



Encoder Decoder LSTM

구현 및 실험 결과 보고

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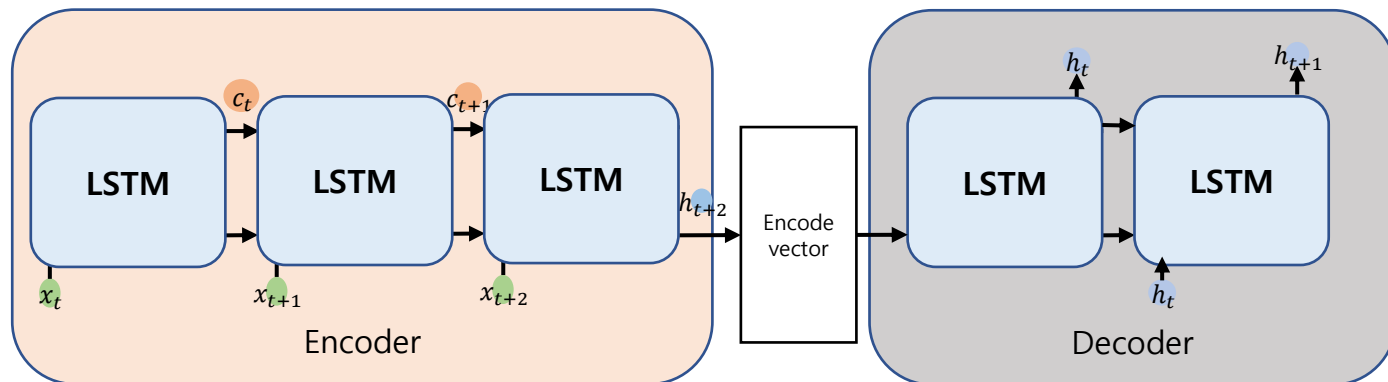
Introduction

- 기존의 LSTM등 RNNs의 모형에서 input length와 output length가 다른 데이터를 다룰 수 없는 문제점이 있음.
- 이를 해결하기 위해 Encoder-Decoder 구조를 LSTM에 적용함.
- input length와 output length가 다른 길이가 되어도 출력이 가능하게 됨.

Related works

- Encoder-Decoder LSTM

- 두개의 LSTM 아키텍처가 결합된 구조.



- Encoder아키텍처에서 셀의 마지막 시점의 hidden state를 Decoder로 넘겨줌
- 받은 hidden state를 Decoder에서 최초의 hidden state로 사용함.

Proposed method

Experimental setting

- Dataset

stocks	N	Train	val	test
KOSPI	5156	3210	979	967
KOSDAQ(2013-03-03 ~)	1898	938	474	486
NASDAQ	5265	3263	1002	1000
S&P 500	5265	3263	1002	1000
다우존스	5265	3263	1002	1000
홍콩 항셱	5151	3196	976	979
일본 니케이	5124	3182	971	971
독일 DAX	5306	3300	1005	1001
프랑스 CAC	5343	3313	1015	1015
스페인 IBEX	5314	3283	1017	1014
대만 기권	5144	3206	971	967
네덜란드 AEX	5347	3316	1016	1015
인도 섀섹스	5151	3204	970	977
브라질 보베스파	5265	3263	1002	1000
Gold price	5050	3067	994	989
Oil price(2000-08-23 ~)	5060	3076	994	990
10년 만기 미국 국채	3264	3264	1027	688
10년 만기 한국 국채				
비트코인 암호화폐(2014-09-17 ~)	2275	1560	359	356
이더리움 암호화폐(2015-08-07 ~)	1951	1236	359	356

