The Best K-Exponential Moving Average with Missing Values: Gold Prices in Indonesia, Saudi Arabia, and Turkey during COVID-19

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Abstract. There have been missing values in the gold price data for Indonesia, Saudi Arabia, and Turkey at the weekend so that imputation techniques have been carried out to solve this problem. The imputation method of replacing NAs with the latest non-NA values also known as last observation carried forward (LOCF) made it a solution to overcome the missing values. This study selected the best k-exponential moving average based on the smallest mean absolute percentage error (MAPE) from $T-1$ simulations. The 2-exponential moving average analysis was the best analysis for the price of gold which has missing values in Indonesia, Saudi Arabia, and Turkey during COVID-19, while the largest MAPE values are different for each country.

1. Introduction

Research related to time series data is needed in predicting things that will happen in the future. One of the analyzes that has been widely used to forecast is the exponential moving average. Although this analysis is simple because it is only a development of a simple moving average analysis, it is still able to do good forecasting and is still very often used [17, 10]. Until now, many studies have used exponential moving average analysis. Exponential moving average analysis has been used for knock limit controllers [20]. In this study, the exponential moving average has been used to predict the average and logarithmic reference of the intensity of the machine beats. This analysis has also been applied to the Kalman filter [21]. Such research has presented a new adaptive extended Kalman filter for nonlinear discrete-time systems that handles variations in noise covariance. The covariance of noise is estimated at each sample time by calculating the covariance of the innovation term with an exponential moving average. The exponential moving average analysis has also been a new stochastic volatility model with expected returns that vary with time on financial markets [15].

One form of investment that is relatively stable for a long time is gold. The current condition of the Covid-19 pandemic caused uncertain economic conditions so that many people are more careful in investing. In general, the type of investment that is considered safe is the choice of many people because gold is not affected by inflation. Research related to the price of gold has been carried out in several countries including China, Ukraine, Saudi Arabia, Venezuela, Argentina [13], Indonesia, Malaysia, Philippines, Singapore, Thailand, China, Japan, South Korea [27], Pakistan [1], Turkey [7], etc. However, not all data on the gold price have complete data, such as those in the World Gold Council or in other words, the data has missing values. In some cases, the data is not completely available or it is better known as data that has missing values. This can happen if the information on

an object is not provided completely, it is difficult to identify, or if the information is not there. If there are many missing values in a study, it can reduce statistical power and can result in biased estimates, potentially leading to invalid conclusions. Therefore imputation technique is needed for this problem [11]. In terms of investment, complete data makes it easy for investors to make decisions quickly. Research related to missing values has been done a lot including for clustering [8], multivariate time series [25], active learning [9], a novel weighted distance threshold method [5], electronic health records [23], air pollution [18], financial statement fraud [6], software performance of components [4], mining gradual patterns [19], mail survey [16], spatial [3], obstetrics clinical data [2], autoencoder [12], transfer learning [14], encoder signals [26], Bayesian network [24], industry [22], etc.

This study selected the best exponential moving average analysis with the missing values of all possible k-exponential moving averages. The value of k that has been tested in this study is from 2 to $T-1$ total data. This analysis has been applied to gold price data in Indonesia, Saudi Arabia and Turkey during COVID-19. These countries represented several Muslim-majority countries that still make gold a symbol of tradition and investment. Indonesia represented Asia, Saudi Arabia represented Arabia, and Turkey represented Europe. The research focused on the COVID-19 pandemic period because this is an important and interesting issue. Finally, the smallest MAPE value has been used to select the k-exponential moving average on gold price data for Indonesia, Saudi Arabia, and Turkey during covid-19.

2. Methods

The data used in this study is the gold price data (troy ounce) which has been obtained from the world gold council from January 1, 2020 to April 30, 2021. In the data obtained, there are missing values for the weekend so imputation techniques have been carried out to solve the problem. This study has replaced NAs with the latest non-NA values. This Mtechnique has been used because it adopted the concept of lag in the time series data. This technique is also known as last observation carried forward (LOCF). After the data is complete, then an exponential moving average analysis has been carried out for all possible k values for each country using (1).

$$EMA_T = \left(\frac{2Y_T}{1+k}\right) + \left(1 - \left(\frac{2}{1+k}\right)\right) EMA_{T-1} \tag{1}$$

where EMA_T is exponential moving average for today, Y_T is actual data for today, k is the number of time periods, and EMA_{T-1} is exponential moving average for yesterday. This study selected the best k based on the smallest mean absolute percentage error (MAPE) using (2). MAPE has been chosen for this study because it is expressed as a percentage so it is easy to explain, does not depend on the scale and can be used to compare forecasts at different scales. In particular, the price of gold used the currency of each country. So there is a large scale difference between the Indonesian currency with Turkey and Saudi Arabia currency.

$$MAPE = \frac{100}{n} \sum_{T=1}^{n} \left| \frac{Y_T - S_T}{Y_T} \right| \tag{2}$$

where n is number the summation iteration happens for non-NA values and S_T is the smoothed values. The total data that has been carried out is 486 (1 January 2020-30 April 2021). So that the exponential moving average analysis for k = 2, 3, …, 485 used for the total data as shown in (3).

$$Simulation\ for\ (k - EMA) = \sum_{k=2}^{T-1} (k - EMA) \tag{3}$$

where $k - EMA$ is exponential moving average with k number of time periods and T is total data in time series.

