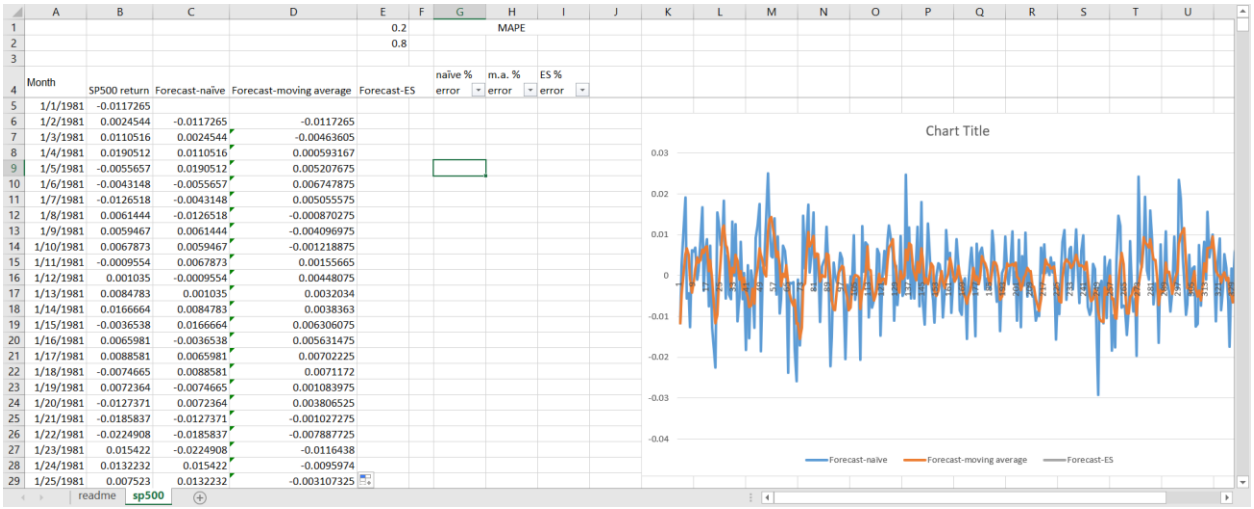
Forecasting and time series: demo notes

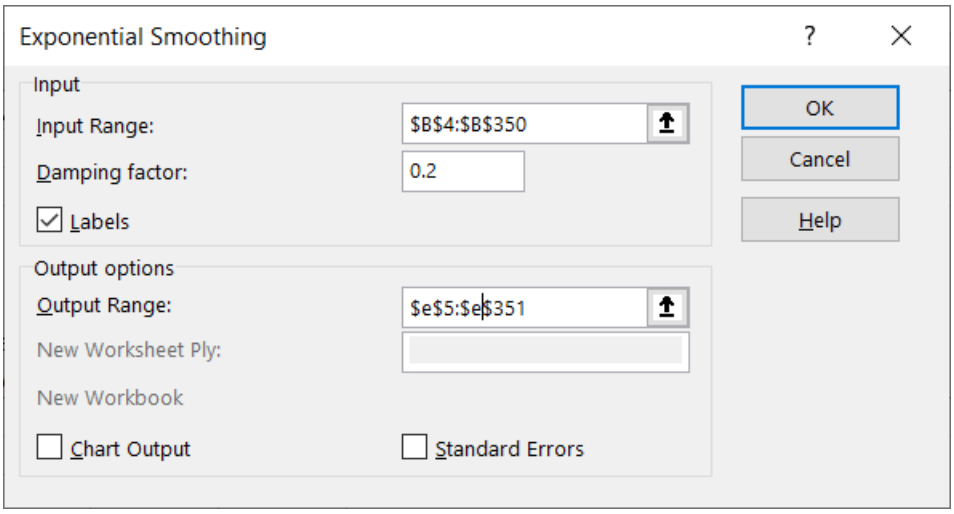
Demo: `sp500.xlsx`

1. We would like to forecast daily returns of the S&P 500. We will use three methods:
    a. Column C is a naive forecast. We will just use the value of the previous period to forecast the next period.
    b. Column D is a rolling average. We will do a rolling average of the last 4 days. For the first three days of the forecast, we don't have that full history so we will just use the first 1, 2 and 3 days. Our chart and data now looks like this.