KOSPI INDEX log difference

2000.01.01 – 2020.12.31

Experimental setting

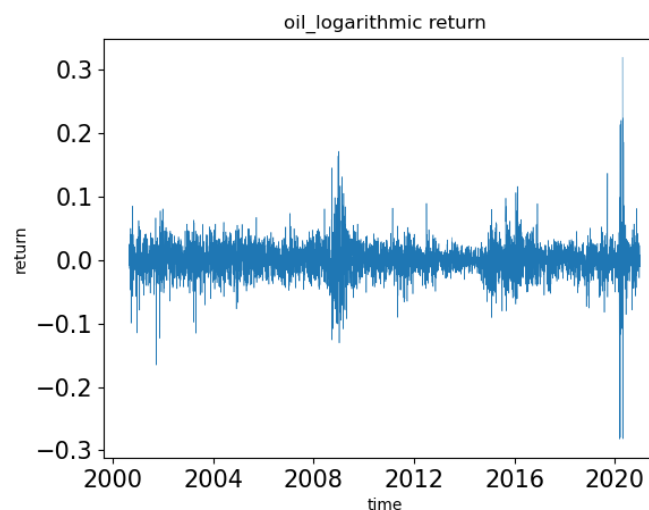
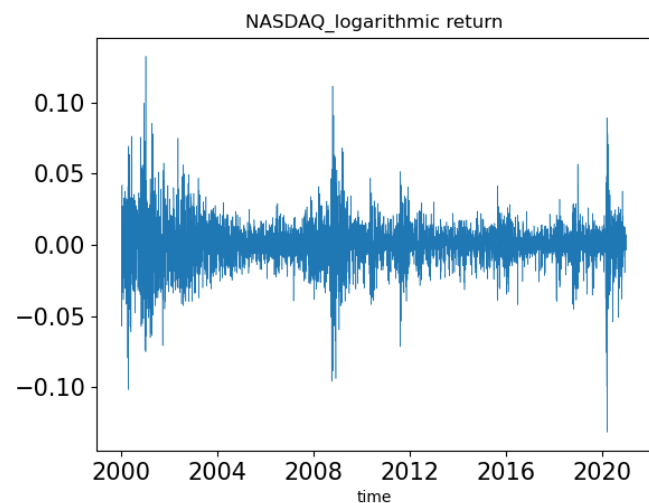
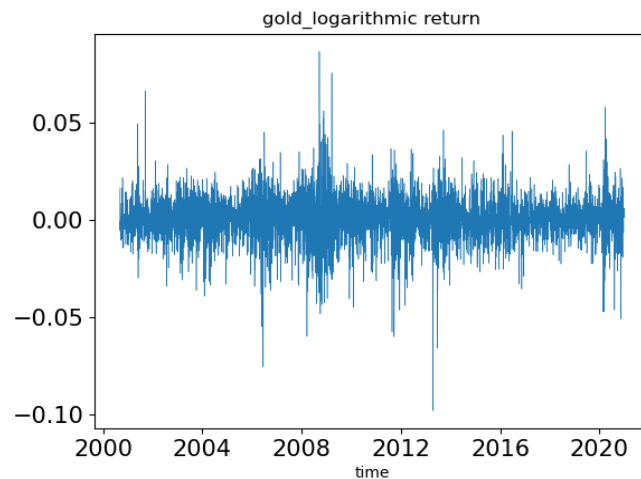
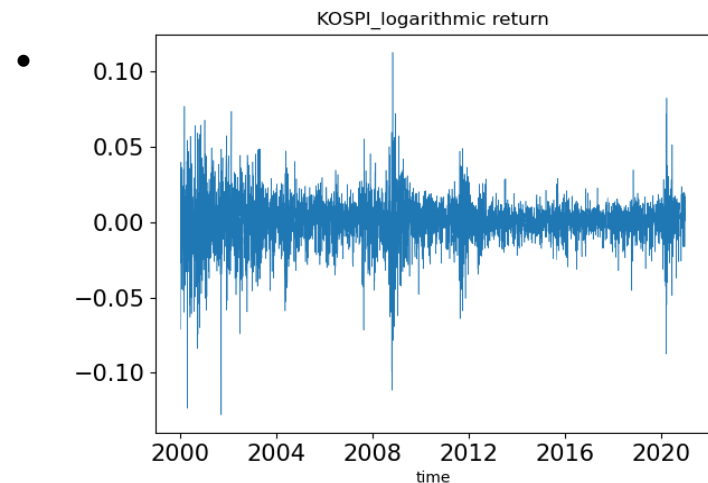
- Statistics

