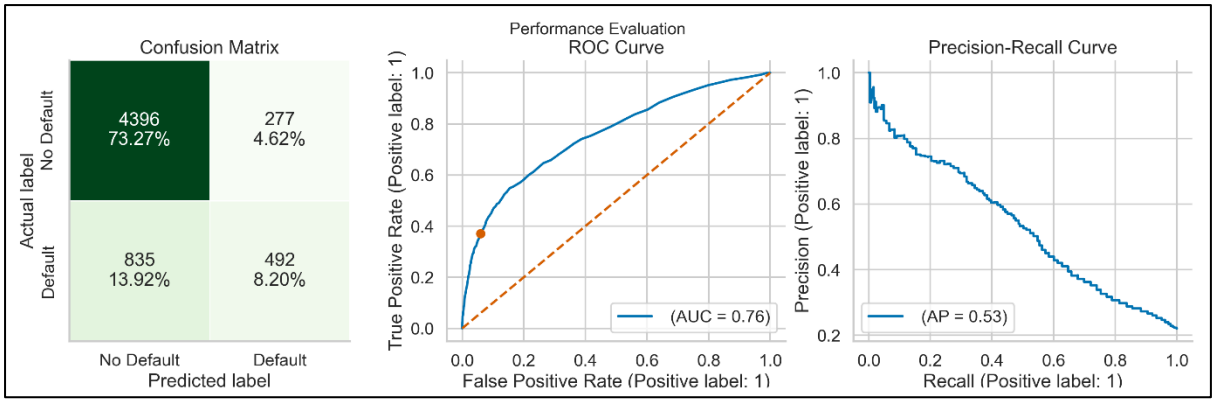
category	target
a	1
a	0
b	1
b	1
b	0

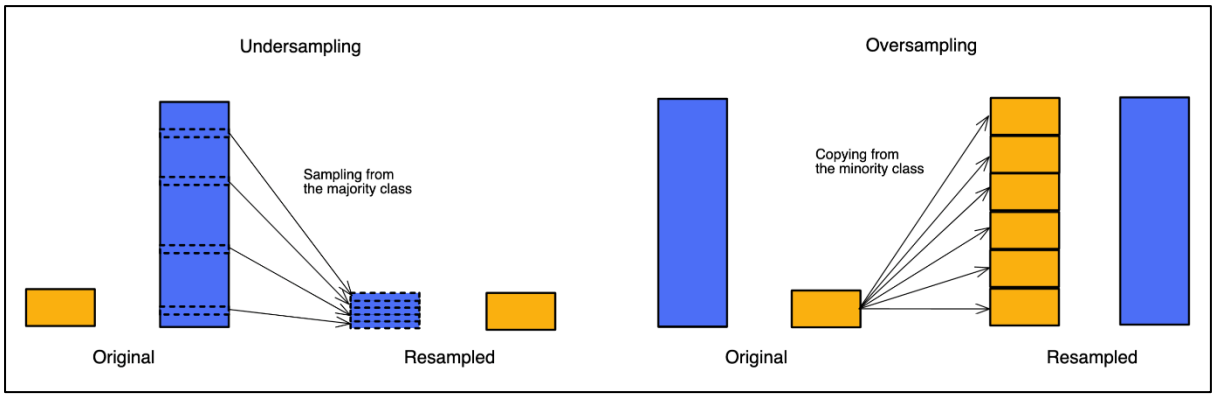
Weight of Evidence

category	# total	# good	# bad	% good	% bad	WoE
a	2	1	1	0,5000	0,3333	0,4055
b	3	1	2	0,5000	0,6667	-0,2877
total	5	2	3			

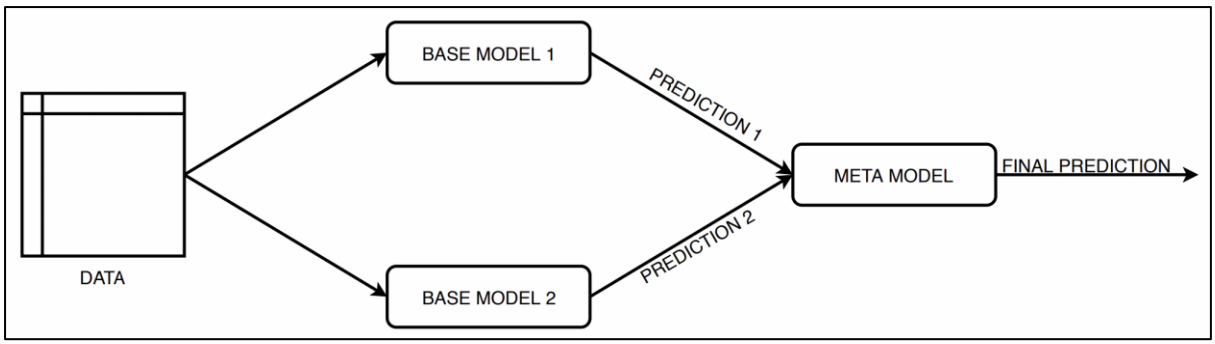


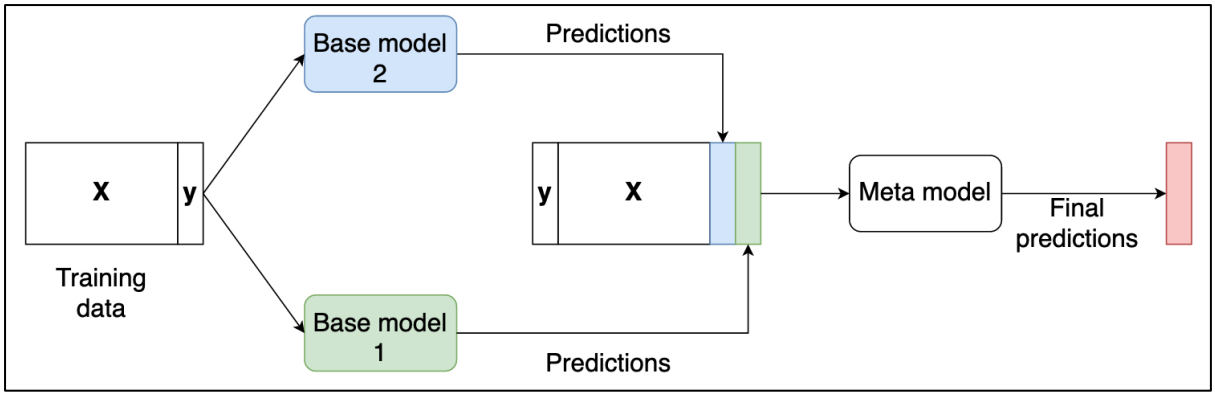




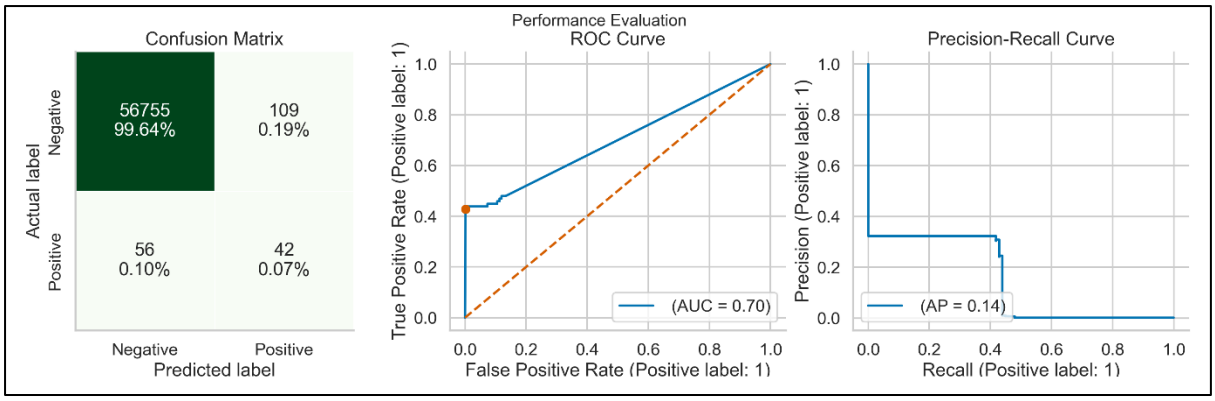


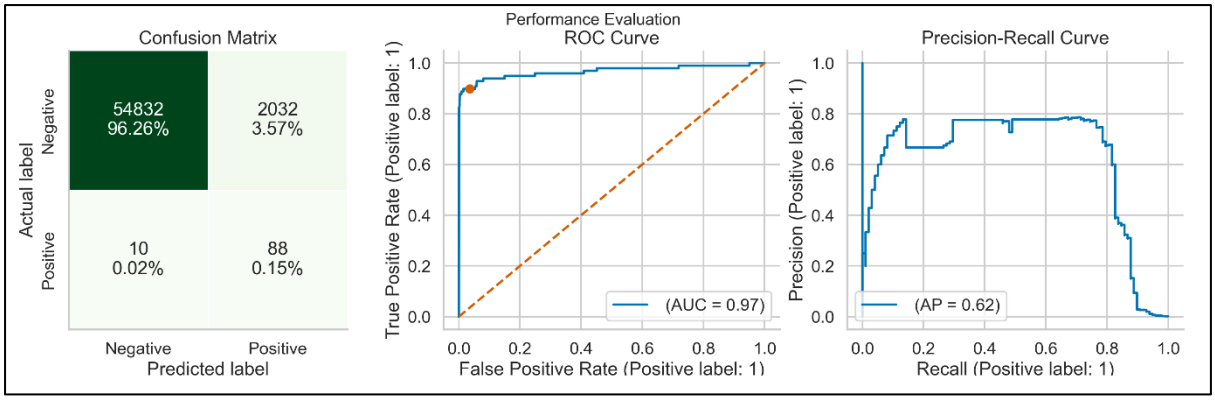
	accuracy	precision	recall	specificity	f1_score	cohens_kappa	matthews_corr_coeff	roc_auc	pr_auc	average_precision
random_forest	0.9996	0.9419	0.8265	0.9999	0.8804	0.8802	0.8821	0.9528	0.8761	0.8715
undersampled rf	0.9672	0.0457	0.9082	0.9673	0.0870	0.0840	0.1996	0.9780	0.7493	0.6894
oversampled_rf	0.9996	0.9506	0.7857	0.9999	0.8603	0.8601	0.8640	0.9526	0.8694	0.8650
smote	0.9995	0.8817	0.8367	0.9998	0.8586	0.8584	0.8587	0.9630	0.8791	0.8779
adasyn	0.9994	0.8511	0.8163	0.9998	0.8333	0.8331	0.8332	0.9731	0.8661	0.8635
random_forest_cw	0.9995	0.9610	0.7551	0.9999	0.8457	0.8455	0.8517	0.9580	0.8572	0.8483
balanced_random_forest	0.9738	0.0567	0.9082	0.9740	0.1067	0.1038	0.2233	0.9761	0.7800	0.7253
balanced_random_forest_cw	0.9864	0.1025	0.8878	0.9866	0.1837	0.1812	0.2990	0.9780	0.7240	0.6759

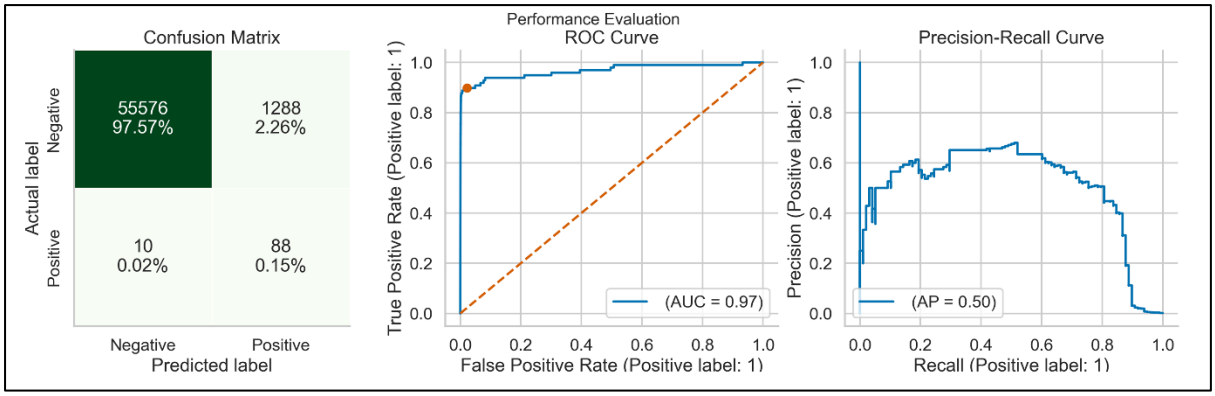


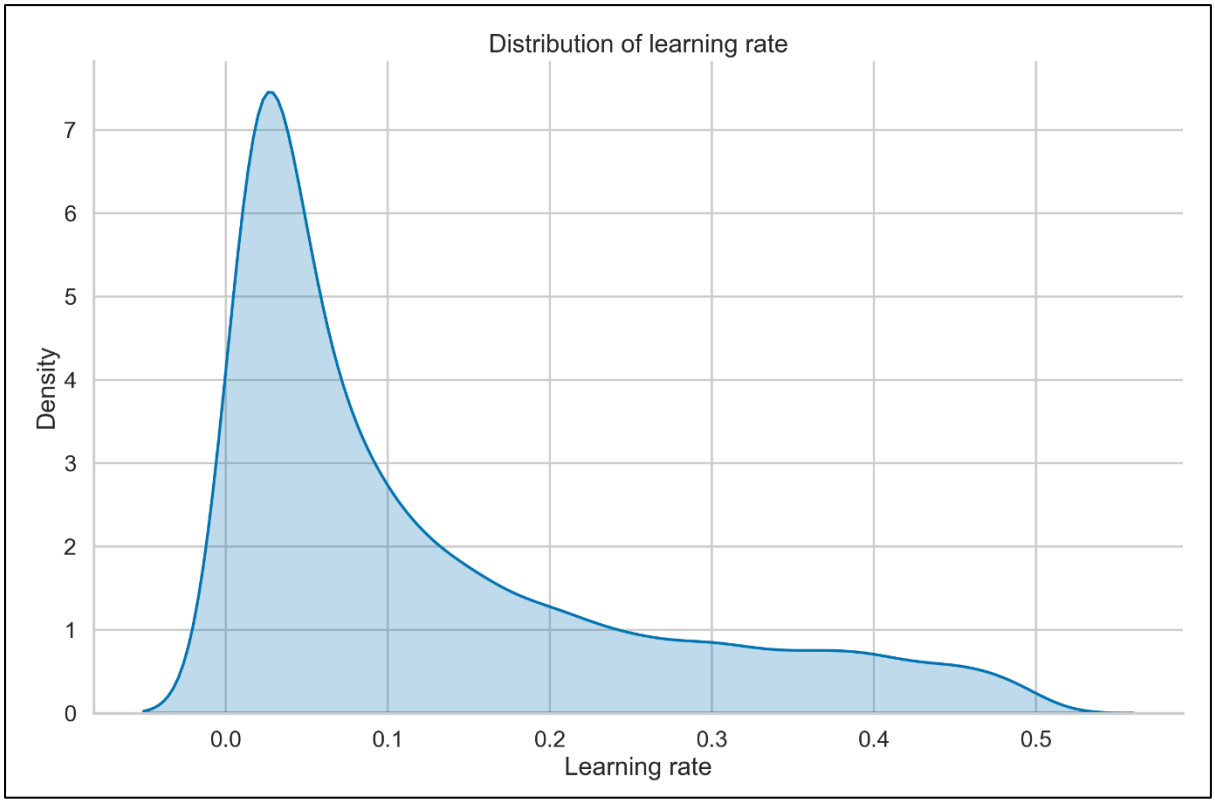


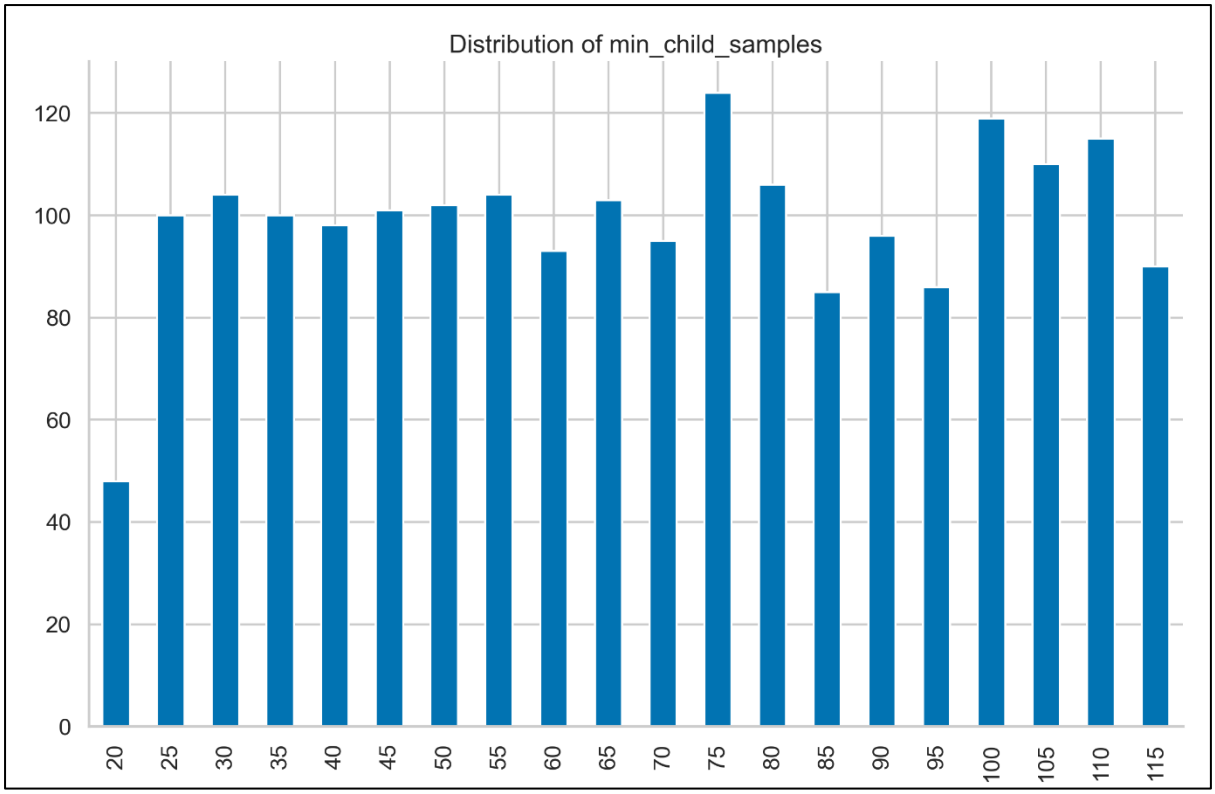
	dec_tree_pred	log_reg_pred	svc_pred	naive_bayes_pred	V1	V2	V3
0	0.0	0.000067	-1.042724	3.814708e-18	0.862468	-0.582668	-0.800214
1	0.0	0.000197	-1.011043	4.686999e-17	0.902013	-0.081009	-1.688308
2	0.0	0.000105	-1.064856	1.901214e-08	-0.452072	0.383882	0.277401
3	0.0	0.000018	-1.064256	2.215227e-17	1.014098	-1.115745	-0.483481
4	0.0	0.000041	-1.061369	3.443033e-17	-0.209097	-0.767259	-0.033341