3. Result

Based on the data that has been obtained, there are missing values every weekend. The percentages of missing values (yellow) and complete data (blue) can be seen in Figure 1. Based on Figure 1, there are 28 percent missing values for Saudi Arabia (SAR), Turkey (TRY), and Indonesia (IDR) country data. After replacing NAs with the latest non-NA values, the percentage of missing data becomes 0 percent and the exponential moving average analysis was ready to be carried out as in Figure 2. Based on Figure 2, there are no longer bar graphs that are yellow or in another sense that the missing values are already overcome.

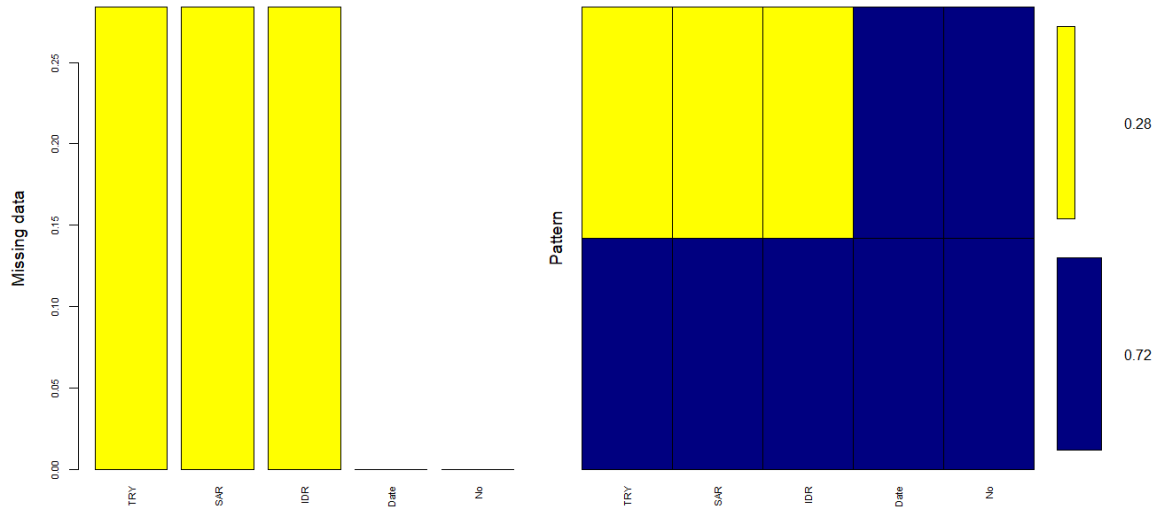

Figure 1. Percentage of data before imputation.