stocks	Mean	Standard deviation	Skewness	Kurtosis(3)	Jerque Bera	ADF
KOSPI	1582.518	587.343	-0.421	1.861	432.61***	-0.438834
KOSDAQ	668.623	103.98	0.46	2.632	78.4663***	-1.173884
NASDAQ	3791.769	2367.556	1.388	4.395	2125.9183***	3.346301
S&P 500	1653.635	674.270	1.033	3.067	941.5057***	1.678640
다우존스	14655.366	5792.134	1.043	2.906	959.6158***	0.870942
홍콩 항셱	19919.806	5726.487	-0.18	2.076	211.8634***	-1.579436
일본 니케이	14640.566	4694.21	0.393	2.009	342.692***	-0.491717
독일 DAX	7661.465	3006.491	0.385	1.978	363.2483***	-0.506127
프랑스 CAC	4469.135	918.824	0.153	2.207	161.6942***	-2.233112
스페인 IBEX	9680.838	2017.084	0.667	3.565	466.6305***	-2.262163
대만 기권	7903.82	2055.782	0.243	2.707	69.2831***	-0.264858
네덜란드 AEX	435.655	108.924	0.265	2.222	197.9852***	-1.899507
인도 섀섹스	17921.698	11385.273	0.401	2.120	305.4783***	0.679944
브라질 보베스파	3791.769	2367.556	1.388	4.395	2125.9183***	3.346301
Gold price	997.637	479.258	-0.105	1.796	315.6375***	-0.459757
Oil price	61.785	25.912	0.400	2.381	216.5233***	-1.997886
10년 만기 미국 국채	118.257	9.575	-0.285	2.145	219.8195***	-2.216594
10년 만기 한국 국채						
비트코인 암호화폐	4925.441	4830.747	1.056	4.332	595.9625***	1.440318
이더리움 암호화폐	223.111	231.702	1.601	6.123	1642.5896***	-2.082944
KOSPI INDEX log difference	0.000193	0.0149	-0.572	10.03	10943.0983***	-33.339841***

Used Close(종가) variable.

Experimental setting

- logarithmic return : $\ln((t+1)/t)$ t : 시점이 t 일때 종가(close)



- logarithmic return
 - 수익률을 나타내는 지표 중의 하나.
 - 일반 수익률보다 실제 수익률에 더 가까운 지표.

Experimental setting

- Data normalization
 - min-max normalization
- Loss function
 - Used MSE Loss as loss function
- Optimizer
 - RMSprop
- Metric
 - $\text{MSE}(e^{\text{predicted value}}, e^{\text{true value}})$
 - $\text{MAE}(e^{\text{predicted value}}, e^{\text{true value}})$
 - $\text{MAPE}(e^{\text{predicted value}}, e^{\text{true value}})$

Hyperparameters	Number
hidden state, cell state dimension	10
input sequence length	20
output sequence length	1
epoch	20
Batch size	128

Experimental setting

- To determine the detailed performance of a model
- Add another model evaluation metric.

- Mean Absolute Percentage Error (MAPE) = $\frac{\sum_{t=1}^n \left| \frac{y_t - \hat{y}_t}{y_t} \right|}{n} \cdot 100(\%)$
 - MAPE is undefined for data points where the value is zero.
 - MAPE is biased towards prediction that are systemically less than the actual values themselves

$$y = 20, \hat{y} = 10, n = 1 \rightarrow MAPE = 50\%$$

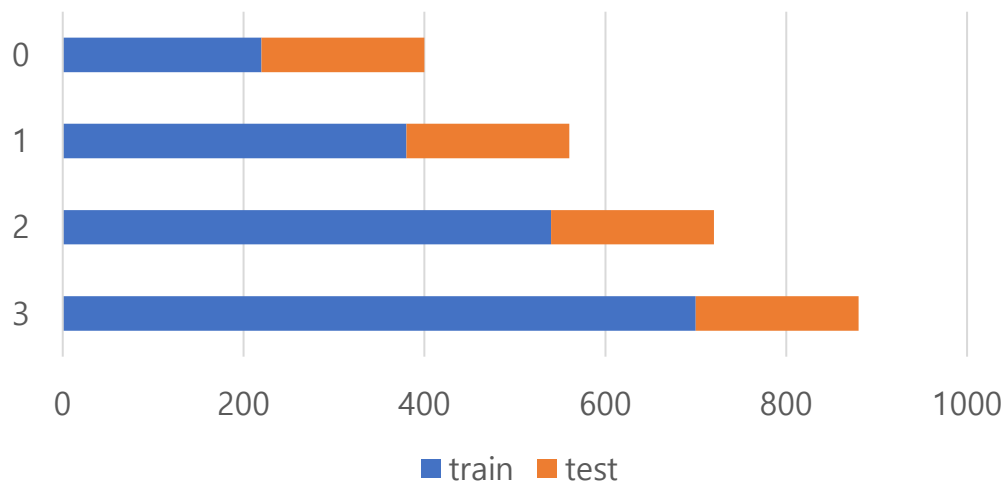
$$y = 10, \hat{y} = 20, n = 1 \rightarrow MAPE = 100\%$$