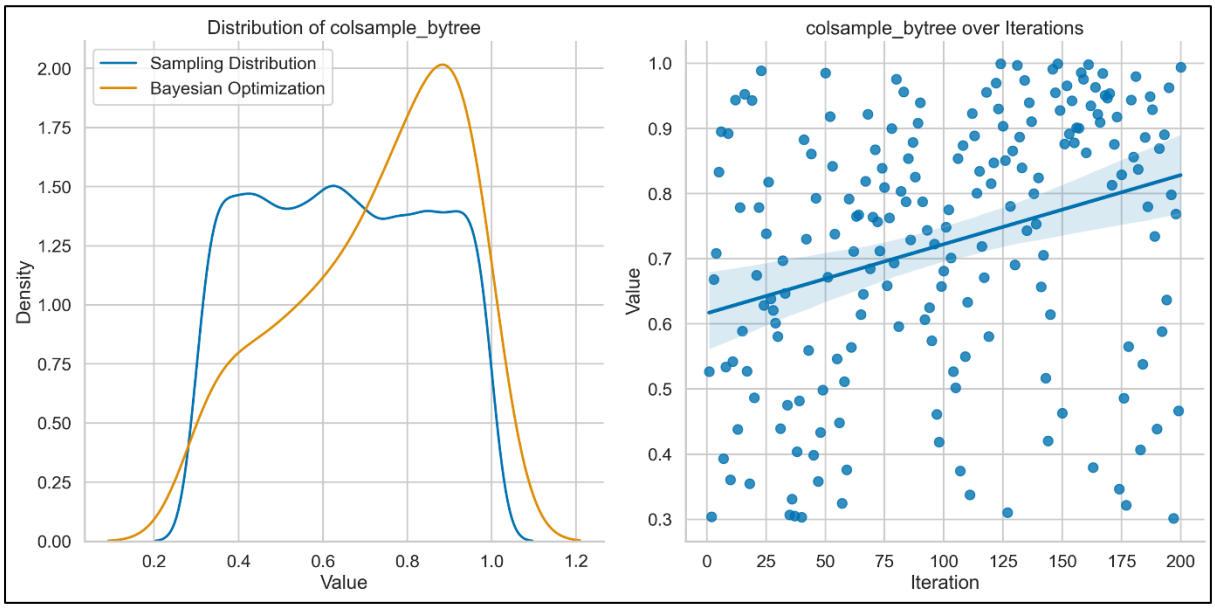


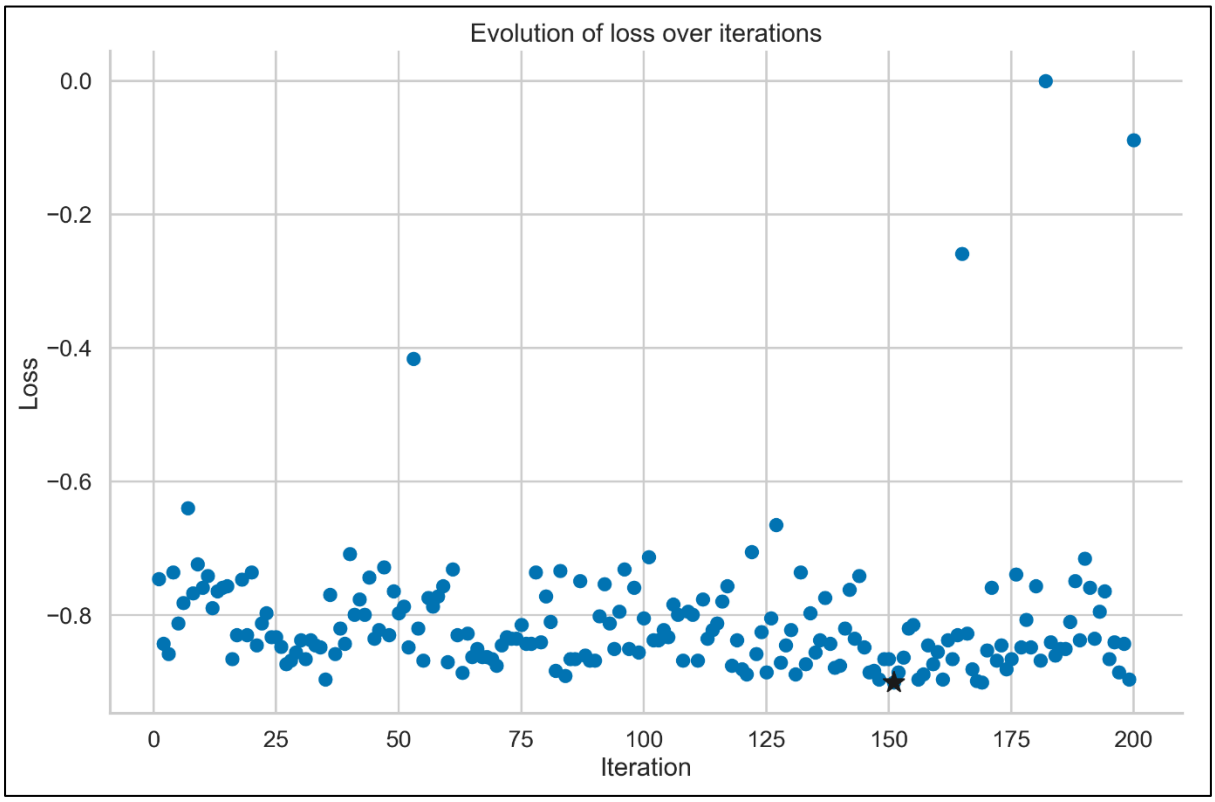

Confusion Matrix
55576
97.57%
1288
2.26%
10
0.02%
88
0.15%
Actual label
Negative
Positive
Negative
Positive
Predicted label
Performance Evaluation
ROC Curve
True Positive Rate (Positive label: 1)
False Positive Rate (Positive label: 1)
(AUC = 0.97)
Precision-Recall Curve
Precision (Positive label: 1)
Recall (Positive label: 1)
(AP = 0.50)

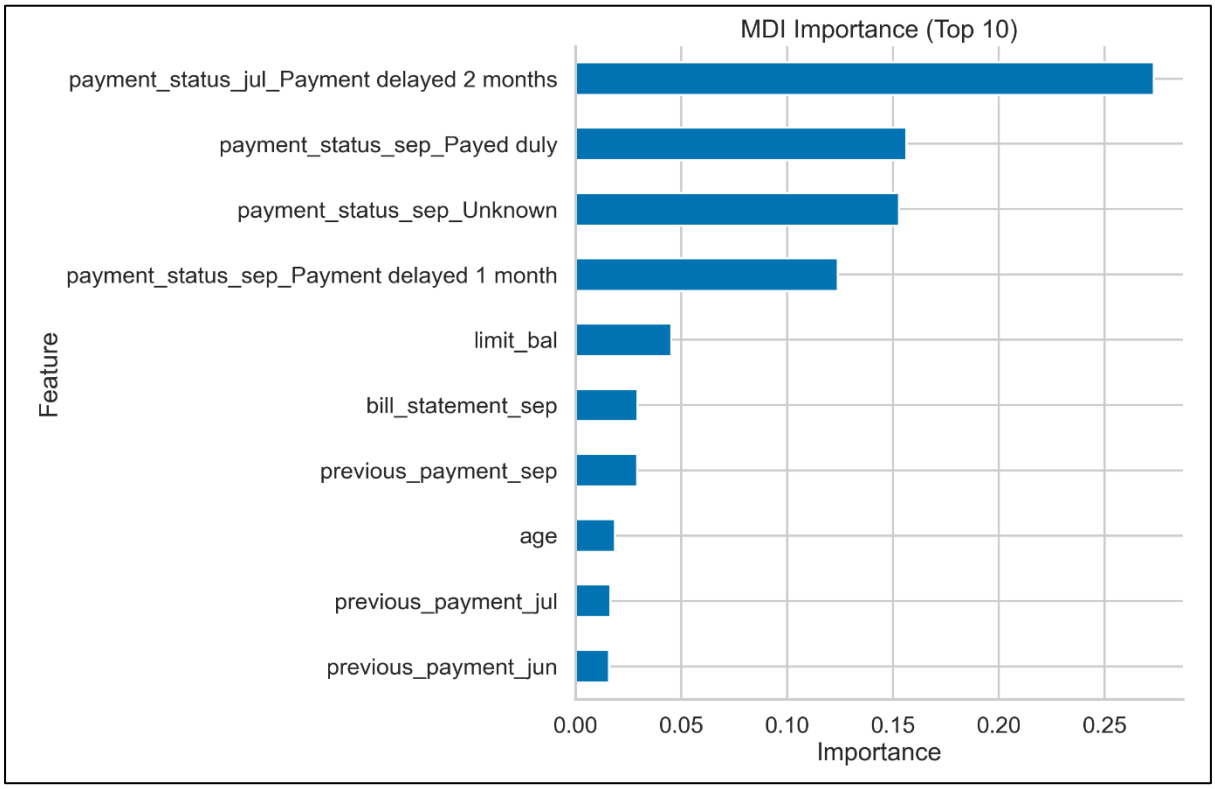

Distribution of learning rate
Density
Learning rate

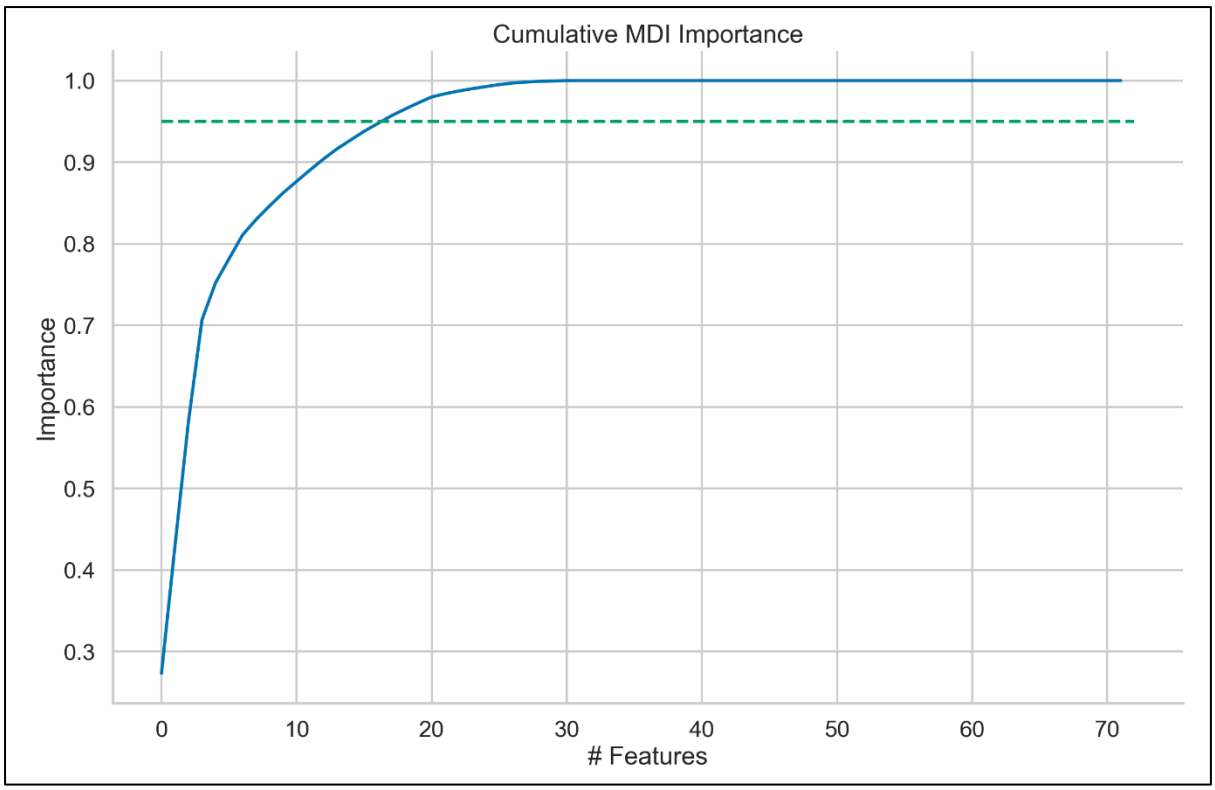


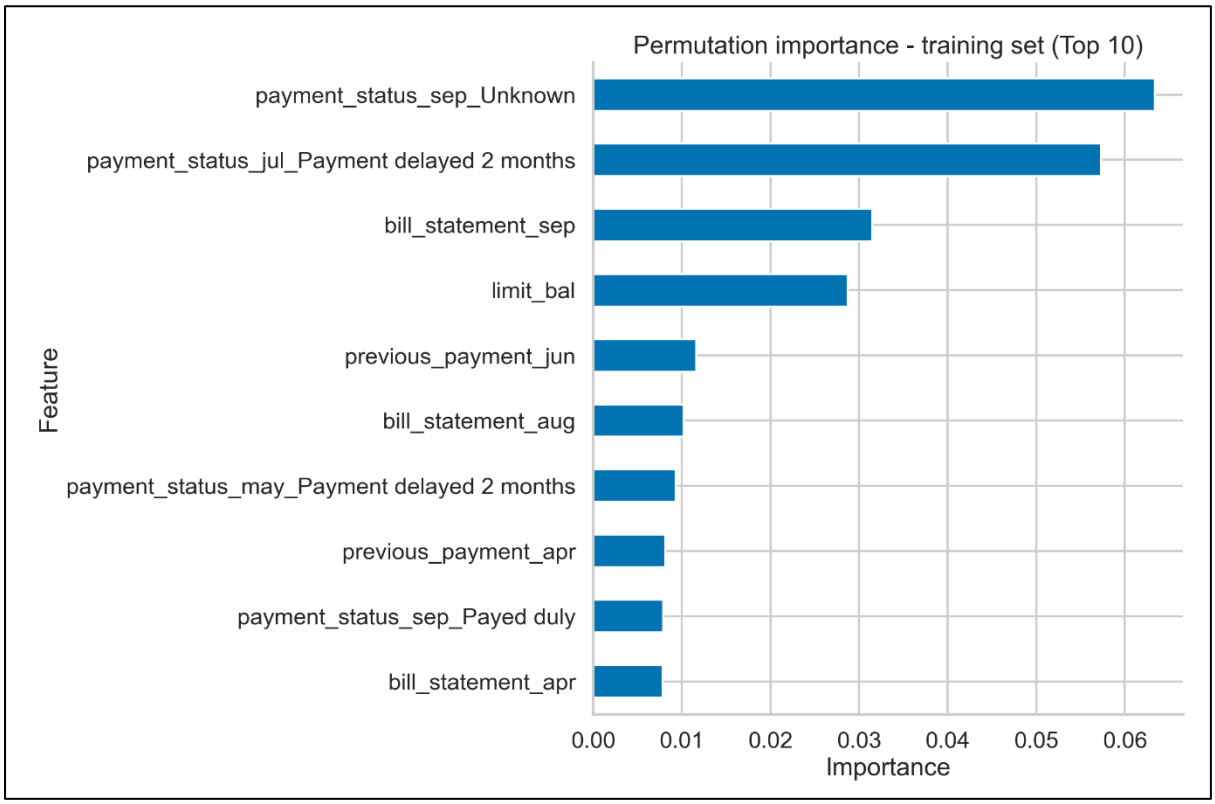
	loss	status	boosting_type	colsample_bytree	is_unbalance	learning_rate	max_depth	min_child_samples	n_estimators	num_leaves	reg_alpha	reg_lambda	iteration
150	-0.901071	ok	dart	0.876430	True	0.019246	19	160	50	16	0.390232	0.483493	151
168	-0.900941	ok	dart	0.946974	True	0.020825	18	235	50	8	0.366738	0.320576	169
167	-0.898475	ok	dart	0.951135	True	0.024895	18	135	50	8	0.362945	0.418759	168
34	-0.896040	ok	goss	0.307030	True	0.086375	3	415	50	82	0.236233	0.408269	35
155	-0.896008	ok	dart	0.901467	True	0.022619	17	135	50	5	0.320720	0.482145	156
...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	-0.639695	ok	gbdt	0.393251	False	0.018363	19	265	50	13	0.996987	0.699079	7
52	-0.416326	ok	dart	0.841847	False	0.012526	6	320	100	73	0.072400	0.769000	53
164	-0.258845	ok	dart	0.921732	False	0.014171	18	110	50	25	0.049658	0.293709	165
199	-0.088608	ok	dart	0.993957	False	0.016164	15	210	50	54	0.242146	0.560007	200
181	-0.000000	ok	dart	0.837517	False	0.012799	15	160	50	23	0.428376	0.251945	182

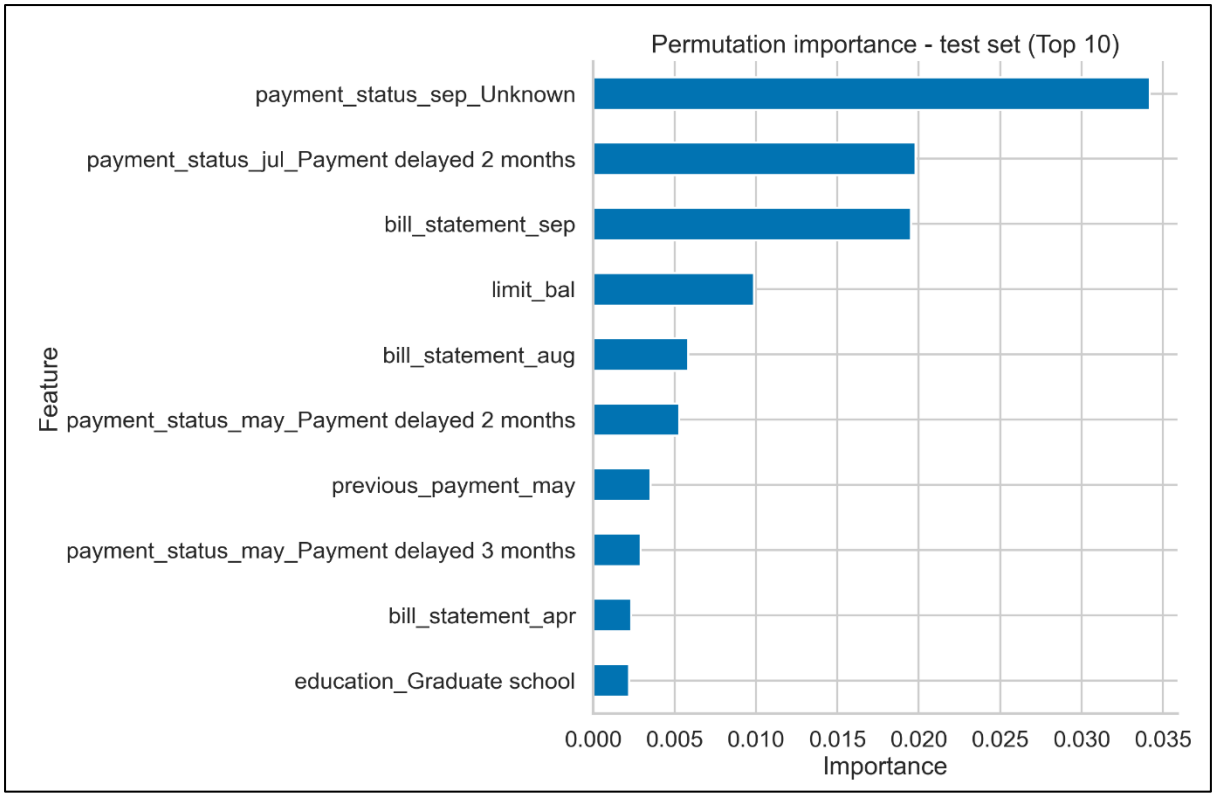


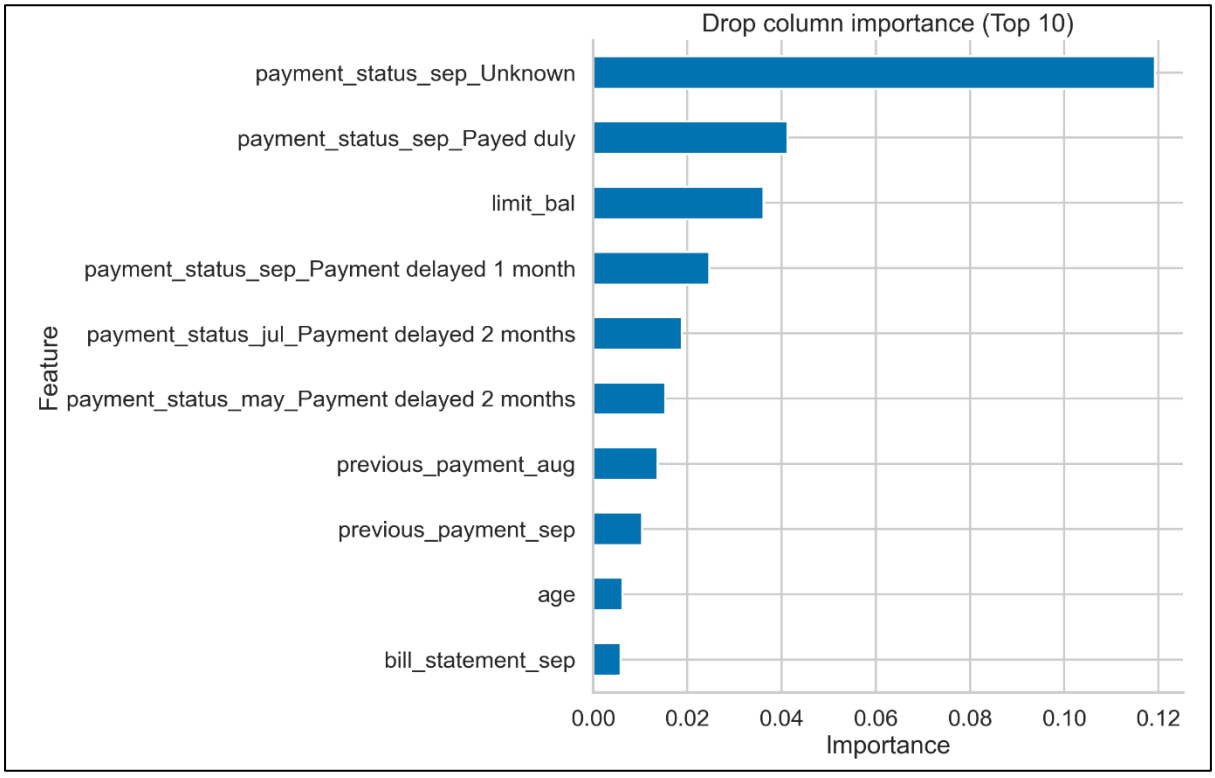

Evolution of loss over iterations
Loss
0.0
−0.2
−0.4
−0.6
−0.8
0
25
50
75
100
125
150
175
200
Iteration