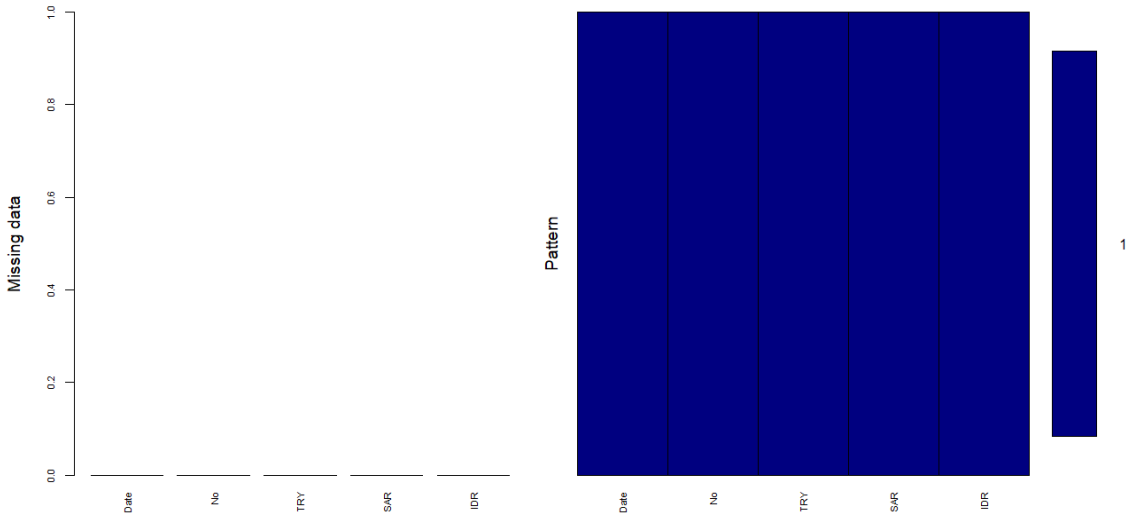

Figure 2. Percentage of data after imputation

The total data available in this study were 486 (1 January 2020-30 April 2021). So that the exponential moving average analysis that has been tried was from the 2-exponential moving average until the 485-exponential moving average. The MAPE that has been obtained from each exponential moving average analysis for each country can be seen in Table 1, Table 2 and Table 3.

Table 1. MAPE EMA for gold price in Indonesia

k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE
2	0.237	40	2.45	78	3.574	116	3.994	154	4.445	192	5.005	230	4.408	268	3.317	306	2.368	344	2.153	382	2.044	420	2.522	458	1.073
3	0.403	41	2.489	79	3.606	117	4.002	155	4.454	193	5.007	231	4.38	269	3.296	307	2.345	345	2.161	383	2.063	421	2.54	459	1.026
4	0.534	42	2.528	80	3.633	118	4.01	156	4.477	194	5.01	232	4.343	270	3.276	308	2.32	346	2.168	384	2.083	422	2.548	460	0.975
5	0.647	43	2.566	81	3.655	119	4.017	157	4.498	195	5.013	233	4.311	271	3.257	309	2.291	347	2.177	385	2.103	423	2.55	461	0.92
6	0.745	44	2.606	82	3.679	120	4.026	158	4.513	196	5.015	234	4.287	272	3.237	310	2.265	348	2.187	386	2.122	424	2.537	462	0.859
7	0.83	45	2.644	83	3.708	121	4.033	159	4.528	197	5.019	235	4.264	273	3.216	311	2.235	349	2.196	387	2.132	425	2.522	463	0.835
8	0.911	46	2.68	84	3.728	122	4.047	160	4.543	198	5.019	236	4.24	274	3.192	312	2.211	350	2.209	388	2.141	426	2.508	464	0.789
9	0.987	47	2.716	85	3.737	123	4.062	161	4.561	199	5.018	237	4.217	275	3.167	313	2.186	351	2.214	389	2.153	427	2.486	465	0.798
10	1.059	48	2.751	86	3.747	124	4.077	162	4.584	200	5.015	238	4.191	276	3.141	314	2.159	352	2.217	390	2.166	428	2.463	466	0.778
11	1.126	49	2.787	87	3.753	125	4.095	163	4.607	201	5.013	239	4.172	277	3.113	315	2.16	353	2.206	391	2.178	429	2.416	467	0.756
12	1.19	50	2.822	88	3.763	126	4.105	164	4.628	202	5.011	240	4.148	278	3.085	316	2.157	354	2.199	392	2.19	430	2.371	468	0.731
13	1.251	51	2.856	89	3.773	127	4.116	165	4.646	203	5.007	241	4.127	279	3.056	317	2.159	355	2.192	393	2.199	431	2.312	469	0.69
14	1.308	52	2.889	90	3.784	128	4.129	166	4.664	204	4.998	242	4.1	280	3.028	318	2.153	356	2.185	394	2.217	432	2.251	470	0.698
15	1.36	53	2.917	91	3.792	129	4.14	167	4.681	205	4.991	243	4.073	281	2.999	319	2.142	357	2.177	395	2.226	433	2.187	471	0.663
16	1.412	54	2.944	92	3.8	130	4.153	168	4.703	206	4.981	244	4.045	282	2.979	320	2.131	358	2.165	396	2.234	434	2.117	472	0.705
17	1.461	55	2.974	93	3.813	131	4.166	169	4.723	207	4.966	245	4.019	283	2.959	321	2.119	359	2.155	397	2.241	435	2.085	473	0.706
18	1.508	56	2.997	94	3.819	132	4.179	170	4.744	208	4.951	246	3.99	284	2.93	322	2.112	360	2.144	398	2.249	436	2.051	474	0.708