- Compare three metrics.
 - MAE
 - MSE
 - MAPE

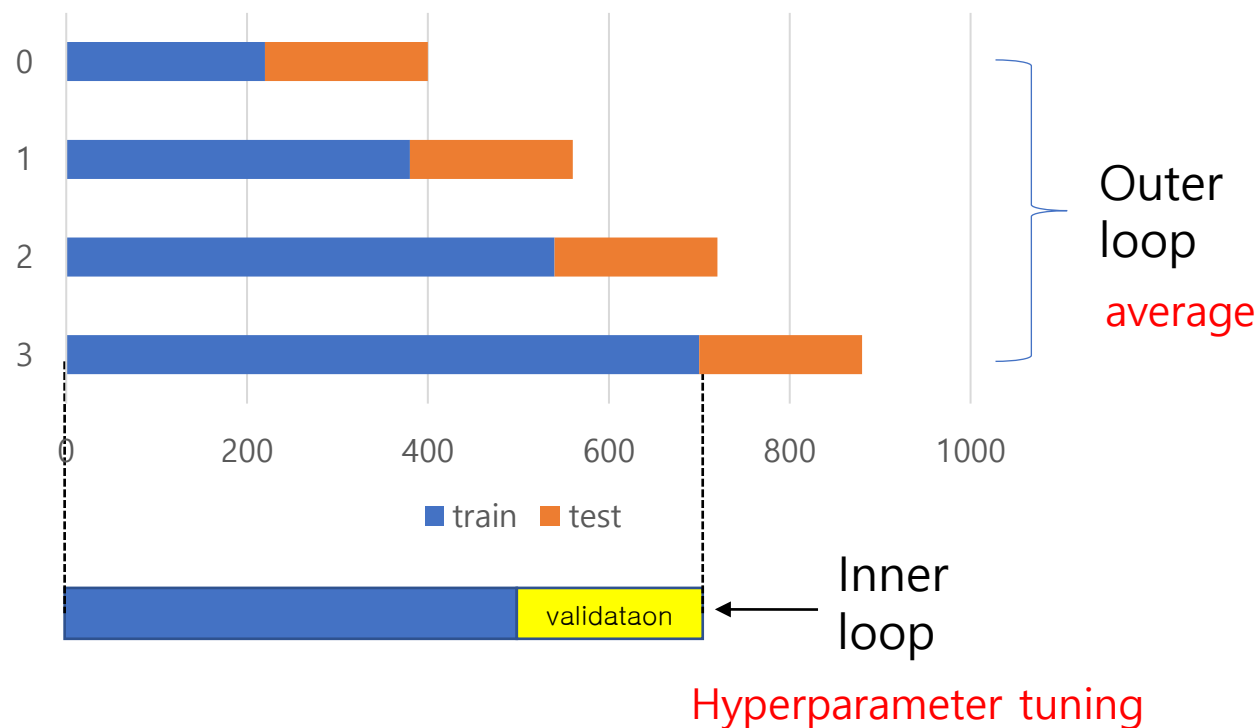
Experimental setting

- Stock dataset split in timeseries data

Expanding window Cross Validation



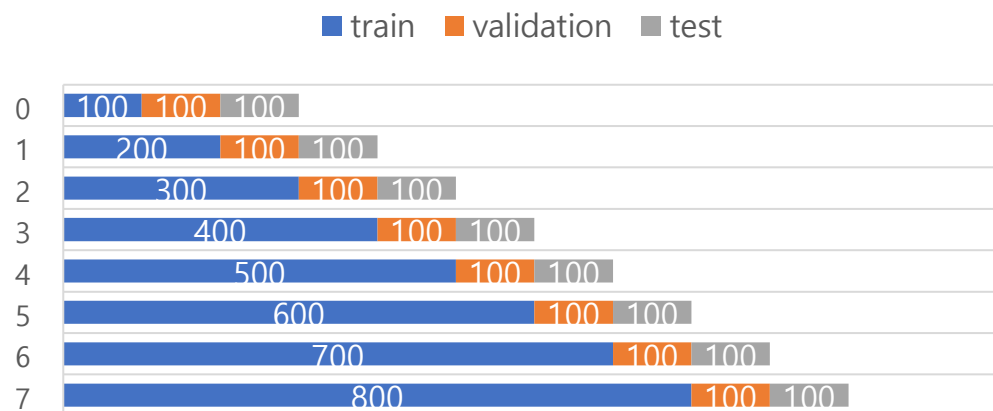
Nasted time series Cross Validation



Experimental setting

- Nested time series Cross Validation

NESTED TIME SERIES CROSS VALIDATION



Train : validation : test = 8 : 1 : 1

- Maximum iteration is 8
- Iteration from 3 to 5 is used universally in timeseries data cross-validation.