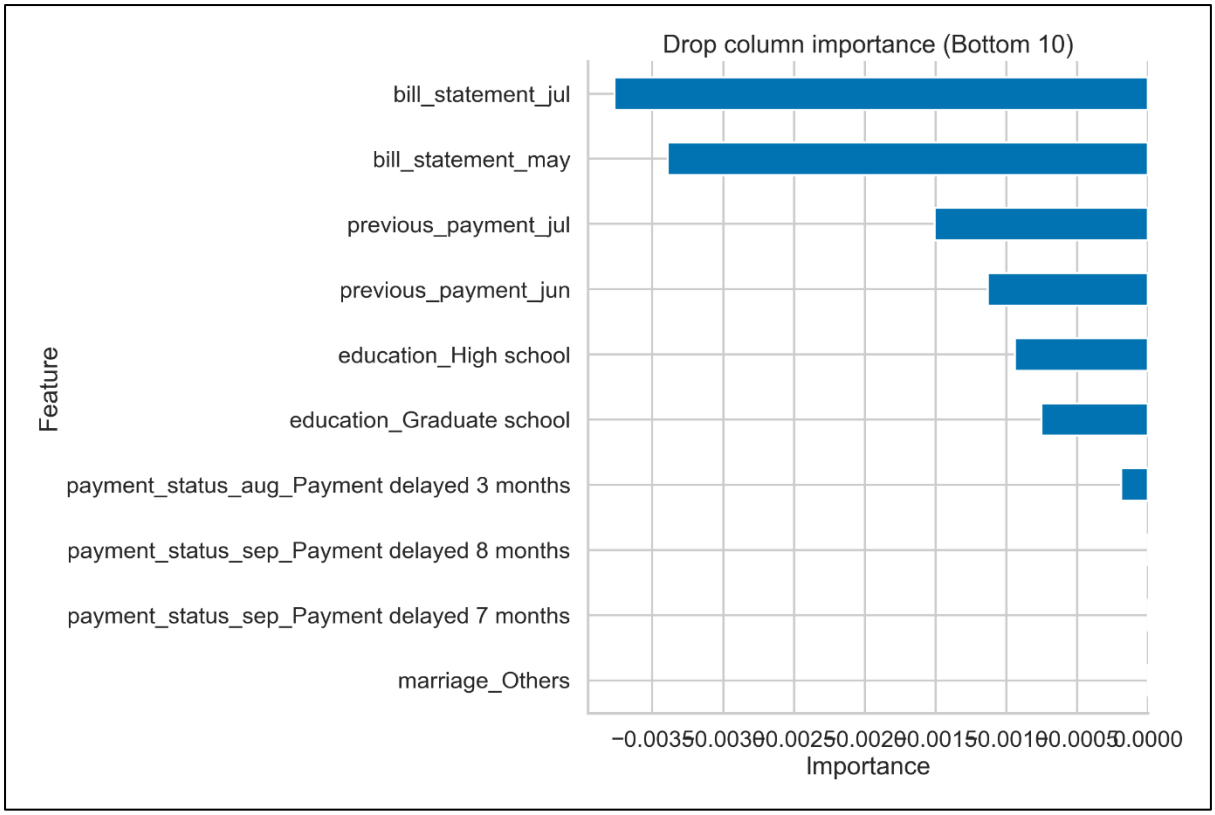

MDI Importance (Top 10)
Feature
payment_status_jul_Payment delayed 2 months
payment_status_sep_Payed duly
payment_status_sep_Unknown
payment_status_sep_Payment delayed 1 month
limit_bal
bill_statement_sep
previous_payment_sep
age
previous_payment_jul
previous_payment_jun
0.00
0.05
0.10
0.15
0.20
0.25
Importance

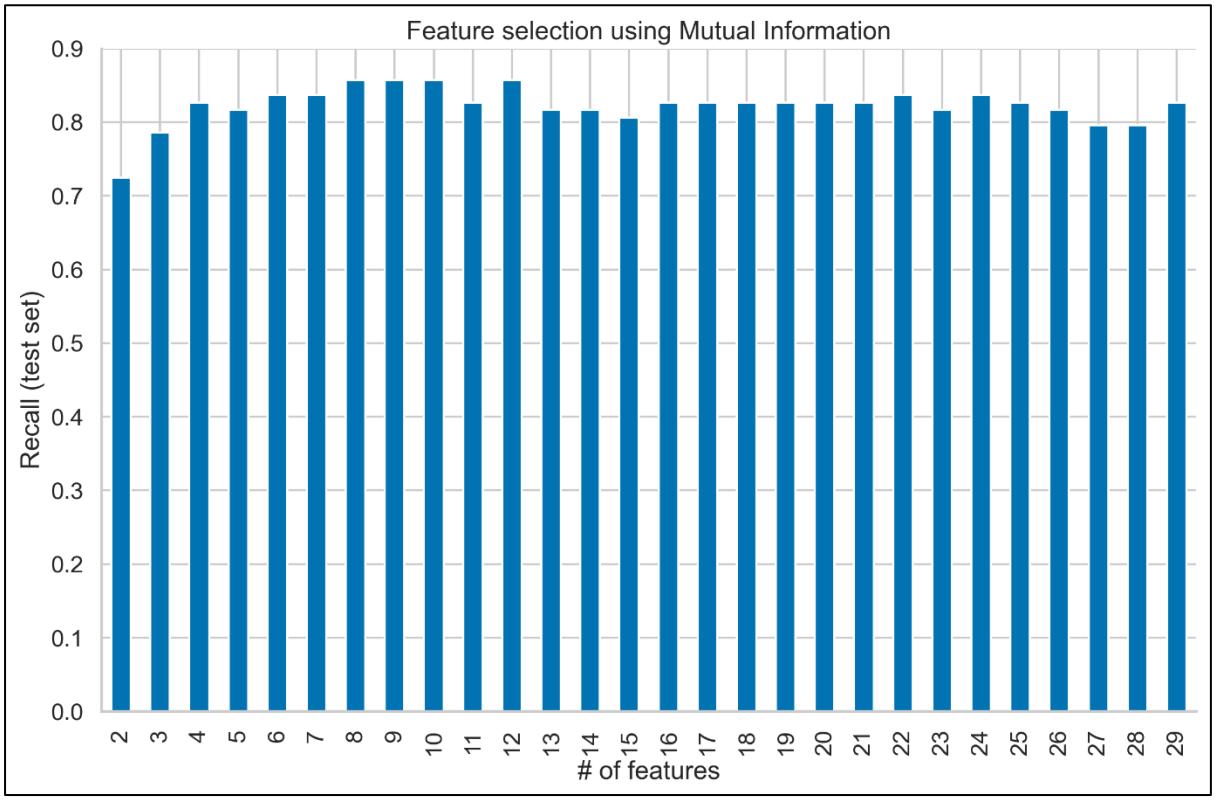

Cumulative MDI Importance
Importance
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50
60
70
Features

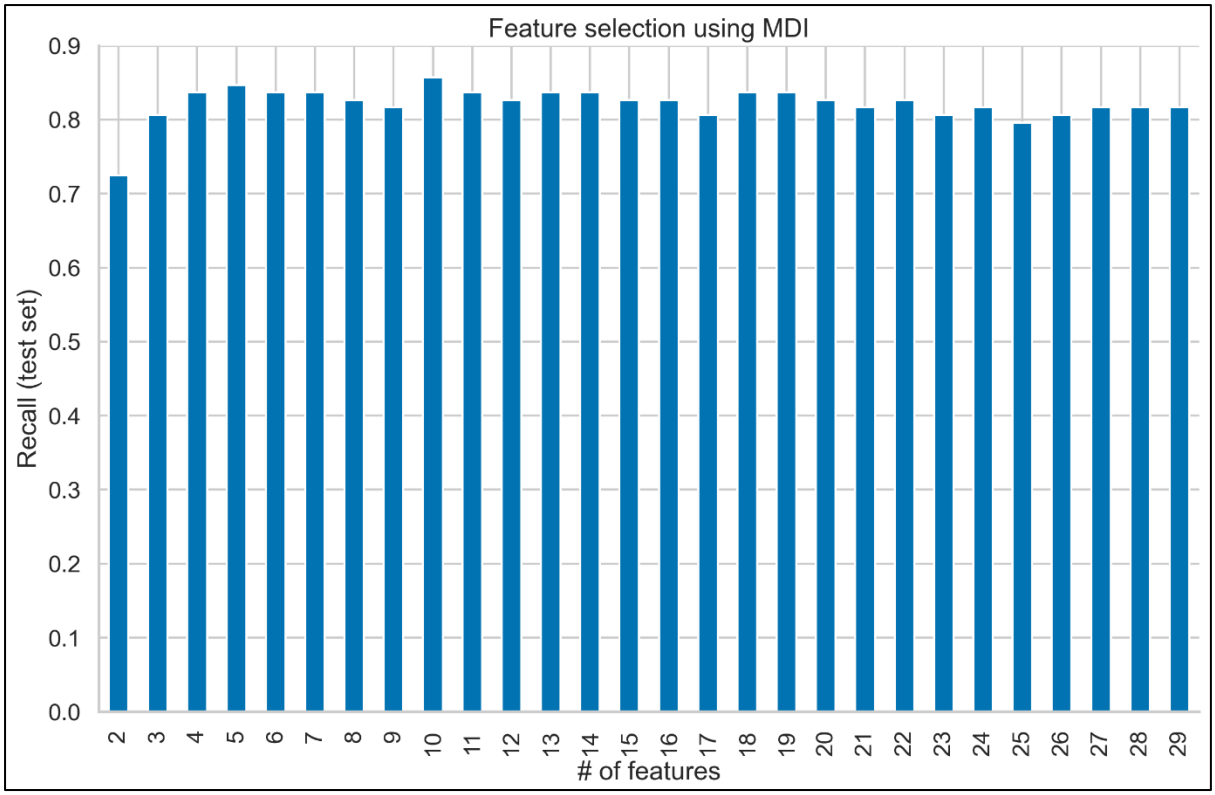

Permutation importance - training set (Top 10)
Feature
payment_status_sep_Unknown
payment_status_jul_Payment delayed 2 months
bill_statement_sep
limit_bal
previous_payment_jun
bill_statement_aug
payment_status_may_Payment delayed 2 months
previous_payment_apr
payment_status_sep_Payed duly
bill_statement_apr
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Importance

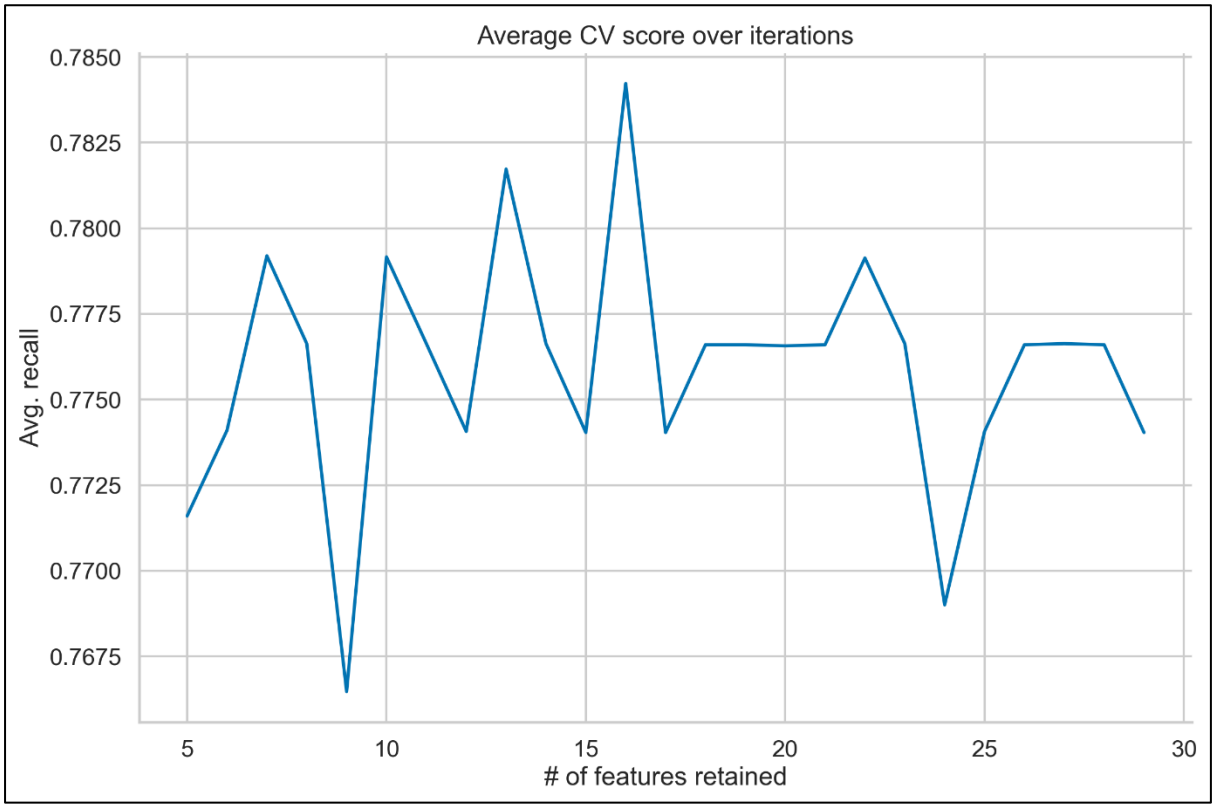

Permutation importance - test set (Top 10)
payment_status_sep_Unknown
payment_status_jul_Payment delayed 2 months
bill_statement_sep
limit_bal
bill_statement_aug
payment_status_may_Payment delayed 2 months
previous_payment_may
payment_status_may_Payment delayed 3 months
bill_statement_apr
education_Graduate school
Feature
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Importance

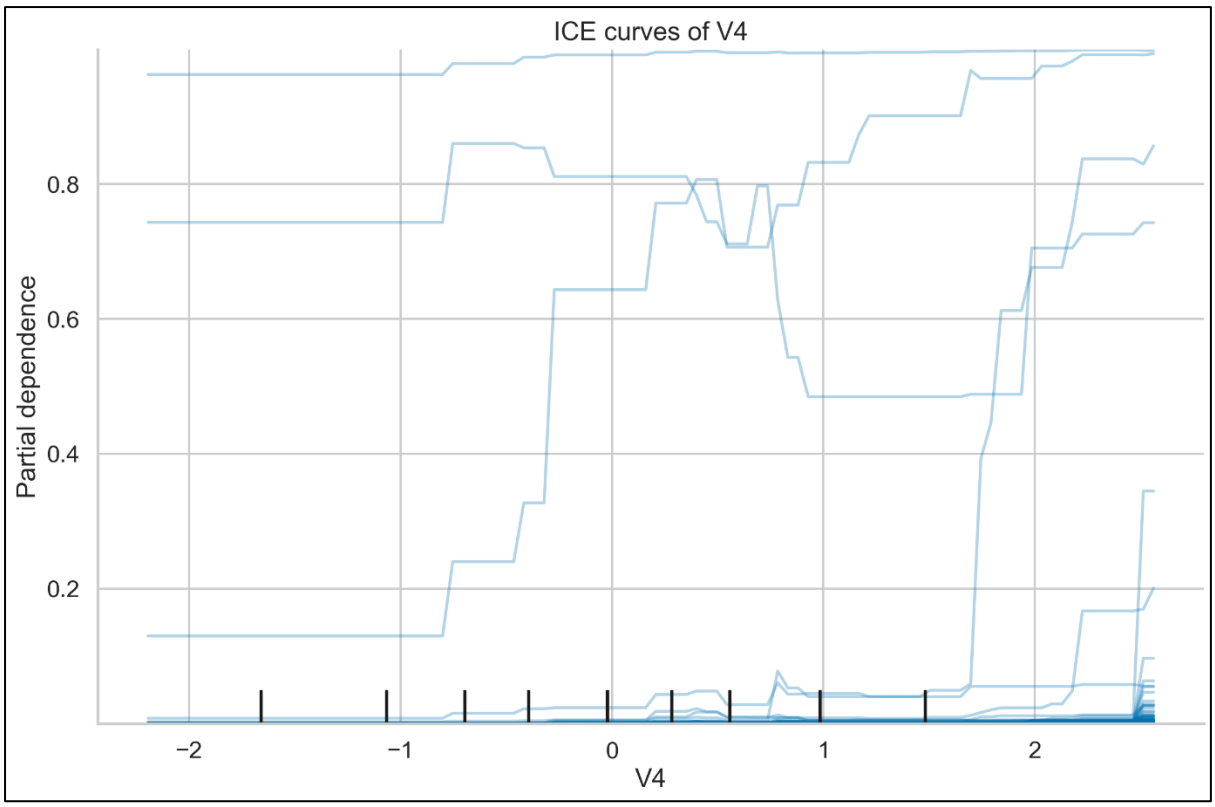

Drop column importance (Top 10)
payment_status_sep_Unknown
payment_status_sep_Payed duly
limit_bal
payment_status_sep_Payment delayed 1 month
payment_status_jul_Payment delayed 2 months
payment_status_may_Payment delayed 2 months
previous_payment_aug
previous_payment_sep
age
bill_statement_sep
Feature
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Importance

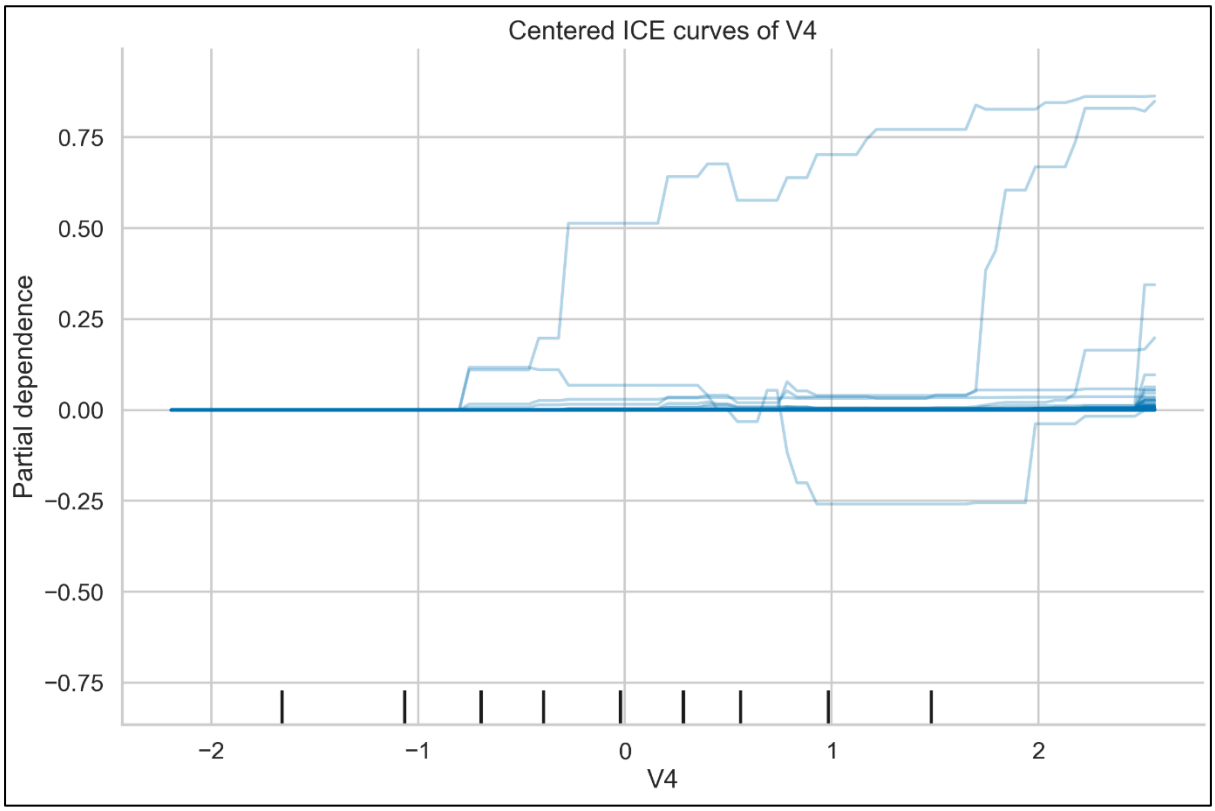

Drop column importance (Bottom 10)
bill_statement_jul
bill_statement_may
previous_payment_jul
previous_payment_jun
education_High school
education_Graduate school
payment_status_aug_Payment delayed 3 months
payment_status_sep_Payment delayed 8 months
payment_status_sep_Payment delayed 7 months
marriage_Others
Feature
−0.0035
−0.0030
−0.0025
−0.0020
−0.0015
−0.0010
−0.0005
0.0000
Importance