19	1.556	57	3.023	95	3.826	133	4.193	171	4.766	209	4.938	247	3.961	285	2.901	323	2.106	361	2.134	399	2.26	437	2.026	475	0.709
20	1.603	58	3.053	96	3.833	134	4.207	172	4.785	210	4.921	248	3.931	286	2.873	324	2.103	362	2.123	400	2.285	438	1.974	476	0.721
21	1.649	59	3.078	97	3.843	135	4.221	173	4.804	211	4.903	249	3.905	287	2.843	325	2.102	363	2.112	401	2.313	439	1.919	477	0.752
22	1.693	60	3.105	98	3.847	136	4.232	174	4.825	212	4.884	250	3.879	288	2.821	326	2.095	364	2.104	402	2.309	440	1.861	478	0.64
23	1.736	61	3.132	99	3.853	137	4.242	175	4.839	213	4.862	251	3.853	289	2.793	327	2.088	365	2.097	403	2.317	441	1.827	479	0.58
24	1.78	62	3.158	100	3.859	138	4.253	176	4.852	214	4.839	252	3.825	290	2.771	328	2.08	366	2.089	404	2.326	442	1.808	480	0.545
25	1.825	63	3.187	101	3.866	139	4.263	177	4.866	215	4.817	253	3.802	291	2.745	329	2.086	367	2.081	405	2.332	443	1.784	481	0.498
26	1.869	64	3.214	102	3.873	140	4.273	178	4.88	216	4.795	254	3.771	292	2.719	330	2.094	368	2.072	406	2.358	444	1.751	482	0.433
27	1.914	65	3.242	103	3.881	141	4.284	179	4.896	217	4.773	255	3.735	293	2.692	331	2.105	369	2.064	407	2.387	445	1.728	483	0.521
28	1.959	66	3.267	104	3.888	142	4.293	180	4.911	218	4.75	256	3.7	294	2.665	332	2.113	370	2.055	408	2.418	446	1.704	484	0.468
29	2.002	67	3.289	105	3.901	143	4.307	181	4.927	219	4.719	257	3.666	295	2.641	333	2.111	371	2.031	409	2.449	447	1.679	485	0.645
30	2.045	68	3.31	106	3.905	144	4.318	182	4.938	220	4.683	258	3.632	296	2.611	334	2.109	372	2.007	410	2.463	448	1.654		
31	2.087	69	3.332	107	3.914	145	4.33	183	4.949	221	4.651	259	3.595	297	2.585	335	2.106	373	1.987	411	2.478	449	1.61		
32	2.128	70	3.354	108	3.917	146	4.341	184	4.961	222	4.618	260	3.56	298	2.558	336	2.099	374	1.973	412	2.494	450	1.576		
33	2.168	71	3.378	109	3.928	147	4.352	185	4.97	223	4.586	261	3.523	299	2.531	337	2.11	375	1.978	413	2.507	451	1.552		
34	2.208	72	3.398	110	3.939	148	4.363	186	4.977	224	4.549	262	3.491	300	2.504	338	2.124	376	1.983	414	2.504	452	1.516		
35	2.248	73	3.43	111	3.949	149	4.38	187	4.983	225	4.528	263	3.458	301	2.478	339	2.133	377	1.989	415	2.5	453	1.478		
36	2.289	74	3.458	112	3.96	150	4.393	188	4.989	226	4.506	264	3.425	302	2.45	340	2.14	378	1.995	416	2.488	454	1.438		
37	2.329	75	3.487	113	3.971	151	4.406	189	4.994	227	4.483	265	3.39	303	2.431	341	2.147	379	2.004	417	2.492	455	1.353		
38	2.369	76	3.511	114	3.98	152	4.419	190	5	228	4.458	266	3.365	304	2.413	342	2.154	380	2.01	418	2.495	456	1.226		
39	2.41	77	3.549	115	3.986	153	4.433	191	5.002	229	4.433	267	3.338	305	2.39	343	2.155	381	2.025	419	2.496	457	1.117		