- More data should be collected.

Experimental setting

- Investment strategie

Problem determining INPUT length

- **Value** (가치투자)
- **Asset allocation** (자산배분 전략) – Low correlation, Percentage of assets
- **Quality** (우량주 투자)
- **Momentum** (모멘텀 전략)
- **Scalping** - futures contract

- Hyperparameter tuning

Experimental setting

- Investment strategie

- normalization applied to **each split sequence**

- “normalization was applied for each vector of a sequence by using”, A LSTM-based method for stock returns prediction : A case study of China stock market (2015)

- normalization applied to **entire sequence**

- “The raw data is normalized using the min-max normalization”, Stock Price Prediction Using Machine Learning and Deep Learning Frameworks

>> Both of the strategies can be selected

Comparison results

- Mean Absolute Error (mean of 30 iteration)

Data	Proposed	Standard Deviation	RNN	Standard Deviation	LSTM	Standard Deviation	GRU	Standard Deviation	Enc-Dec LSTM	Standard Deviation
KOSPI(^KS11)			0.43766	0.16118	0.47766	0.17696	0.35498	0.20511		
KOSDAQ(^KQ11)			0.67542	0.42041	0.34396	0.23591	0.58558	0.15540		
NASDAQ(^IXIC)			0.16982	0.12240	0.19992	0.14701	0.30154	0.29105		
S&P 500(^GSPC)			0.27173	0.17314	0.30381	0.18892	0.32777	0.21366		
다우존스(^DJI)			0.46639	0.19636	0.32416	0.27579	0.30381	0.28222		
홍콩 항셱(^HSI)			0.46317	0.36042	0.43535	0.16284	0.48169	0.42692		
일본 니케이(^N225)			0.34984	0.38875	0.36982	0.27727	0.41324	0.29420		
독일 DAX(^GDAXI)			0.62471	0.38013	0.58874	0.33467	0.79542	0.26657		
프랑스 CAC(^FCHI)			0.60441	0.34994	0.63870	0.26792	0.59372	0.45986		
스페인 IBEX(^IBEX)			0.63394	0.36560	0.77685	0.36033	0.86915	0.30716		
대만 기권(^TWII)			0.41339	0.31937	0.31519	0.20755	0.20310	0.10558		
네덜란드 AEX(^AEX)			0.49485	0.27032	0.59644	0.09128	0.36838	0.26837		
인도 섹스(^BSESN)			0.33171	0.24805	0.13168	0.10168	0.38599	0.21899		
브라질 보베스파(^BVSP)			0.41152	0.37538	0.36163	0.20548	0.35056	0.26931		
Gold price(GC=F)			0.29466	0.21839	0.33495	0.28829	0.42788	0.30360		
Oil price(음수 존재)			0.79086	0.38909	0.97982	0.41658	0.89699	0.44741		
10년 만기 미국 국채										
10년 만기 한국 국채										
비트코인 암호화폐(BTC-USD)			0.22535	0.26065	0.12989	0.09778	0.27947	0.21729		
이더리움 암호화폐(ETH-USD)			0.29825	0.37333	0.22369	0.18312	0.23613	0.29791		

Comparison results

- Mean Squared Error (mean of 30 iteration)