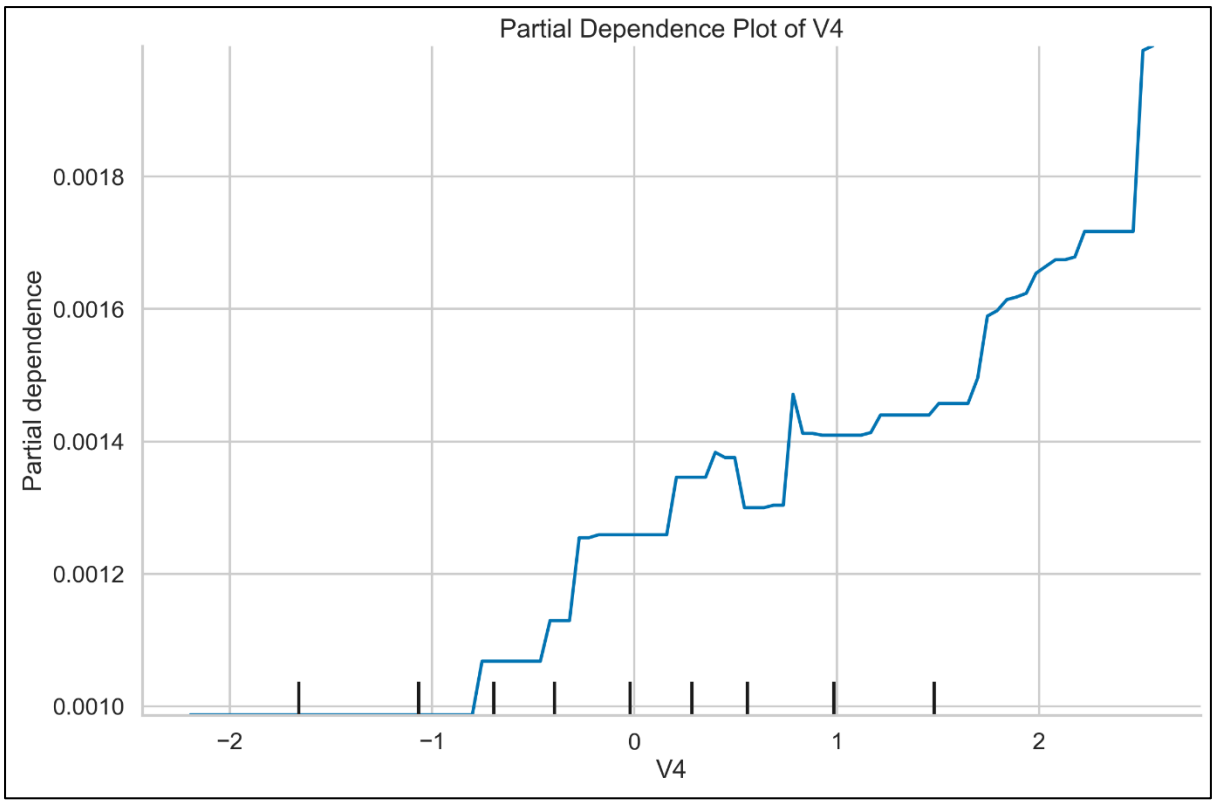

Feature selection using Mutual Information
Recall (test set)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
# of features

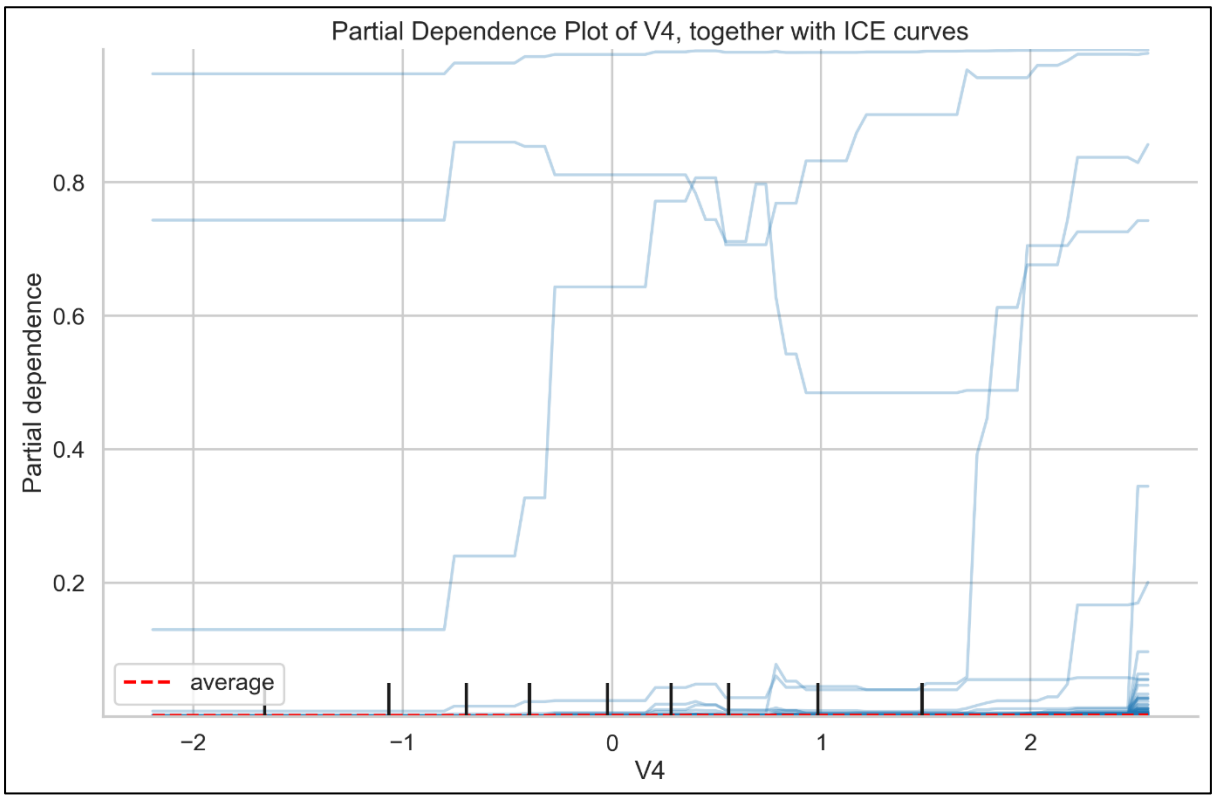

Feature selection using MDI
Recall (test set)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
# of features

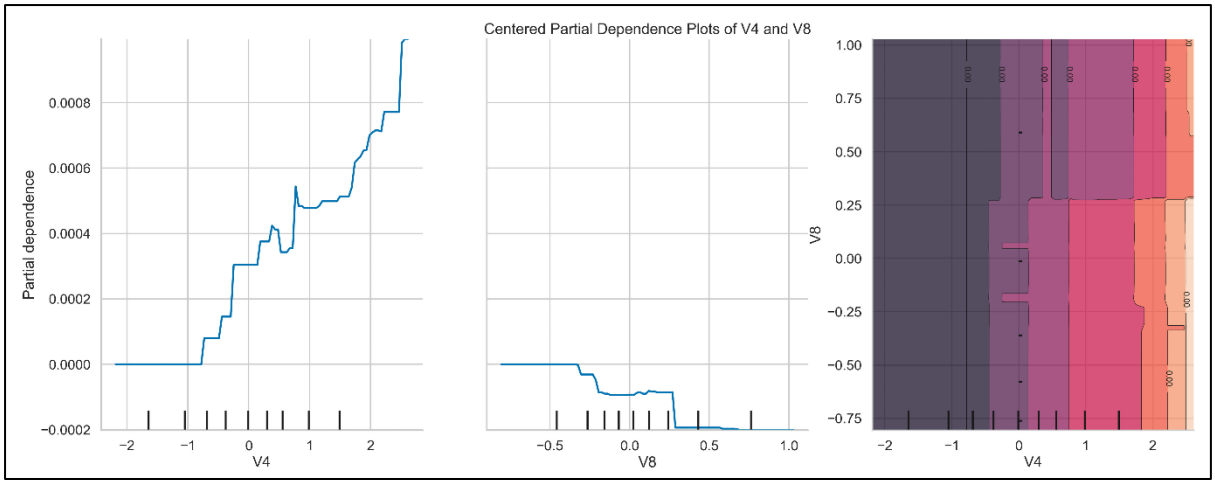

Average CV score over iterations
Avg. recall
0.7675
0.7700
0.7725
0.7750
0.7775
0.7800
0.7825
0.7850
5
10
15
20
25
30
# of features retained

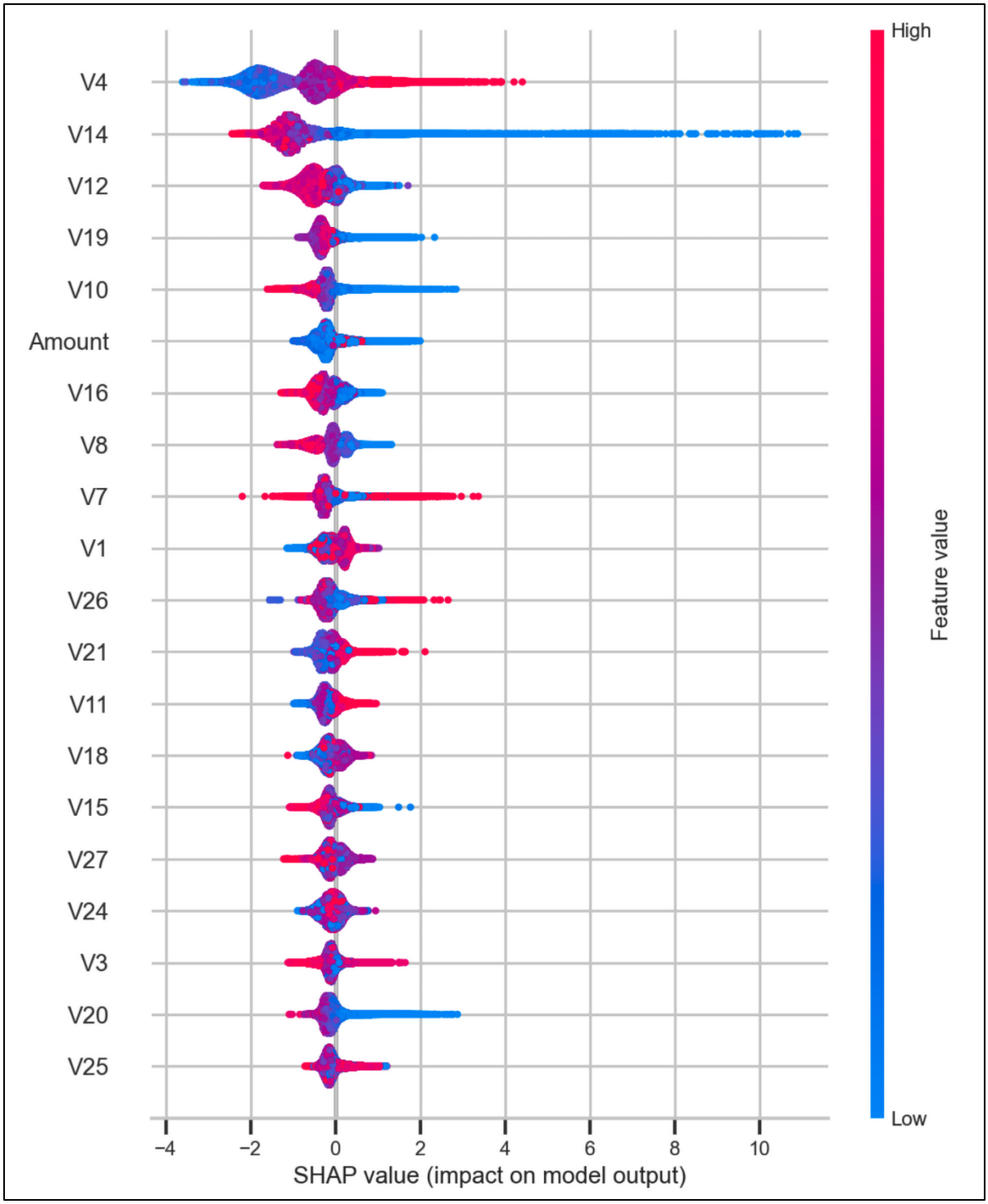

ICE curves of V4
Partial dependence
0.8
0.6
0.4
0.2
−2
−1
0
1
2
V4

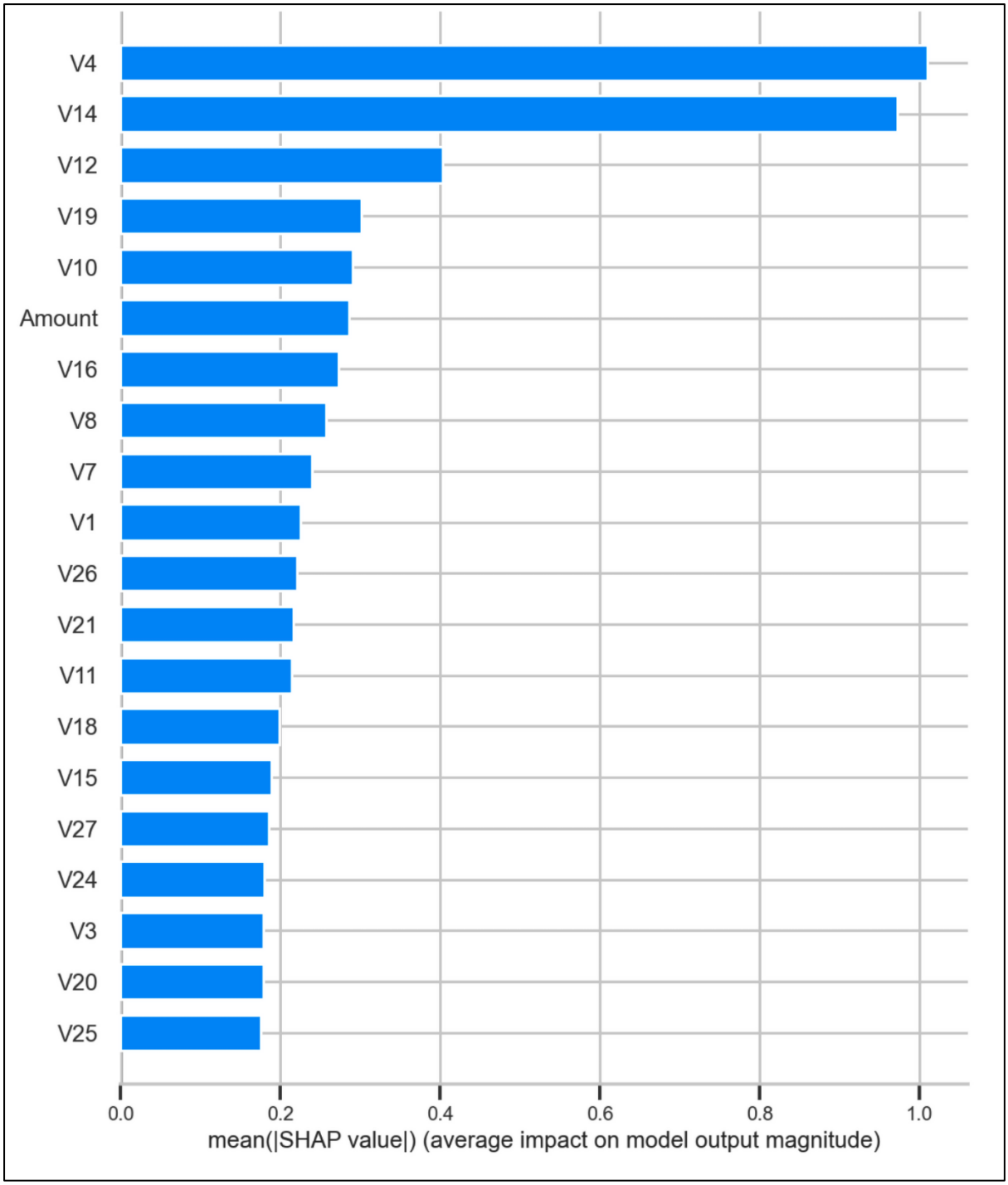

Centered ICE curves of V4
Partial dependence
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−2
−1
0
1
2
V4

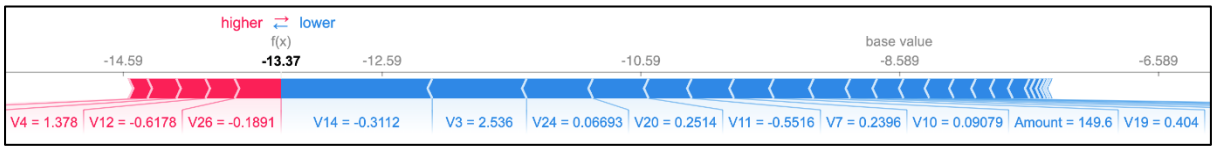

Partial Dependence Plot of V4
Partial dependence
0.0018
0.0016
0.0014
0.0012
0.0010
−2
−1
0
1
2
V4

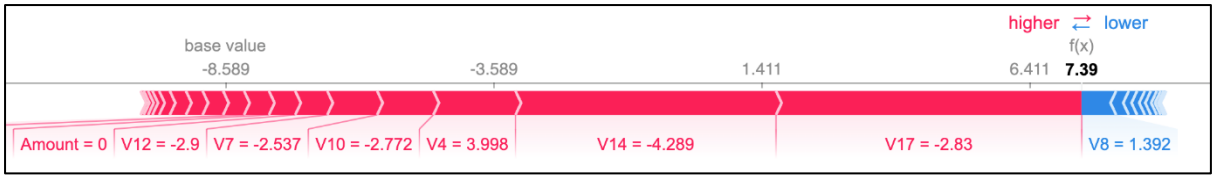

Partial Dependence Plot of V4, together with ICE curves
Partial dependence
0.8
0.6
0.4
0.2
average
−2
−1
0
1
2
V4

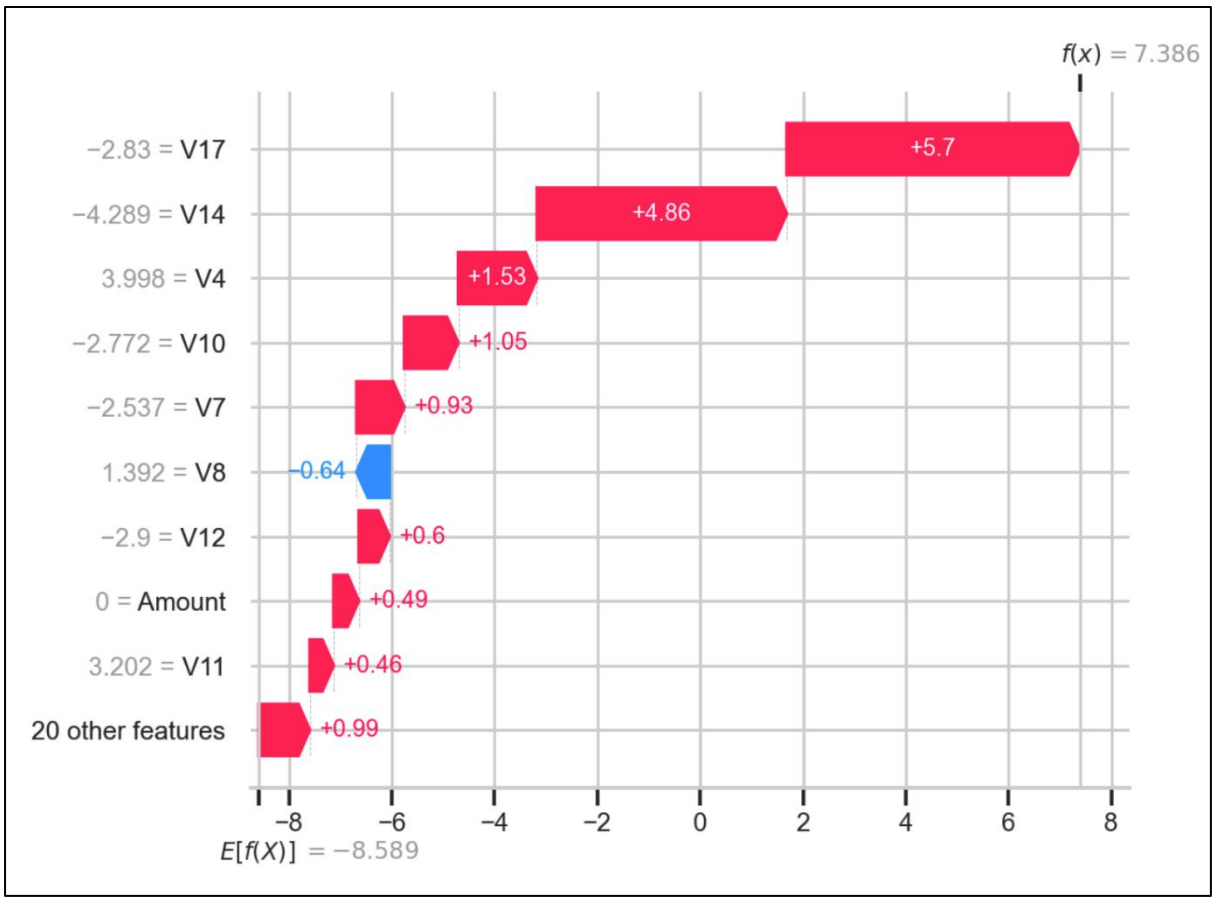

Centered Partial Dependence Plots of V4 and V8
Partial dependence
0.0008
0.0006
0.0004
0.0002
0.0000
−0.0002
−2
−1
0
1
2
V4
−0.5
0.0
0.5
1.0
V8
V8
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−2
−1
0
1
2
V4