Table 2. MAPE EMA for gold price in Saudi Arabia

k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE
2	0.225	40	1.98	78	2.824	116	3.54	154	4.159	192	4.674	230	4.482	268	3.967	306	3.495	344	3.193	382	2.426	420	2.189	458	1.192
3	0.384	41	2.008	79	2.832	117	3.556	155	4.171	193	4.682	231	4.47	269	3.963	307	3.484	345	3.188	383	2.416	421	2.205	459	1.134
4	0.51	42	2.037	80	2.837	118	3.571	156	4.188	194	4.69	232	4.451	270	3.959	308	3.471	346	3.182	384	2.406	422	2.232	460	1.072
5	0.617	43	2.065	81	2.846	119	3.585	157	4.205	195	4.698	233	4.432	271	3.955	309	3.453	347	3.177	385	2.398	423	2.27	461	1.005
6	0.709	44	2.095	82	2.854	120	3.603	158	4.224	196	4.704	234	4.423	272	3.951	310	3.438	348	3.172	386	2.39	424	2.276	462	0.932
7	0.785	45	2.124	83	2.864	121	3.62	159	4.244	197	4.712	235	4.414	273	3.947	311	3.413	349	3.166	387	2.37	425	2.281	463	0.899
8	0.853	46	2.151	84	2.884	122	3.636	160	4.264	198	4.72	236	4.405	274	3.939	312	3.387	350	3.165	388	2.346	426	2.288	464	0.847
9	0.912	47	2.179	85	2.908	123	3.654	161	4.285	199	4.726	237	4.397	275	3.931	313	3.36	351	3.156	389	2.327	427	2.287	465	0.835
10	0.968	48	2.207	86	2.935	124	3.672	162	4.302	200	4.733	238	4.383	276	3.919	314	3.331	352	3.148	390	2.308	428	2.276	466	0.783
11	1.02	49	2.235	87	2.957	125	3.693	163	4.319	201	4.74	239	4.377	277	3.907	315	3.321	353	3.124	391	2.288	429	2.253	467	0.726
12	1.071	50	2.263	88	2.98	126	3.708	164	4.333	202	4.747	240	4.366	278	3.895	316	3.308	354	3.104	392	2.266	430	2.23	468	0.662
13	1.118	51	2.289	89	3.004	127	3.725	165	4.347	203	4.754	241	4.358	279	3.883	317	3.3	355	3.084	393	2.243	431	2.189	469	0.564
14	1.161	52	2.314	90	3.028	128	3.744	166	4.362	204	4.757	242	4.344	280	3.869	318	3.289	356	3.063	394	2.228	432	2.147	470	0.507
15	1.203	53	2.336	91	3.05	129	3.761	167	4.375	205	4.761	243	4.33	281	3.853	319	3.273	357	3.042	395	2.206	433	2.104	471	0.398
16	1.242	54	2.357	92	3.072	130	3.778	168	4.393	206	4.761	244	4.316	282	3.844	320	3.257	358	3.022	396	2.177	434	2.046	472	0.36
17	1.279	55	2.379	93	3.101	131	3.796	169	4.409	207	4.756	245	4.303	283	3.835	321	3.24	359	3.002	397	2.149	435	2.022	473	0.383
18	1.314	56	2.397	94	3.124	132	3.813	170	4.424	208	4.752	246	4.285	284	3.818	322	3.225	360	2.982	398	2.119	436	1.995	474	0.411
19	1.348	57	2.417	95	3.148	133	3.831	171	4.441	209	4.75	247	4.271	285	3.801	323	3.208	361	2.962	399	2.09	437	1.977	475	0.443
20	1.38	58	2.439	96	3.171	134	3.849	172	4.456	210	4.742	248	4.258	286	3.783	324	3.194	362	2.941	400	2.079	438	1.935	476	0.481
21	1.411	59	2.457	97	3.197	135	3.867	173	4.47	211	4.734	249	4.247	287	3.763	325	3.186	363	2.921	401	2.067	439	1.891	477	0.51
22	1.443	60	2.482	98	3.219	136	3.883	174	4.486	212	4.725	250	4.235	288	3.752	326	3.172	364	2.9	402	2.085	440	1.844	478	0.42
23	1.473	61	2.506	99	3.239	137	3.897	175	4.498	213	4.715	251	4.224	289	3.735	327	3.159	365	2.878	403	2.093	441	1.819	479	0.379
24	1.502	62	2.529	100	3.263	138	3.912	176	4.509	214	4.703	252	4.211	290	3.724	328	3.143	366	2.852	404	2.102	442	1.808	480	0.374
25	1.531	63	2.555	101	3.281	139	3.926	177	4.52	215	4.692	253	4.203	291	3.709	329	3.138	367	2.825	405	2.109	443	1.789	481	0.368
26	1.559	64	2.579	102	3.3	140	3.941	178	4.531	216	4.68	254	4.189	292	3.694	330	3.147	368	2.798	406	2.095	444	1.765	482	0.36
27	1.591	65	2.6	103	3.318	141	3.957	179	4.545	217	4.671	255	4.17	293	3.679	331	3.152	369	2.77	407	2.078	445	1.752	483	0.432
28	1.621	66	2.618	104	3.337	142	3.97	180	4.558	218	4.662	256	4.155	294	3.664	332	3.157	370	2.742	408	2.058	446	1.739	484	0.399
29	1.652	67	2.634	105	3.359	143	3.986	181	4.572	219	4.643	257	4.139	295	3.651	333	3.173	371	2.691	409	2.041	447	1.725	485	0.533
30	1.684	68	2.649	106	3.372	144	4.001	182	4.582	220	4.62	258	4.124	296	3.631	334	3.188	372	2.64	410	2.039	448	1.712		
31	1.715	69	2.664	107	3.388	145	4.016	183	4.593	221	4.602	259	4.106	297	3.617	335	3.203	373	2.593	411	2.038	449	1.682		
32	1.746	70	2.679	108	3.4	146	4.032	184	4.604	222	4.584	260	4.09	298	3.601	336	3.226	374	2.549	412	2.036	450	1.658		
33	1.775	71	2.697	109	3.419	147	4.046	185	4.613	223	4.567	261	4.07	299	3.586	337	3.232	375	2.53	413	2.035	451	1.643		
34	1.804	72	2.714	110	3.437	148	4.06	186	4.623	224	4.541	262	4.055	300	3.57	338	3.234	376	2.51	414	2.052	452	1.619		
35	1.833	73	2.737	111	3.454	149	4.08	187	4.633	225	4.531	263	4.038	301	3.555	339	3.233	377	2.49	415	2.081	453	1.593		
36	1.863	74	2.759	112	3.472	150	4.097	188	4.644	226	4.523	264	4.02	302	3.537	340	3.228	378	2.477	416	2.105	454	1.566		
37	1.893	75	2.781	113	3.493	151	4.113	189	4.652	227	4.512	265	3.999	303	3.528	341	3.223	379	2.466	417	2.13	455	1.49		
38	1.923	76	2.8	114	3.511	152	4.128	190	4.662	228	4.502	266	3.987	304	3.519	342	3.218	380	2.447	418	2.155	456	1.366		
39	1.951	77	2.809	115	3.524	153	4.143	191	4.669	229	4.491	267	3.974	305	3.507	343	3.208	381	2.436	419	2.18	457	1.246		