Data	Proposed	Standard Deviation	RNN	Standard Deviation	LSTM	Standard Deviation	GRU	Standard Deviation	Enc-Dec LSTM	Standard Deviation
KOSPI(^KS11)			0.22728	0.14274	0.26626	0.18000	0.17899	0.13924		
KOSDAQ(^KQ11)			0.65732	0.74672	0.18085	0.19230	0.37660	0.16560		
NASDAQ(^IXIC)			0.05209	0.05710	0.06397	0.08652	0.18330	0.32174		
S&P 500(^GSPC)			0.14021	0.11880	0.12992	0.13232	0.16066	0.16487		
다우존스(^DJI)			0.26034	0.14951	0.18290	0.25362	0.17818	0.25300		
홍콩 항셱(^HSI)			0.35978	0.44986	0.22423	0.13424	0.44076	0.58950		
일본 니케이(^N225)			0.27942	0.51590	0.21703	0.18422	0.26168	0.25765		
독일 DAX(^GDAXI)			0.54582	0.50546	0.46994	0.38980	0.71604	0.38921		
프랑스 CAC(^FCHI)			0.51147	0.43619	0.48356	0.43489	0.57309	0.69745		
스페인 IBEX(^IBEX)			0.55217	0.53490	0.74537	0.55371	0.86404	0.52654		
대만 기권(^TWII)			0.27999	0.29800	0.14459	0.16020	0.06273	0.04288		
네덜란드 AEX(^AEX)			0.34038	0.30328	0.37092	0.11577	0.22267	0.27000		
인도 섹스(^BSESN)			0.17762	0.23462	0.02900	0.04069	0.20793	0.24125		
브라질 보베스파(^BVSP)			0.33830	0.50504	0.18680	0.17276	0.20316	0.30504		
Gold price(GC=F)			0.14913	0.19464	0.20655	0.30246	0.31766	0.34988		
Oil price(음수 존재)			0.78436	0.71295	1.13945	0.86519	1.04687	0.90051		
10년 만기 미국 국채										
10년 만기 한국 국채										
비트코인 암호화폐(BTC-USD)			0.16711	0.35788	0.03088	0.04052	0.13302	0.16808		
이더리움 암호화폐(ETH-USD)			0.39393	0.91982	0.10260	0.17476	0.16625	0.37993		

Comparison results

- Mean Absolute Percentage Error (mean of 30 iteration)

Data	Proposed	Standard Deviation	RNN	Standard Deviation	LSTM	Standard Deviation	GRU	Standard Deviation	Enc-Dec LSTM	Standard Deviation
KOSPI(^KS11)			0.27415	0.09080	0.29619	0.09165	0.23634	0.14553		
KOSDAQ(^KQ11)			0.38287	0.17882	0.22036	0.16053	0.34785	0.07961		
NASDAQ(^IXIC)			0.12517	0.09508	0.14031	0.10567	0.20263	0.15708		
S&P 500(^GSPC)			0.17679	0.12533	0.19892	0.12371	0.19812	0.11783		
다우존스(^DJI)			0.27011	0.10301	0.18000	0.13435	0.17178	0.14753		
홍콩 항셱(^HSI)			0.27908	0.20657	0.25255	0.08884	0.26589	0.21251		
일본 니케이(^N225)			0.19605	0.19877	0.22172	0.17049	0.22913	0.15448		
독일 DAX(^GDAXI)			0.29871	0.16001	0.27856	0.13360	0.39148	0.09879		
프랑스 CAC(^FCHI)			0.32702	0.17926	0.34767	0.12899	0.30068	0.20690		
스페인 IBEX(^IBEX)			0.33080	0.15535	0.40299	0.15519	0.45582	0.09680		
대만 기권(^TWII)			0.26344	0.19173	0.20676	0.11777	0.14647	0.09095		
네덜란드 AEX(^AEX)			0.27884	0.15051	0.32757	0.04650	0.20485	0.14349		
인도 섹스(^BSESN)			0.20594	0.13583	0.08452	0.07276	0.24718	0.12276		
브라질 보베스파(^BVSP)			0.23672	0.16168	0.23684	0.10880	0.22980	0.14019		
Gold price(GC=F)			0.19963	0.11654	0.22386	0.15307	0.29347	0.16696		
Oil price(음수 존재)			0.38608	0.13687	0.48556	0.15632	0.43495	0.15239		
10년 만기 미국 국채										
10년 만기 한국 국채										
비트코인 암호화폐(BTC-USD)			0.16539	0.16590	0.10095	0.06925	0.22029	0.15019		
이더리움 암호화폐(ETH-USD)			0.19662	0.18721	0.16590	0.10238	0.16713	0.15998		

Comparison results

- Issue
 - 거의 모든 데이터에서 긴 길이의 데이터를 이용한 iteration 부분이 error가 많이 높은 경향이 있음.
 - 한국 주식시장과 미국 금리

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Appendix

Appendix

- Jarque–bera test
 - 왜도와 첨도가 정규분포와 일치하는지 판단하는 적합도 검정
- ADF test
 - 시계열 데이터가 정상성(stationary)을 만족하는지에 대한 검정
- LM-ARCH 검정
 - ARCH, GARCH와 같은 모형을 적용할 수 있는지에 대한 검정.