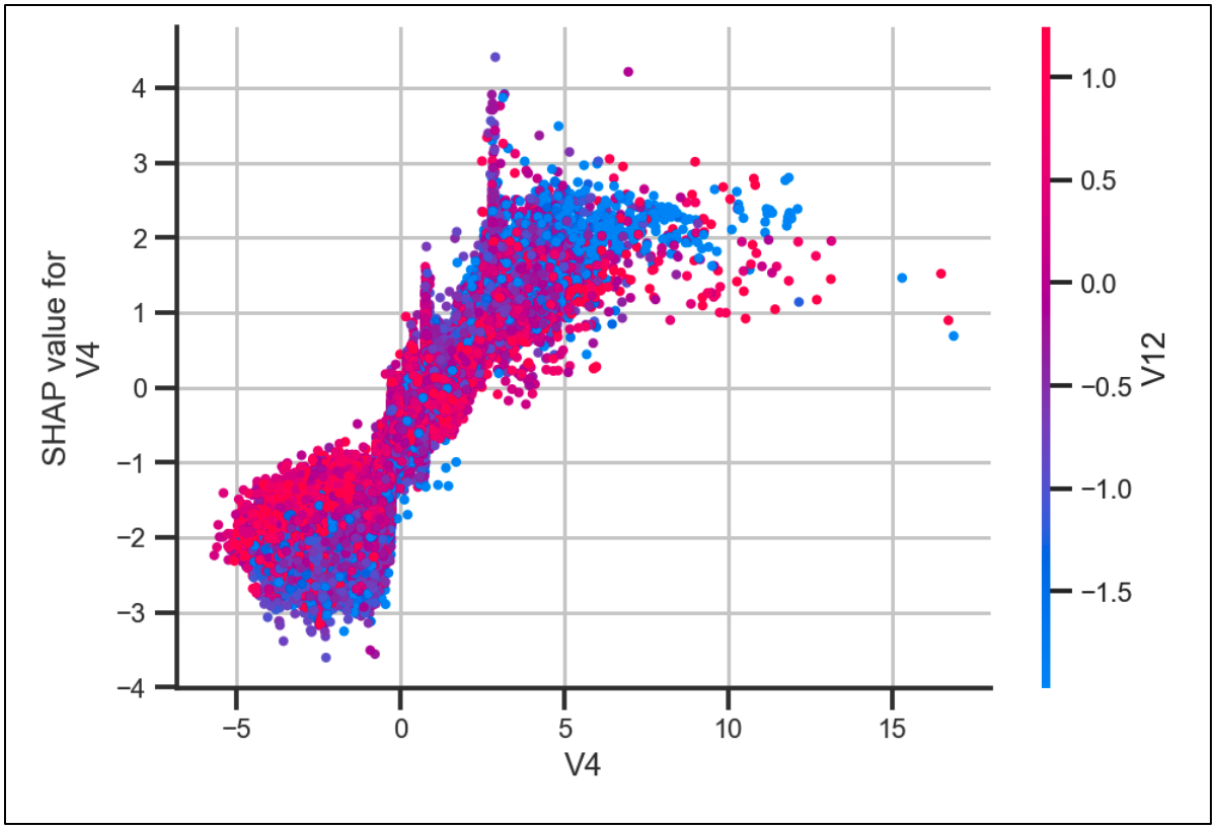

V4
V14
V12
V19
V10
Amount
V16
V8
V7
V1
V26
V21
V11
V18
V15
V27
V24
V3
V20
V25
−4
−2
0
2
4
6
8
10
SHAP value (impact on model output)
High
Feature value
Low


V4
V14
V12
V19
V10
Amount
V16
V8
V7
V1
V26
V21
V11
V18
V15
V27
V24
V3
V20
V25
0.0
0.2
0.4
0.6
0.8
1.0
mean(|SHAP value|) (average impact on model output magnitude)


higher ⇄ lower
f(x)
-13.37
base value
-8.589
-14.59
-12.59
-10.59
-6.589
V4 = 1.378
V12 = -0.6178
V26 = -0.1891
V14 = -0.3112
V3 = 2.536
V24 = 0.06693
V20 = 0.2514
V11 = -0.5516
V7 = 0.2396
V10 = 0.09079
Amount = 149.6
V19 = 0.404


higher ⇄ lower
base value
-8.589
-3.589
1.411
f(x)
6.411 7.39
Amount = 0
V12 = -2.9
V7 = -2.537
V10 = -2.772
V4 = 3.998
V14 = -4.289
V17 = -2.83
V8 = 1.392

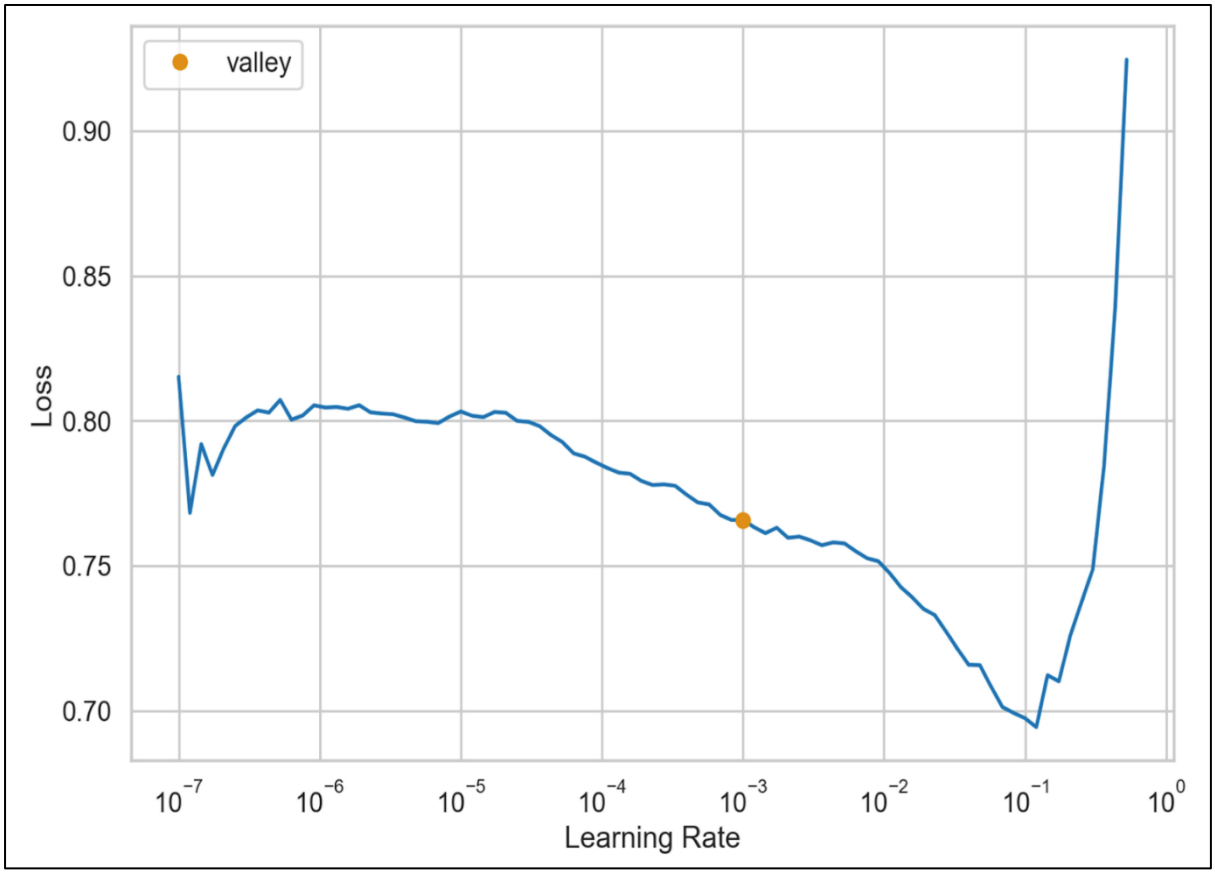

f(x) = 7.386
−2.83 = V17
−4.289 = V14
3.998 = V4
−2.772 = V10
−2.537 = V7
1.392 = V8
−2.9 = V12
0 = Amount
3.202 = V11
20 other features
+5.7
+4.86
+1.53
+1.05
+0.93
−0.64
+0.6
+0.49
+0.46
+0.99
−8
−6
−4
−2
0
2
4
6
8
E[f(X)] = −8.589


SHAP value for V4
4
3
2
1
0
−1
−2
−3
−4
−5
0
5
10
15
V4
1.0
0.5
0.0
−0.5
−1.0
−1.5
V12

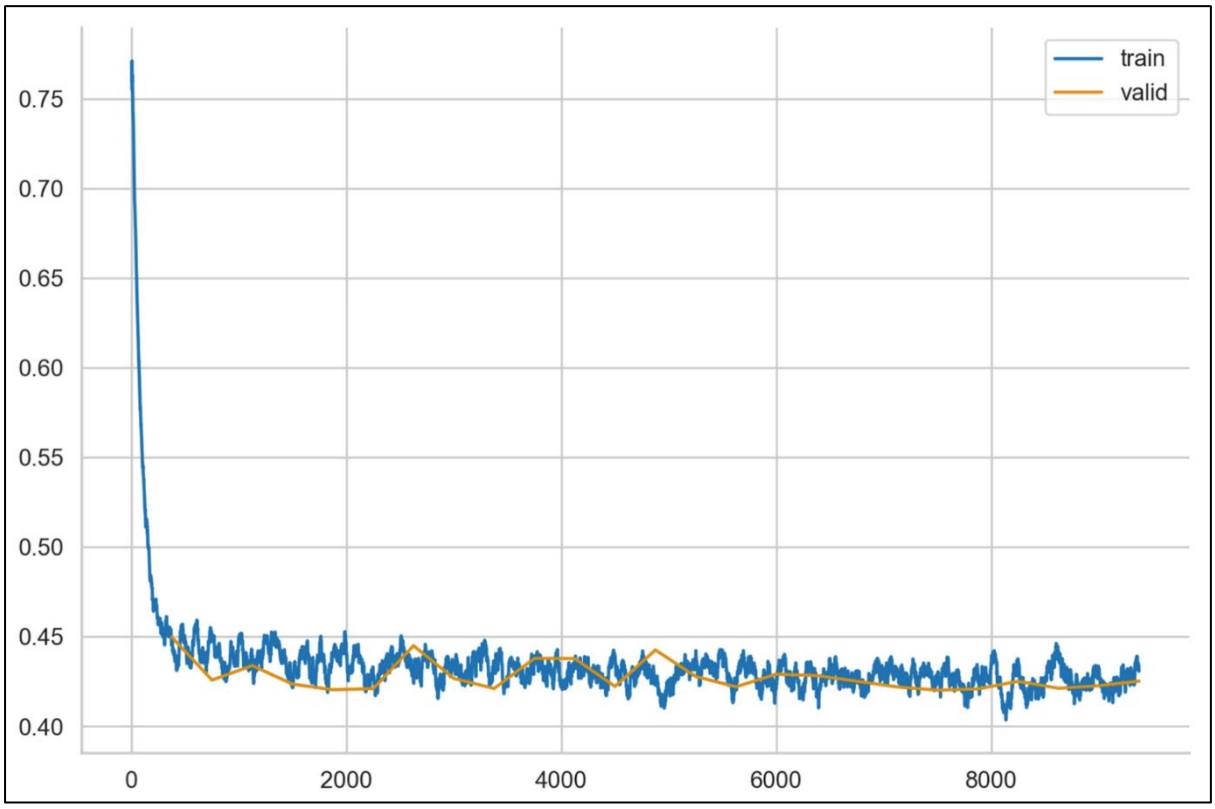
Chapter 15: Deep Learning in Finance

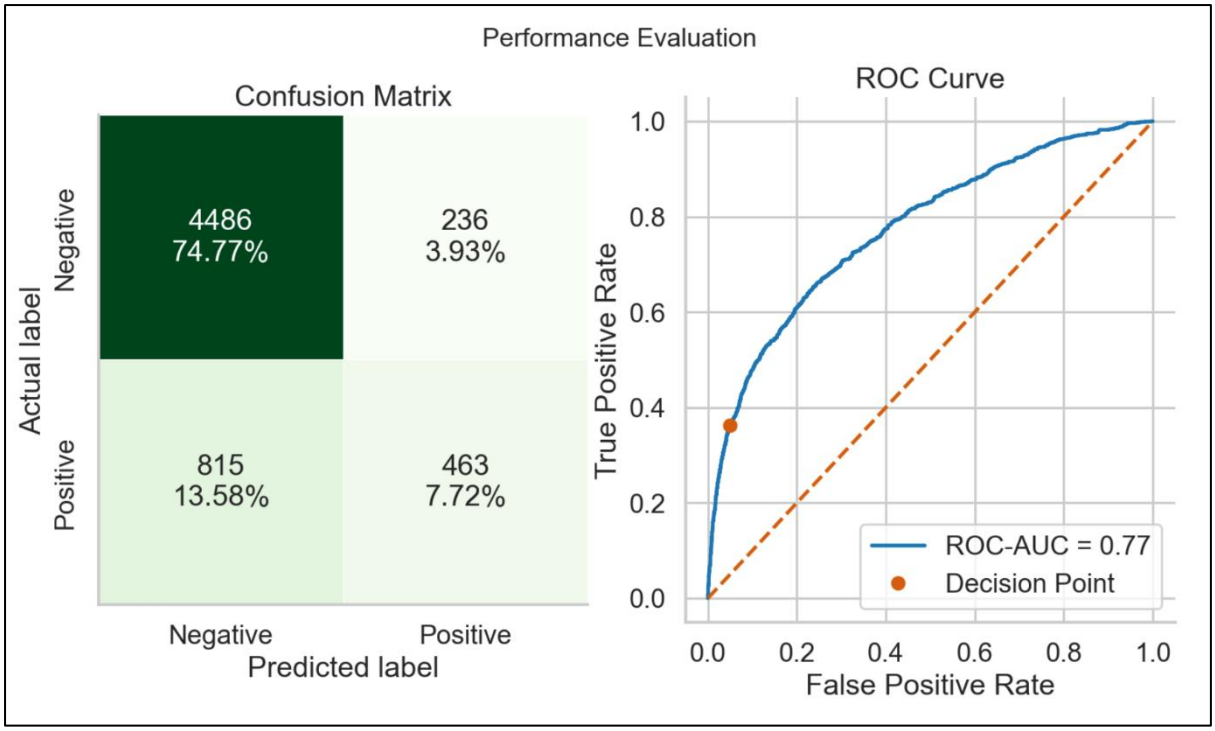
	sex	education	marriage	payment_status_sep	age_na	limit_bal	age	bill_statement_sep
27362	2	4	3	10	1	-0.290227	-0.919919	-0.399403
16258	1	4	1	10	1	-0.443899	-0.266960	0.731335
19716	1	1	3	2	1	2.014862	-0.158134	-0.493564
9066	1	2	3	3	1	-0.674408	-0.919919	-0.646319
1258	2	1	3	1	1	0.324464	-0.266960	-0.692228

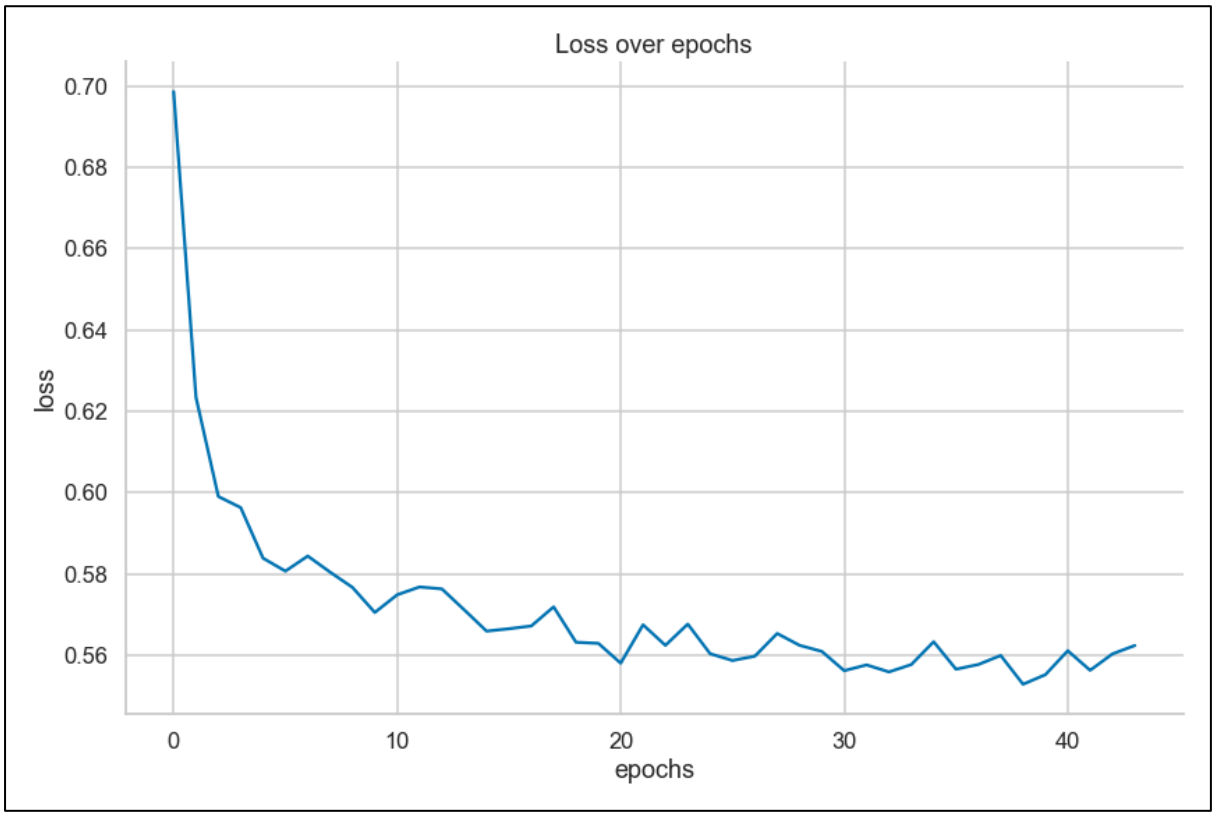
	sex	education	marriage	payment_status_sep	payment_status_aug	payment_status_jul	payment_status_jun	payment_status_may
0	Male	Graduate school	Single	Payed duly	Payed duly	Unknown	Unknown	Unknown
1	Female	Graduate school	Single	Payed duly	Payed duly	Payed duly	Unknown	Unknown
2	Female	High school	Married	Unknown	Unknown	Unknown	Unknown	Unknown
3	Male	High school	Married	Unknown	Unknown	Unknown	Unknown	Unknown
4	Female	University	Single	Payed duly	Payed duly	Payed duly	Payed duly	Payed duly
5	Male	University	Married	Payment delayed 1 month	Payment delayed 2 months	Payment delayed 2 months	Unknown	Unknown
6	Female	University	Married	Unknown	Unknown	Unknown	Unknown	Unknown
7	Female	Graduate school	Single	Unknown	Unknown	Unknown	Unknown	Unknown
8	Female	Graduate school	Single	Unknown	Unknown	Unknown	Unknown	Unknown
9	Female	Graduate school	Single	Payed duly	Payed duly	Payed duly	Payed duly	Payed duly