Table 3. MAPE EMA for gold price in Turkey

k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE	k	MAPE
2	0.265	40	3.469	78	5.585	116	6.98	154	7.961	192	8.95	230	9.212	268	8.905	306	7.877	344	6.702	382	5.775	420	6.91	458	11.32
3	0.462	41	3.534	79	5.639	117	7.004	155	7.986	193	8.97	231	9.206	269	8.896	307	7.828	345	6.674	383	5.765	421	7.008	459	11.398
4	0.622	42	3.598	80	5.697	118	7.028	156	8.017	194	8.99	232	9.192	270	8.888	308	7.777	346	6.641	384	5.755	422	7.088	460	11.481
5	0.76	43	3.663	81	5.75	119	7.05	157	8.048	195	9.011	233	9.186	271	8.879	309	7.72	347	6.61	385	5.745	423	7.171	461	11.571
6	0.886	44	3.727	82	5.803	120	7.076	158	8.08	196	9.031	234	9.184	272	8.872	310	7.667	348	6.578	386	5.737	424	7.252	462	11.673
7	0.996	45	3.79	83	5.859	121	7.102	159	8.112	197	9.051	235	9.182	273	8.86	311	7.607	349	6.544	387	5.724	425	7.335	463	11.729
8	1.099	46	3.852	84	5.911	122	7.128	160	8.145	198	9.072	236	9.182	274	8.839	312	7.541	350	6.513	388	5.712	426	7.418	464	11.798
9	1.2	47	3.914	85	5.955	123	7.153	161	8.178	199	9.092	237	9.183	275	8.826	313	7.475	351	6.477	389	5.701	427	7.539	465	11.841
10	1.295	48	3.975	86	6.001	124	7.18	162	8.207	200	9.112	238	9.178	276	8.808	314	7.398	352	6.443	390	5.69	428	7.654	466	11.901
11	1.386	49	4.038	87	6.044	125	7.208	163	8.237	201	9.132	239	9.178	277	8.788	315	7.358	353	6.402	391	5.68	429	7.774	467	11.967
12	1.472	50	4.1	88	6.087	126	7.232	164	8.263	202	9.152	240	9.174	278	8.768	316	7.308	354	6.371	392	5.665	430	7.903	468	12.038
13	1.557	51	4.16	89	6.13	127	7.258	165	8.289	203	9.172	241	9.174	279	8.747	317	7.281	355	6.338	393	5.658	431	8.02	469	12.171
14	1.639	52	4.219	90	6.175	128	7.281	166	8.315	204	9.19	242	9.17	280	8.727	318	7.259	356	6.307	394	5.652	432	8.141	470	12.27
15	1.718	53	4.275	91	6.214	129	7.304	167	8.34	205	9.207	243	9.165	281	8.703	319	7.236	357	6.273	395	5.644	433	8.268	471	12.454
16	1.796	54	4.33	92	6.254	130	7.327	168	8.368	206	9.221	244	9.16	282	8.681	320	7.212	358	6.241	396	5.638	434	8.378	472	12.612
17	1.874	55	4.387	93	6.296	131	7.351	169	8.396	207	9.232	245	9.156	283	8.657	321	7.189	359	6.21	397	5.631	435	8.468	473	12.733
18	1.952	56	4.438	94	6.336	132	7.374	170	8.422	208	9.242	246	9.147	284	8.629	322	7.163	360	6.183	398	5.622	436	8.59	474	12.871
19	2.028	57	4.49	95	6.373	133	7.396	171	8.45	209	9.254	247	9.142	285	8.6	323	7.137	361	6.156	399	5.63	437	8.722	475	13.034
20	2.103	58	4.545	96	6.41	134	7.422	172	8.475	210	9.263	248	9.135	286	8.572	324	7.111	362	6.128	400	5.652	438	8.857	476	13.201
21	2.176	59	4.596	97	6.45	135	7.449	173	8.501	211	9.267	249	9.129	287	8.54	325	7.102	363	6.096	401	5.674	439	8.998	477	13.373
22	2.247	60	4.65	98	6.483	136	7.474	174	8.528	212	9.27	250	9.123	288	8.514	326	7.083	364	6.081	402	5.731	440	9.145	478	13.387
23	2.321	61	4.703	99	6.516	137	7.499	175	8.552	213	9.272	251	9.117	289	8.483	327	7.063	365	6.07	403	5.791	441	9.286	479	13.319
24	2.394	62	4.755	100	6.548	138	7.524	176	8.575	214	9.273	252	9.109	290	8.455	328	7.045	366	6.057	404	5.853	442	9.434	480	13.164
25	2.465	63	4.807	101	6.58	139	7.548	177	8.599	215	9.274	253	9.105	291	8.425	329	7.02	367	6.038	405	5.919	443	9.553	481	12.957
26	2.535	64	4.865	102	6.612	140	7.572	178	8.624	216	9.274	254	9.095	292	8.396	330	6.995	368	6.018	406	5.958	444	9.772	482	12.665
27	2.606	65	4.92	103	6.644	141	7.601	179	8.65	217	9.277	255	9.083	293	8.366	331	6.97	369	5.997	407	6	445	9.983	483	12.529
28	2.673	66	4.971	104	6.678	142	7.626	180	8.676	218	9.283	256	9.072	294	8.335	332	6.946	370	5.981	408	6.044	446	10.204	484	12.428
29	2.741	67	5.02	105	6.711	143	7.655	181	8.704	219	9.281	257	9.062	295	8.307	333	6.936	371	5.943	409	6.093	447	10.452	485	12.408
30	2.809	68	5.07	106	6.736	144	7.682	182	8.727	220	9.263	258	9.051	296	8.276	334	6.926	372	5.905	410	6.16	448	10.544		
31	2.876	69	5.119	107	6.762	145	7.709	183	8.751	221	9.253	259	9.038	297	8.244	335	6.914	373	5.882	411	6.228	449	10.662		
32	2.941	70	5.168	108	6.782	146	7.736	184	8.775	222	9.245	260	9.026	298	8.21	336	6.912	374	5.849	412	6.297	450	10.758		
33	3.006	71	5.218	109	6.807	147	7.76	185	8.798	223	9.24	261	9.011	299	8.175	337	6.892	375	5.841	413	6.38	451	10.843		
34	3.071	72	5.264	110	6.832	148	7.789	186	8.821	224	9.222	262	8.999	300	8.142	338	6.867	376	5.833	414	6.458	452	10.904		
35	3.136	73	5.316	111	6.857	149	7.822	187	8.844	225	9.223	263	8.983	301	8.104	339	6.847	377	5.825	415	6.525	453	10.968		
36	3.203	74	5.369	112	6.883	150	7.852	188	8.868	226	9.223	264	8.967	302	8.059	340	6.82	378	5.812	416	6.591	454	11.037		
37	3.272	75	5.422	113	6.911	151	7.879	189	8.889	227	9.222	265	8.948	303	8.017	341	6.794	379	5.8	417	6.664	455	11.105		
38	3.339	76	5.472	114	6.934	152	7.907	190	8.912	228	9.218	266	8.935	304	7.975	342	6.769	380	5.785	418	6.738	456	11.172		
39	3.404	77	5.532	115	6.956	153	7.934	191	8.931	229	9.214	267	8.919	305	7.926	343	6.737	381	5.785	419	6.819	457	11.247		

Based on Table 1-3, the smallest MAPE value for gold prices in Indonesia, Saudi Arabia, and Turkey occurred when k = 2, while the largest MAPE value was different for each country. Based on Table 1, it can be seen that the smallest MAPE value of EMA for Indonesia was 0.237% when k = 2, while the largest value was 5.019% when k = 198. It can also be seen in the table that the relative MAPE increased along with the increase in the value of k until it reaches the highest MAPE when k = 198. Furthermore, the MAPE value slowly decreased again relatively to k = 485. For Saudi Arabia, the smallest MAPE EMA value was 0.225% when k = 2 and the largest value was 4.761% when k = 205 can be seen in Table 2. Based on Table 2 as well, the MAPE value that has been obtained from the exponential moving average analysis increased gradually relative to k = 205 then relative to k = 485. And it can also be seen in Table 3, the MAPE EMA for Turkey has the smallest value of 0.265% when k = 2 and the largest value was 13.387% when k = 478. Based on Table 3, Turkey has a unique MAPE value because the MAPE value increased relatively when k = 2 to k = 218. It has also been seen from the table that the MAPE value decreased relatively from k = 218 to k = 398. Finally, according to Table 3, when k = 398 increased relatively until it reaches the highest MAPE value when k = 478 and the MAPE value decreased relatively slightly when k = 485.