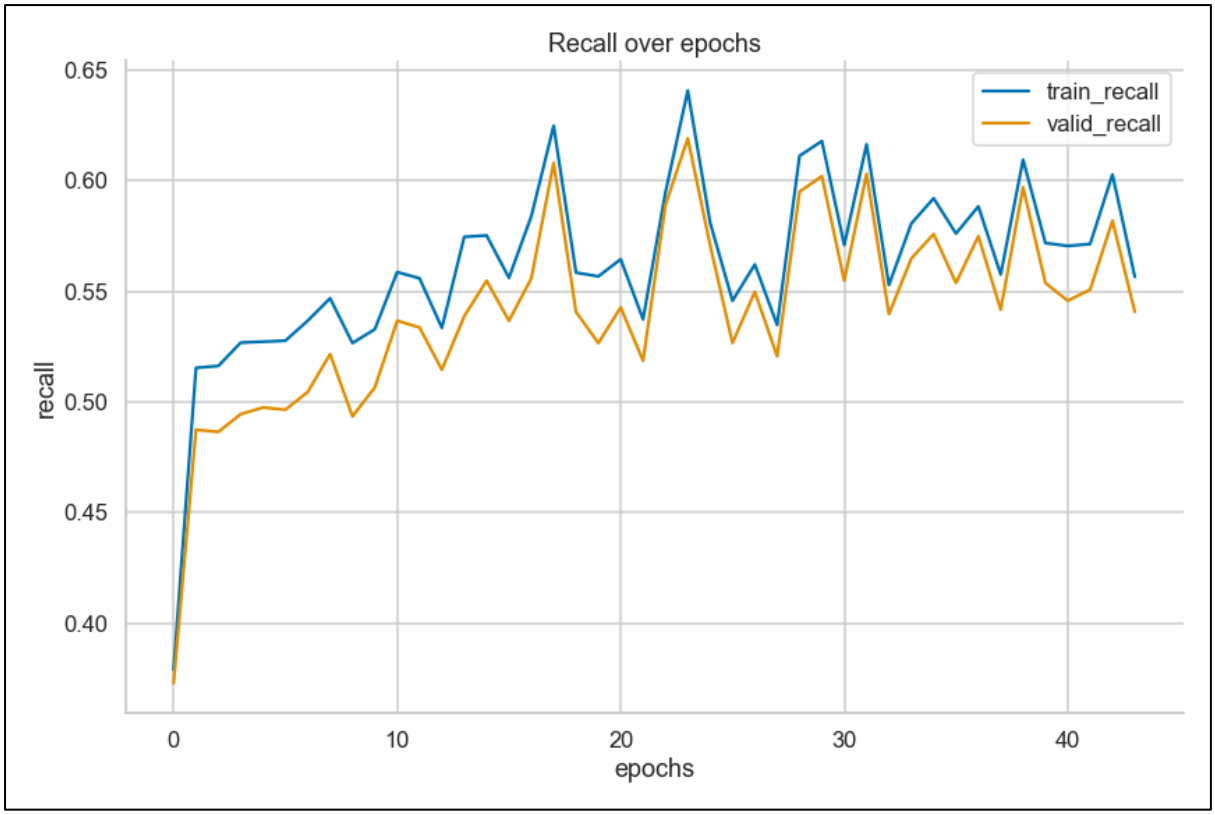


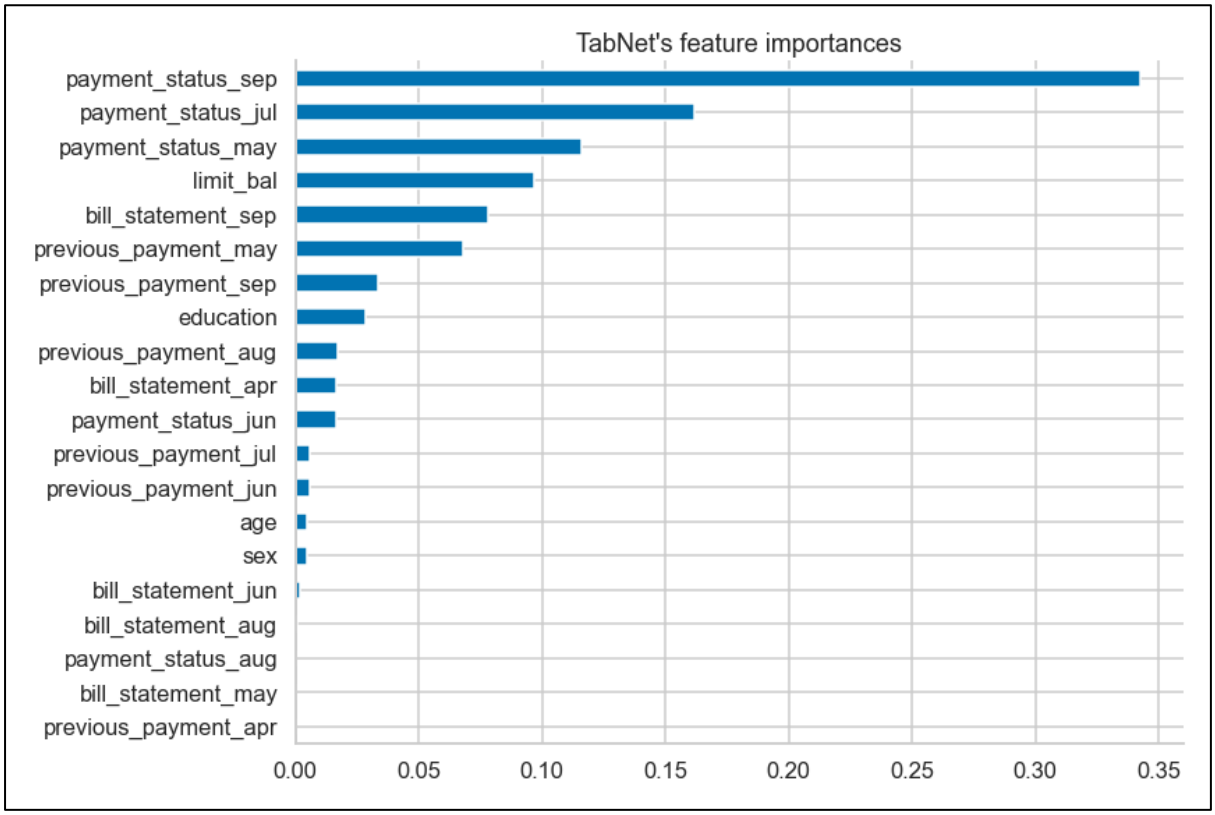
epoch	train_loss	valid_loss	accuracy	recall_score	precision_score	time
0	0.448089	0.437355	0.819500	0.321596	0.655502	00:02
1	0.434199	0.440029	0.819667	0.383412	0.625000	00:01
2	0.438905	0.435580	0.823000	0.369327	0.648352	00:01
3	0.447201	0.423070	0.826667	0.366980	0.670000	00:02
4	0.440682	0.429869	0.821667	0.370110	0.640921	00:02
5	0.426624	0.424457	0.825500	0.344288	0.677966	00:01
6	0.433349	0.422457	0.825333	0.327856	0.689145	00:02
7	0.438918	0.422934	0.824000	0.343505	0.669207	00:01
8	0.431417	0.423400	0.825667	0.360720	0.668116	00:02
9	0.431647	0.429696	0.824167	0.371674	0.653370	00:01



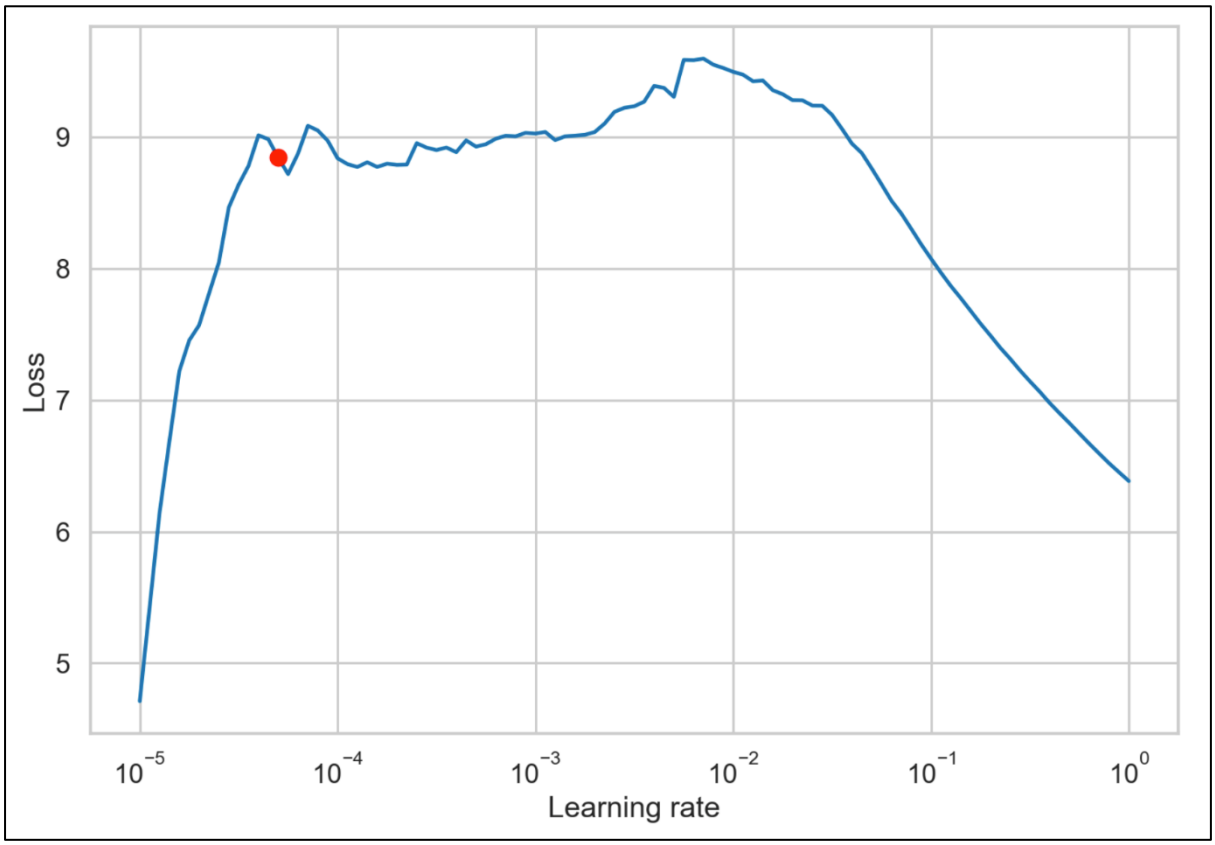

Performance Evaluation
Confusion Matrix
Actual label
Negative
Positive
4486
74.77%
236
3.93%
815
13.58%
463
7.72%
Negative
Positive
Predicted label
ROC Curve
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC-AUC = 0.77
Decision Point

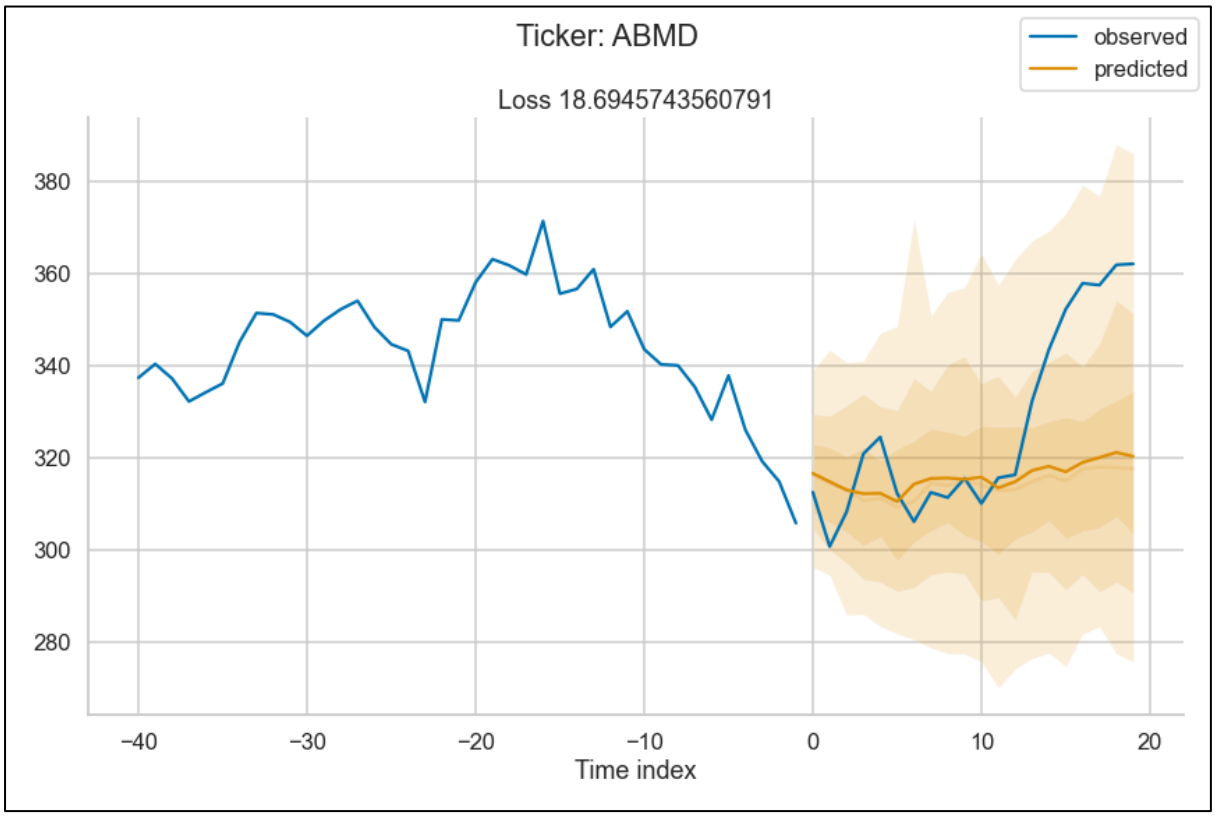

Loss over epochs
loss
epochs
0.70
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0
10
20
30
40

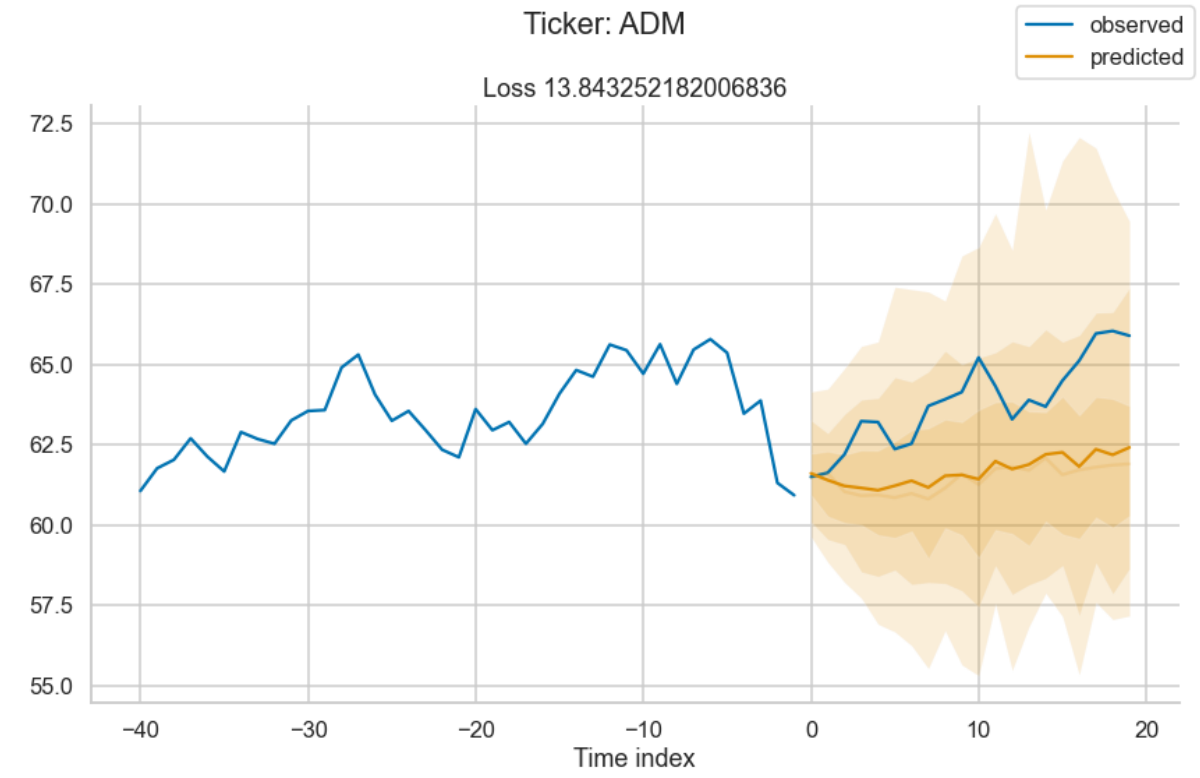

Recall over epochs
train_recall
valid_recall
recall
epochs
0.65
0.60
0.55
0.50
0.45
0.40
0
10
20
30
40

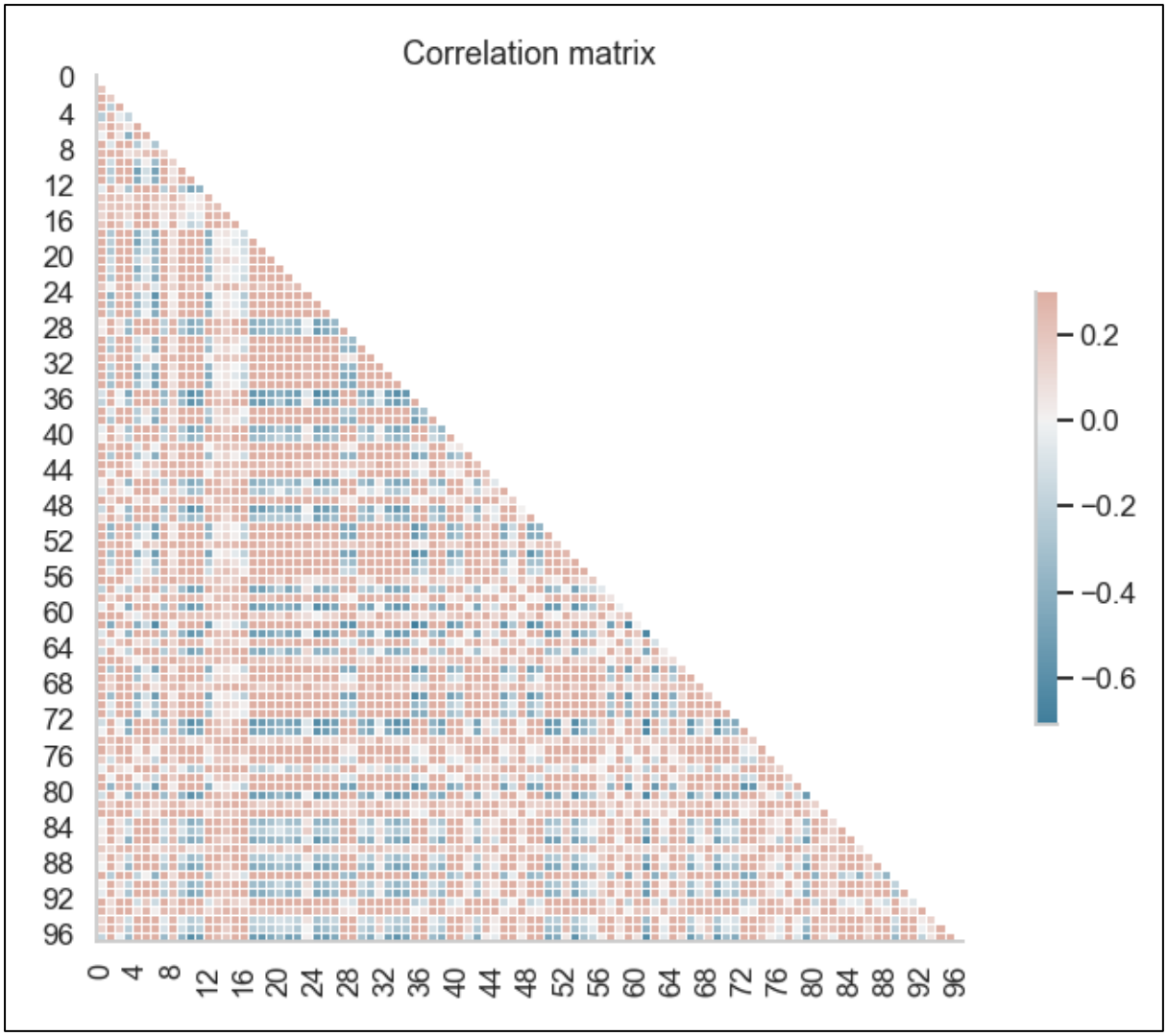

TabNet's feature importances
payment_status_sep
payment_status_jul
payment_status_may
limit_bal
bill_statement_sep
previous_payment_may
previous_payment_sep
education
previous_payment_aug
bill_statement_apr
payment_status_jun
previous_payment_jul
previous_payment_jun
age
sex
bill_statement_jun
bill_statement_aug
payment_status_aug
bill_statement_may
previous_payment_apr
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