Figure 3. Graph of actual data and EMA for gold price in Indonesia

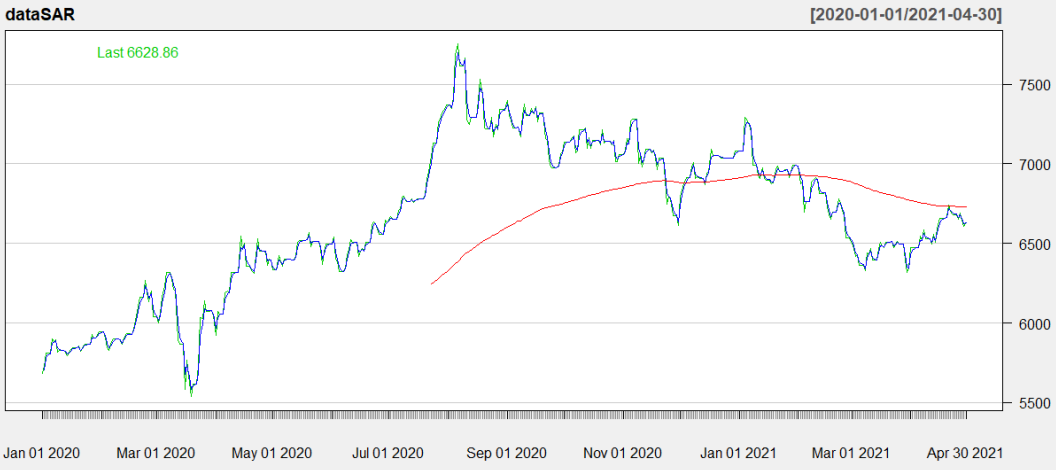

Figure 4. Graph of actual data and EMA for gold price in Saudi Arabia

Figure 5. Graph of actual data and EMA for gold price in Turkey

Gold price chart, exponential moving average when k = 2 (2-EMA), and exponential moving average when k = 198 (198-EMA) for Indonesia can be seen in Figure 3. For Saudi Arabia, gold price chart, exponential moving average when k = 2 (2-EMA), and the exponential moving average when k = 205 (205-EMA) can be seen in Figure 4. Figure 5 was a graph that has been formed from the price of gold, the exponential moving average when k = 2 (2-EMA), and the current exponential moving average k = 478 (478-EMA) for Turkey. Based on Figure 3-5, it can be seen that the green line was a graph of the actual gold price data from January 1, 2020 to April 30, 2021. Based on Figure 3, it can be seen that the blue line was 2-EMA and the red line was 198-EMA for gold price in Indonesia. The blue line that can be seen based on Figure 4 was 2-EMA and the red line was 205-EMA for Saudi Arabia. Meanwhile, based on Figure 5, the 478-EMA which has been denoted by the red line and the 2-EMA which has been denoted by the blue line was the exponential moving average for Turkey.

4. Conclusion and Discussion

This study replaced NA with previous non-NA values for the case of missing values. This missing value imputation technique is also known as the last observation carried forward (LOCF). After the data was complete, then the exponential moving average analysis is carried out for all possible k values for each country. The value of k that has been used was from 2 to 485 because the number of series in this study was 486. Based on the results explained that the exponential moving average analysis when k = 2 for gold prices in Indonesia, Saudi Arabia, and Turkey was the best analysis for data that had missing values. The imputation technique produced a relatively small MAPE. The MAPE that has been generated from the exponential moving average analysis when k = 2 for gold prices in Indonesia was 0.237%, in Saudi Arabia it was 0.225%, and in Turkey it was 0.265%. The mentioned MAPE values were even less than 1%.

Based on the results obtained previously, of course the 2-EMA method can be used as a reference for gold investment in the future. The research that has been done, of course, still has a lot of potential that can be developed, such as using bigger data and even being applied to big data. Comparing several dynamic imputation techniques which are then compared to MAPE or the error that will be obtained is also a special topic of interest to be developed for the future. In addition, in further research, it is necessary to form an exponential moving average model that can be used for forecasting.

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