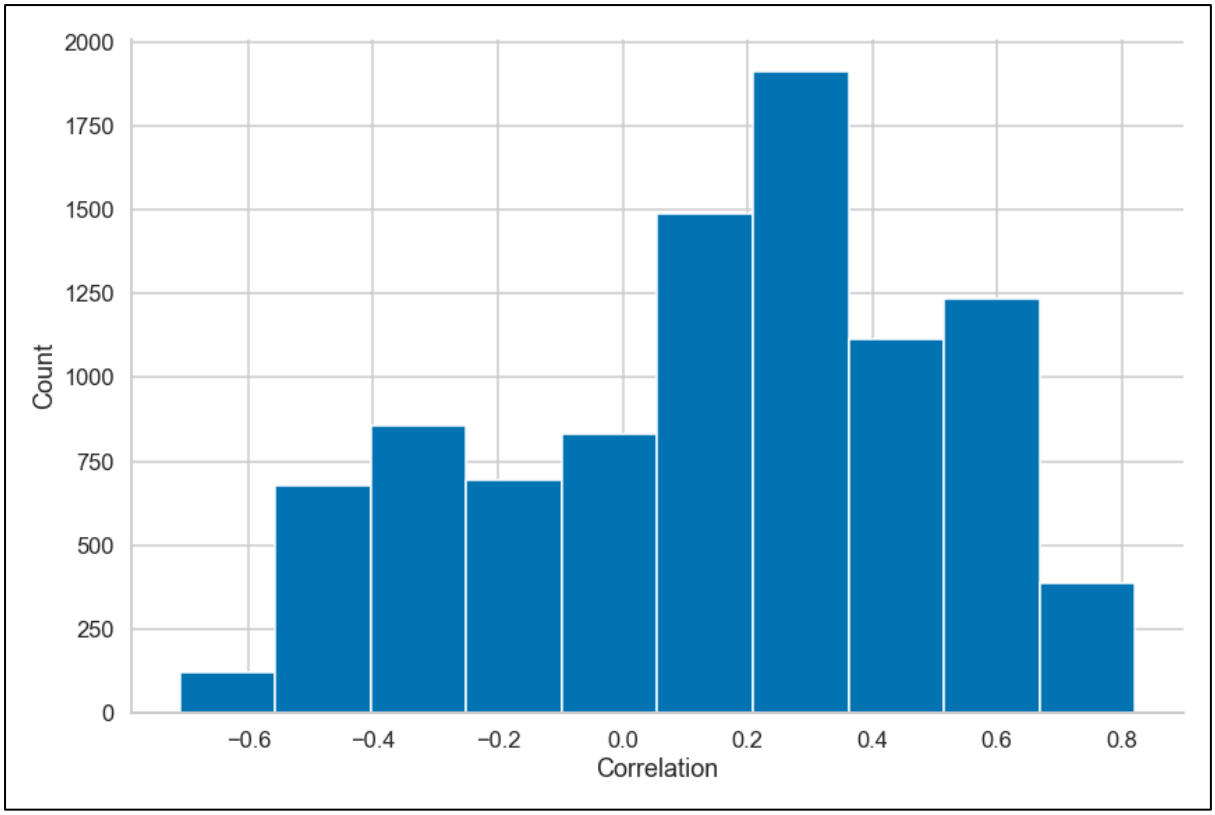
	Date	ticker	price	time_idx
0	2019-12-31	ABC	81.503716	0
1	2020-01-02	ABC	81.561249	1
2	2020-01-03	ABC	80.535492	2
3	2020-01-06	ABC	81.714615	3
4	2020-01-07	ABC	81.129845	4
...	...	...	...	...
48980	2021-12-23	XYL	116.300835	500
48981	2021-12-27	XYL	117.082787	501
48982	2021-12-28	XYL	118.300217	502
48983	2021-12-29	XYL	118.141861	503
48984	2021-12-30	XYL	117.884506	504

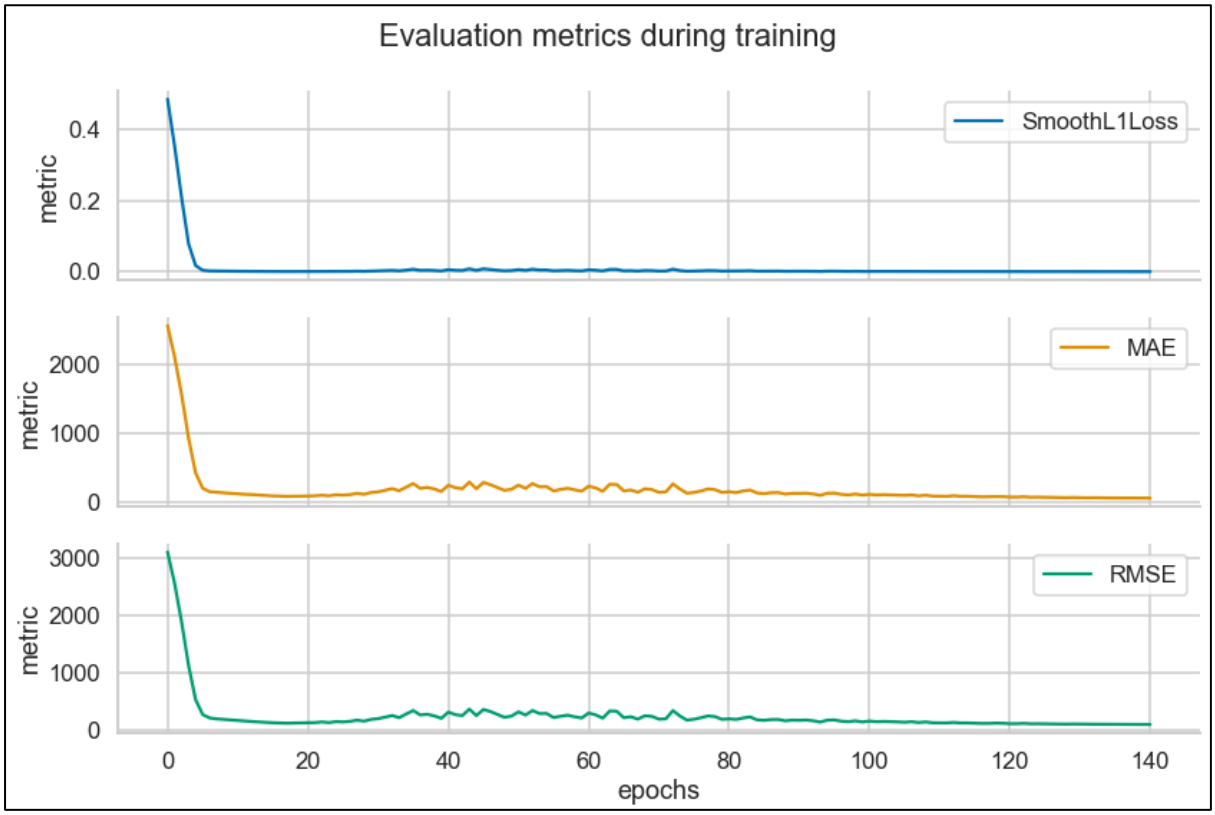


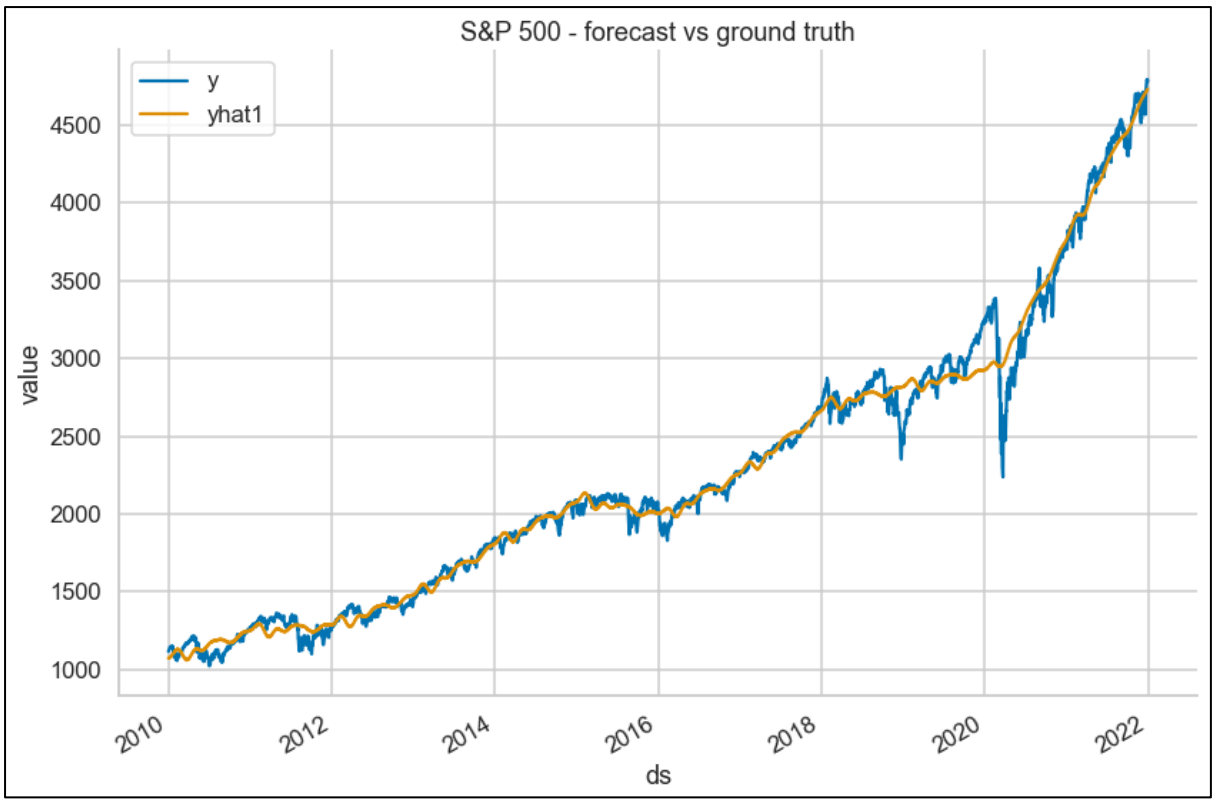

Ticker: ABMD
Loss 18.6945743560791
observed
predicted
380
360
340
320
300
280
−40
−30
−20
−10
0
10
20
Time index

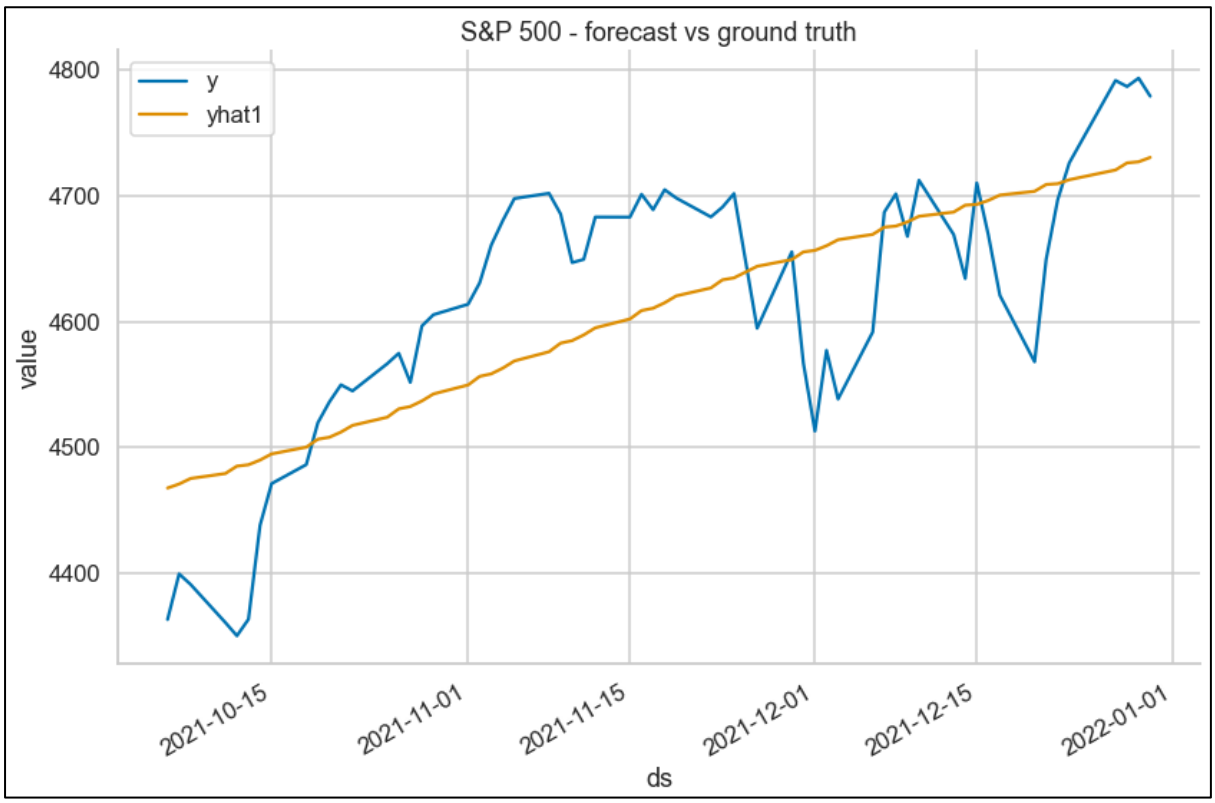

Ticker: ADM
Loss 13.843252182006836
observed
predicted
72.5
70.0
67.5
65.0
62.5
60.0
57.5
55.0
−40
−30
−20
−10
0
10
20
Time index

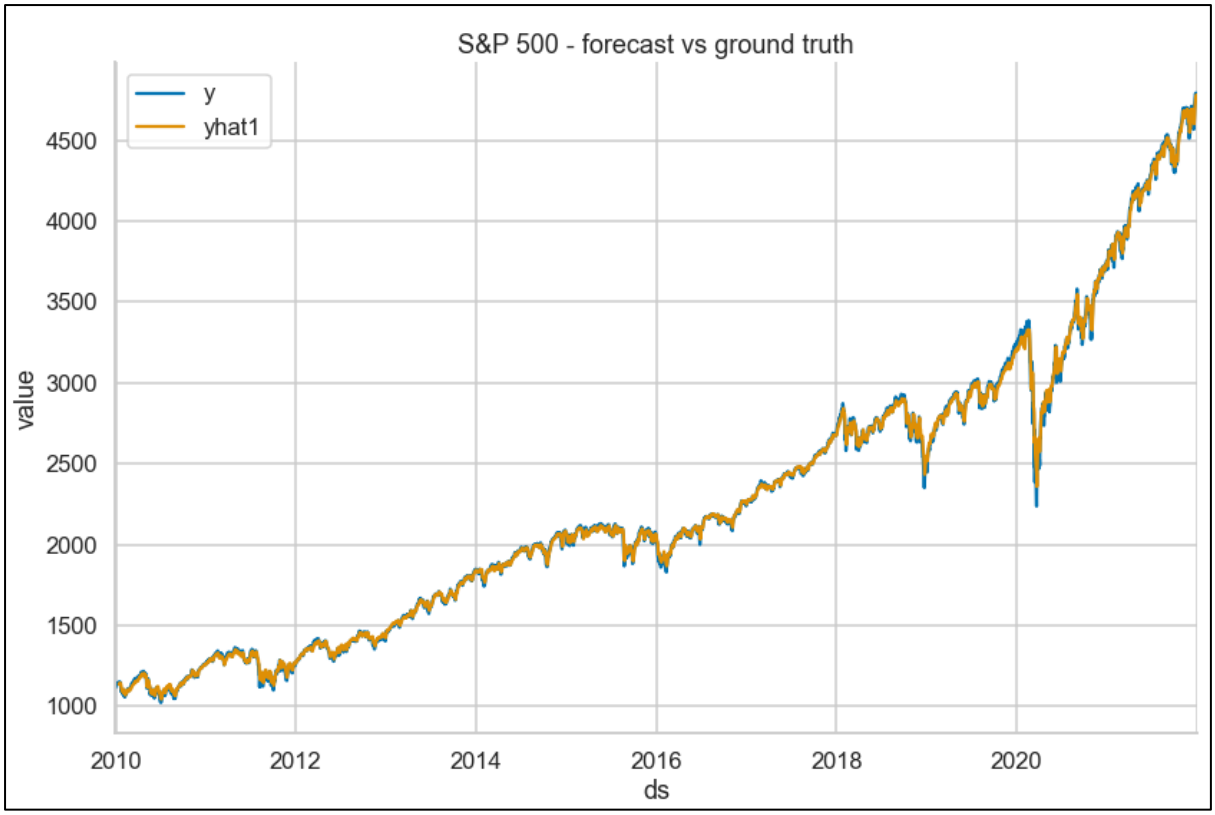

Correlation matrix
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
84
88
92
96
0.2
0.0
−0.2
−0.4
−0.6

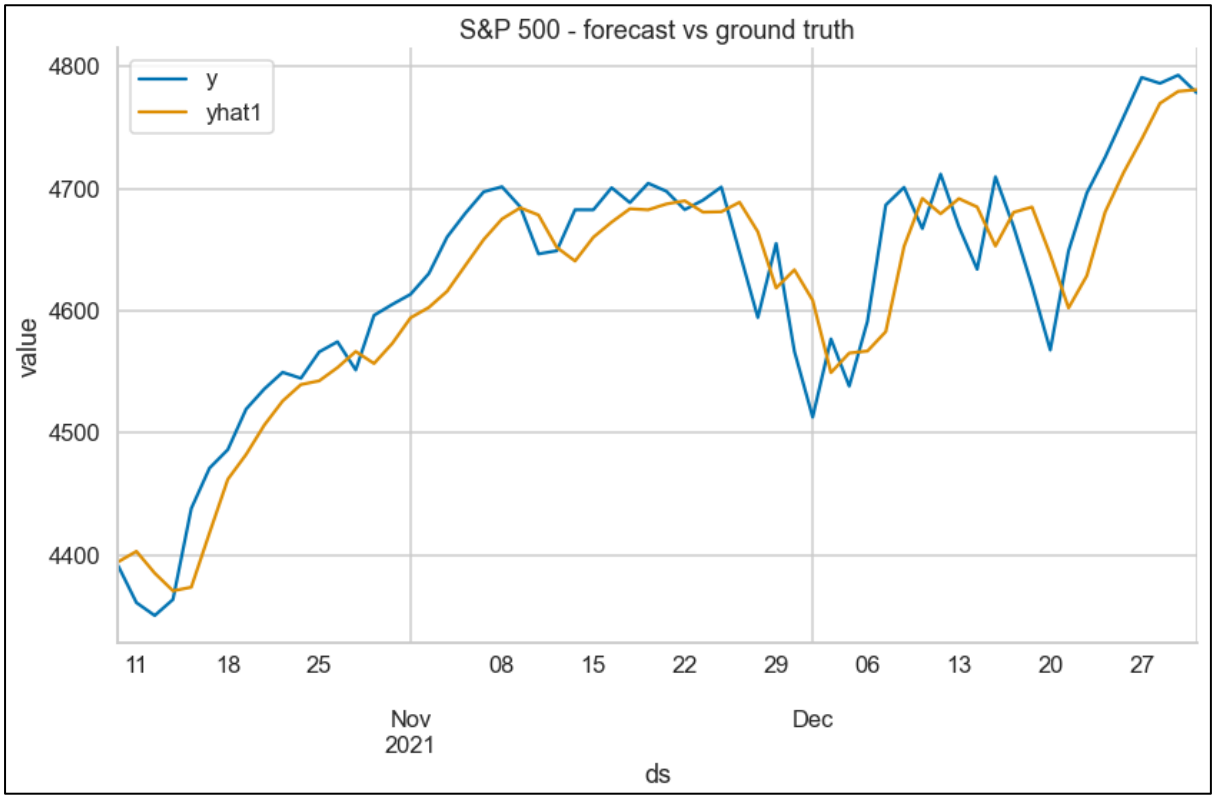

2000
1750
1500
1250
1000
750
500
250
0
Count
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
Correlation

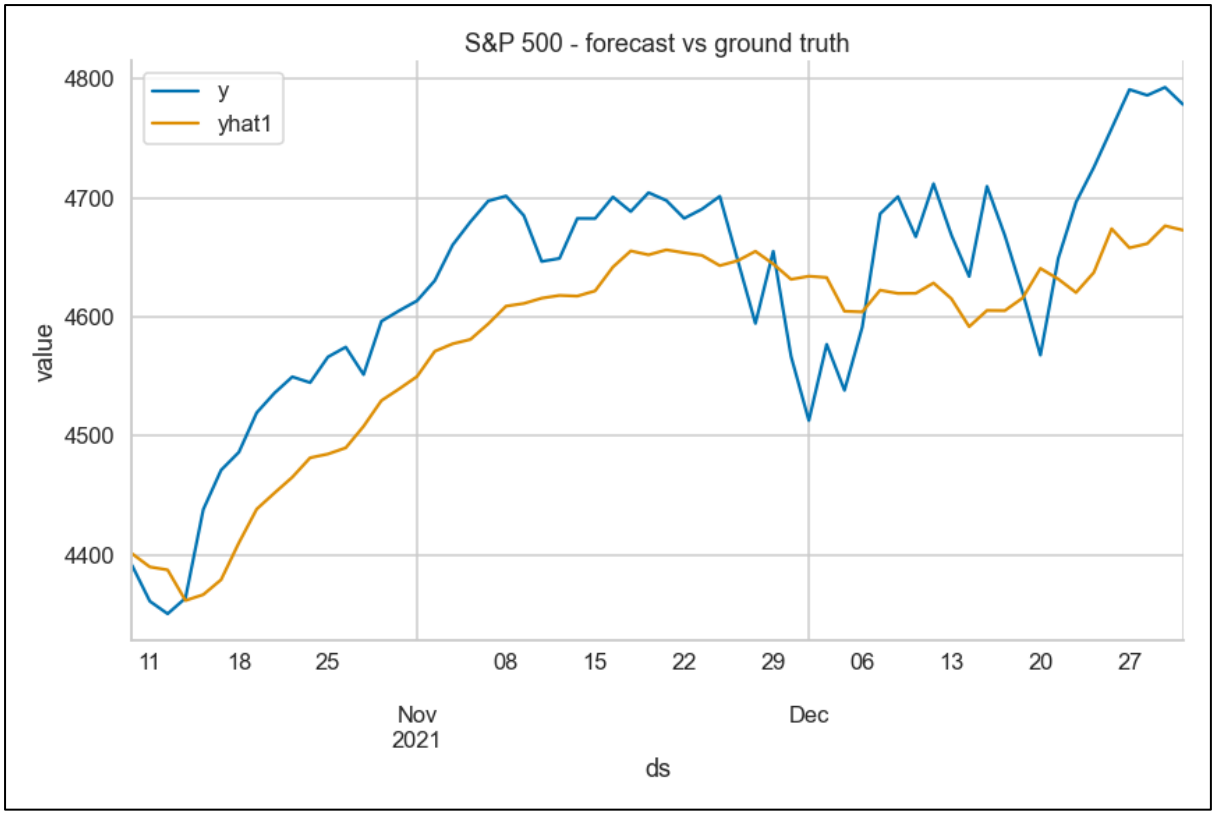

Evaluation metrics during training
SmoothL1Loss
MAE
RMSE
metric
0.4
0.2
0.0
2000
1000
0
3000
2000
1000
0
0
20
40
60
80
100
120
140
epochs

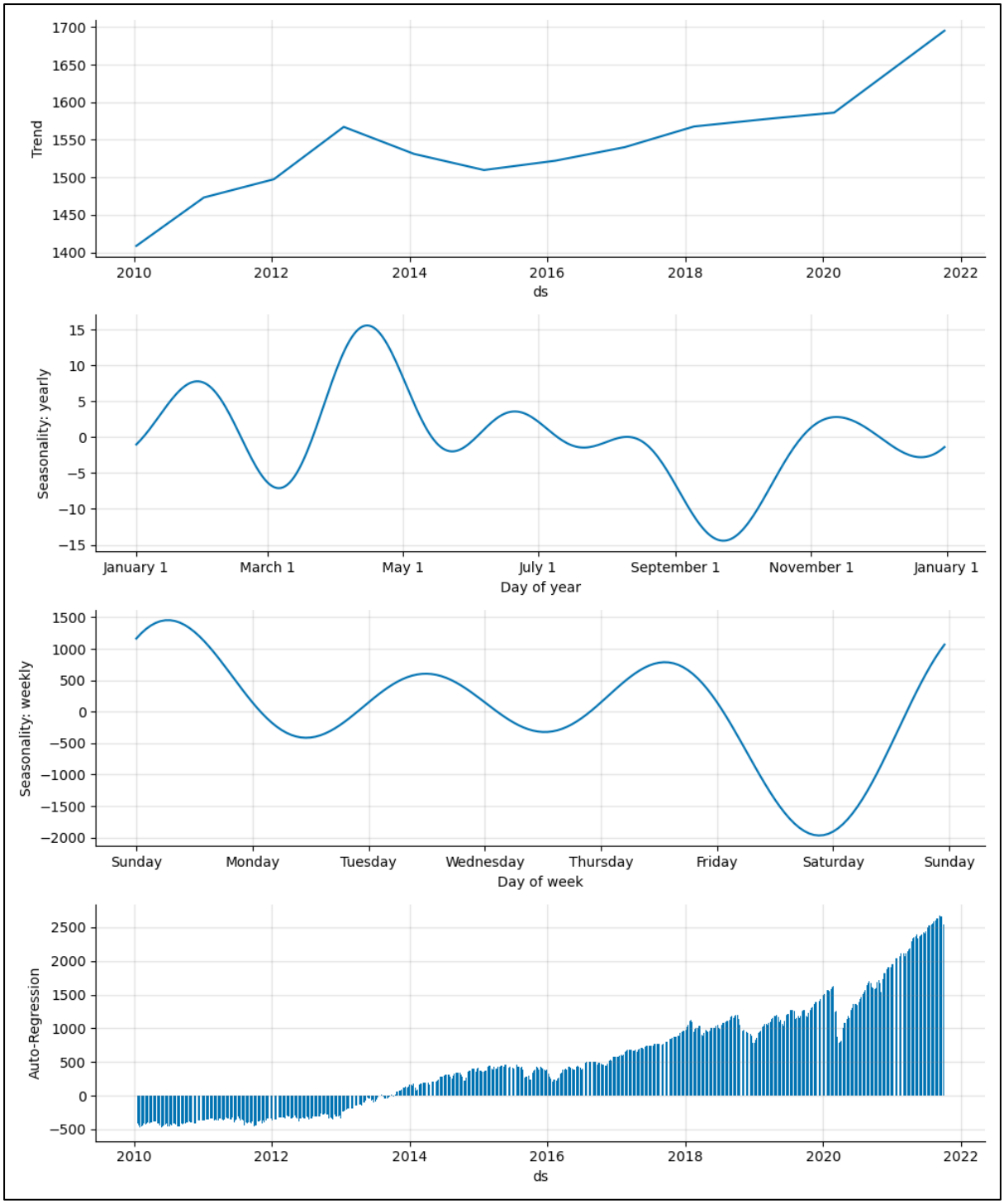

S&P 500 - forecast vs ground truth
y
yhat1
4500
4000
3500
3000
2500
2000
1500
1000
value
2010
2012
2014
2016
2018
2020
2022
ds

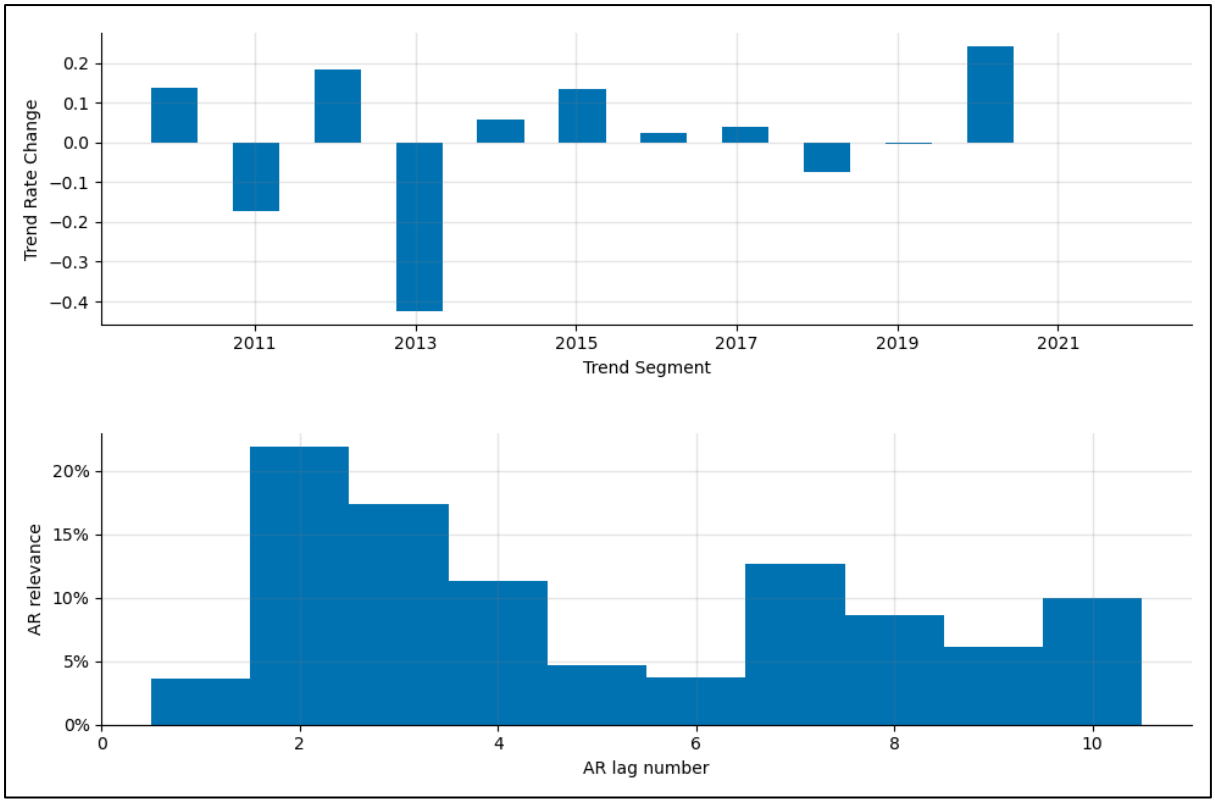

S&P 500 - forecast vs ground truth
y
yhat1
4800
4700
4600
4500
4400
value
2021-10-15
2021-11-01
2021-11-15
2021-12-01
2021-12-15
2022-01-01
ds

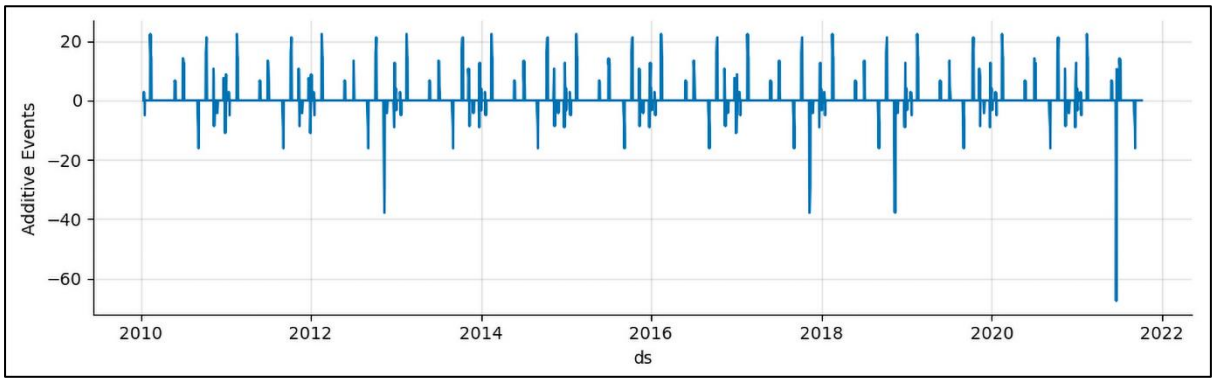

S&P 500 - forecast vs ground truth
y
yhat1
4500
4000
3500
3000
2500
2000
1500
1000
value
2010
2012
2014
2016
2018
2020
ds


S&P 500 - forecast vs ground truth
y
yhat1
4800
4700
4600
4500
4400
value
11
18
25
08
15
22
29
06
13
20
27
Nov
2021
Dec
ds


S&P 500 - forecast vs ground truth
y
yhat1
4800
4700
4600
4500
4400
value
11
18
25
08
15
22
29
06
13
20
27
Nov
2021
Dec
ds

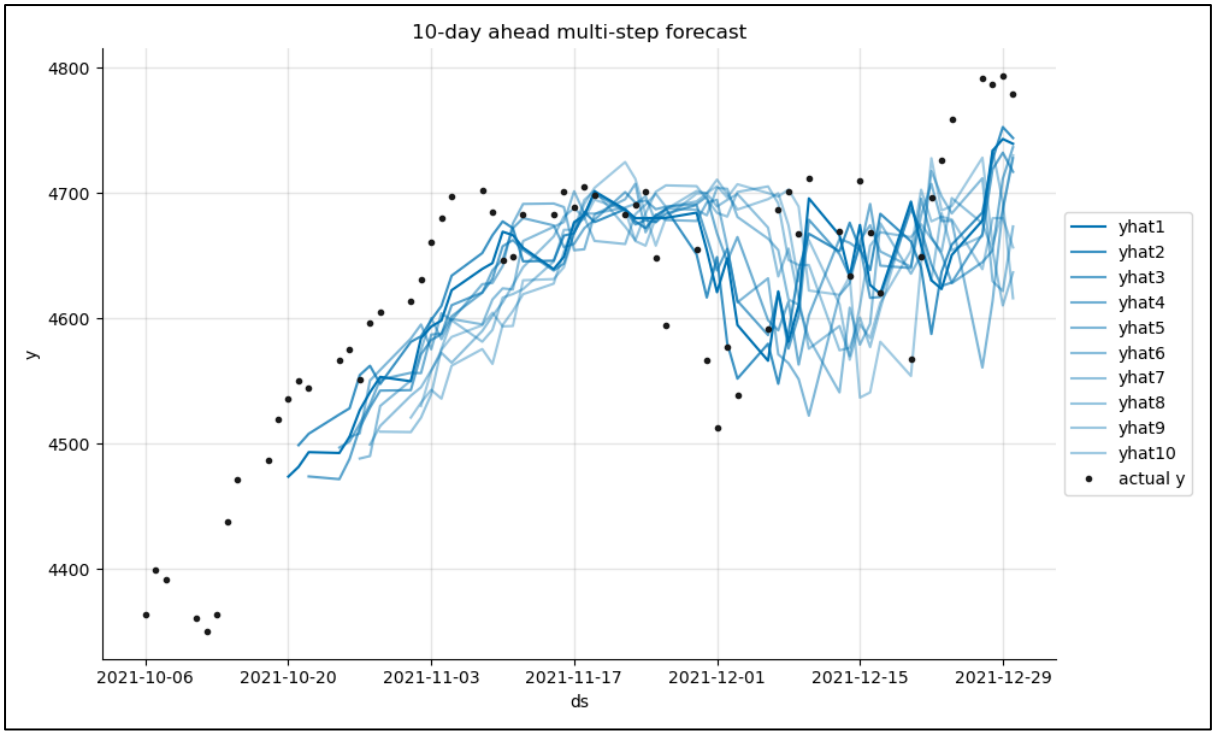

Trend
1700
1650
1600
1550
1500
1450
1400
2010
2012
2014
2016
2018
2020
2022
ds
Seasonality: yearly
15
10
5
0
−5
−10
−15
January 1
March 1
May 1
July 1
September 1
November 1
January 1
Day of year
Seasonality: weekly
1500
1000
500
0
−500
−1000
−1500
−2000
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Day of week
Auto-Regression
2500
2000
1500
1000
500
0
−500
2010
2012
2014
2016
2018
2020
2022
ds

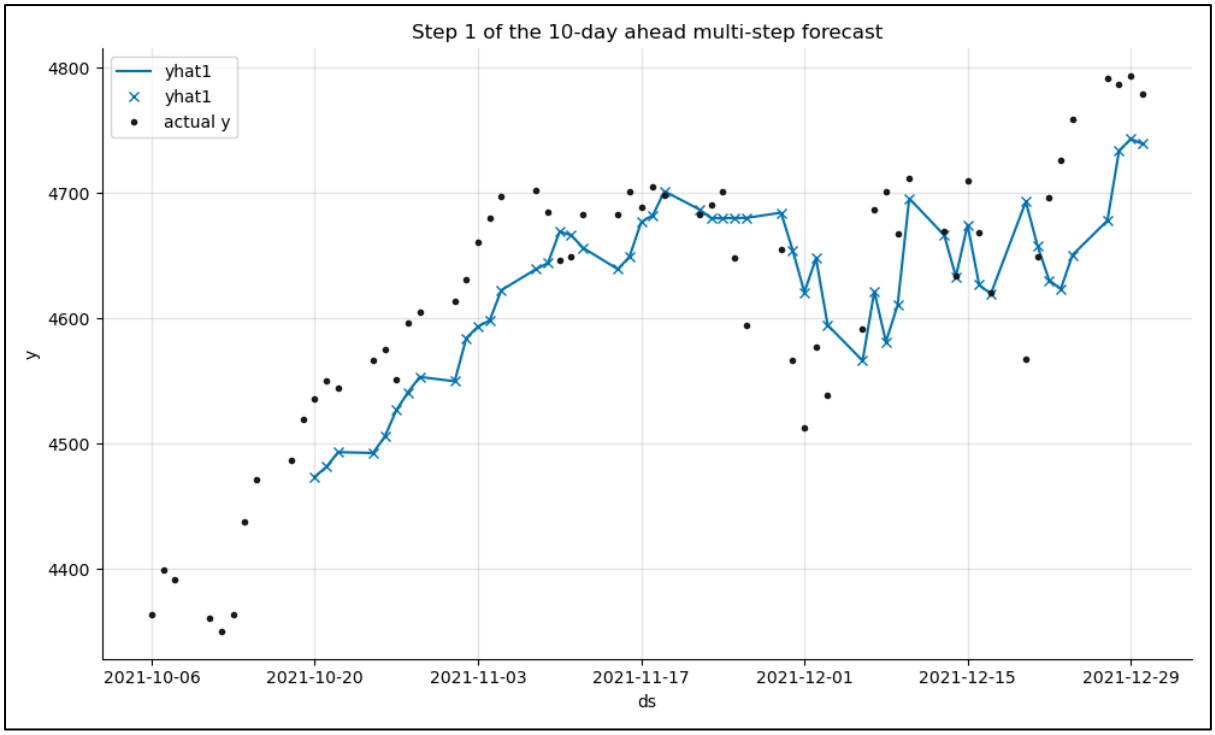




	ds	y	yhat1	residual1	yhat2	residual2	yhat3	residual3
3126	2021-12-24	4758.489990	4650.537109	-107.952881	4658.835938	-99.654053	4628.593262	-129.896729
3127	2021-12-27	4791.189941	4678.010742	-113.179199	4684.404785	-106.785156	4667.214355	-123.975586
3128	2021-12-28	4786.350098	4733.727051	-52.623047	4726.821777	-59.52832	4719.004395	-67.345703
3129	2021-12-29	4793.060059	4743.061035	-49.999023	4752.594238	-40.46582	4732.162598	-60.897461
3130	2021-12-30	4778.729980	4739.231934	-39.498047	4743.820801	-34.90918	4716.883789	-61.846191

	ds	step0	step1	step2	step3	step4
3116	2021-12-24	4650.540039	4684.399902	4719.000000	4711.359863	4727.819824
3117	2021-12-27	4678.009766	4726.819824	4732.160156	4736.580078	4733.509766
3118	2021-12-28	4733.729980	4752.589844	4716.879883	4745.649902	4740.490234
3119	2021-12-29	4743.060059	4743.819824	4702.350098	4733.750000	4747.859863
3120	2021-12-30	4739.229980	4752.520020	4730.939941	4760.689941	4776.040039




Step 1 of the 10-day ahead multi-step forecast
yhat1
yhat1
actual y
4800
4700
4600
4500
4400
y
2021-10-06
2021-10-20
2021-11-03
2021-11-17
2021-12-01
2021-12-15
2021-12-29
ds