	A	B	C	D	E	F	G	H	I	J
1					0.2			MAPE		
2					0.8					
3										
4	Month	SP500 return	Forecast-naïve	Forecast-moving average	Forecast-ES		naïve % error	m.a. % error	ES % error	
5	1/1/1981	-0.0117265								
6	1/2/1981	0.0024544	-0.0117265	-0.0117265						
7	1/3/1981	0.0110516	0.0024544	-0.00463605						
8	1/4/1981	0.0190512	0.0110516	0.000593167						
9	1/5/1981	-0.0055657	0.0190512	0.005207675						
10	1/6/1981	-0.0043148	-0.0055657	0.006747875						
11	1/7/1981	-0.0126518	-0.0043148	0.005055575						
12	1/8/1981	0.0061444	-0.0126518	-0.000870275						
13	1/9/1981	0.0059467	0.0061444	-0.004096975						
14	1/10/1981	0.0067873	0.0059467	-0.001218875						
15	1/11/1981	-0.0009554	0.0067873	0.00155665						
16	1/12/1981	0.001035	-0.0009554	0.00448075						
17	1/13/1981	0.0084783	0.001035	0.0032034						
18	1/14/1981	0.0166664	0.0084783	0.0038363						
19	1/15/1981	-0.0036538	0.0166664	0.006306075						
20	1/16/1981	0.0065981	-0.0036538	0.005631475						
21	1/17/1981	0.0088581	0.0065981	0.00702225						
22	1/18/1981	-0.0074665	0.0088581	0.0071172						
23	1/19/1981	0.0072364	-0.0074665	0.001083975						
24	1/20/1981	-0.0127371	0.0072364	0.003806525						
25	1/21/1981	-0.0185837	-0.0127371	-0.001027275						
26	1/22/1981	-0.0224908	-0.0185837	-0.007887725						
27	1/23/1981	0.015422	-0.0224908	-0.0116438						
28	1/24/1981	0.0132232	0.015422	-0.0095974						
29	1/25/1981	0.007523	0.0132232	-0.003107325						

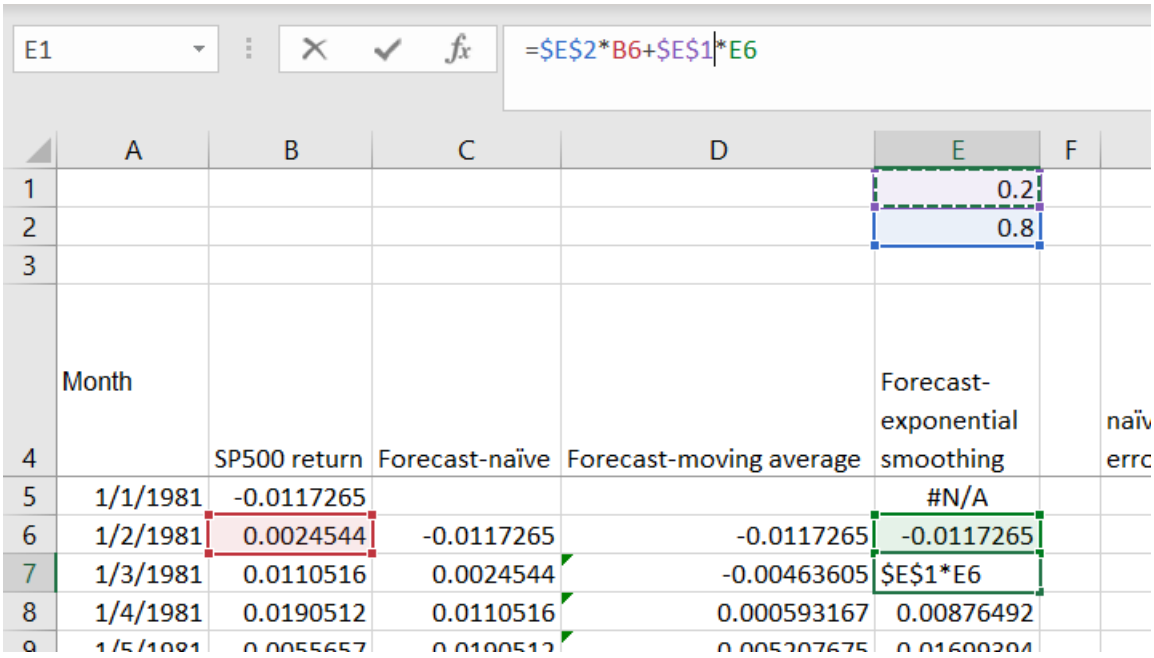
    c. For the last one, exponential smoothing, we will use the ToolPak. Go to **Data > Data Analysis > Exponential Smoothing.**
        i. Your input range is the actual S&P data in column B.
        ii. We will start with a damping factor of .2.
        iii. Our output range will be the blank column E. Do *not* include the label row.



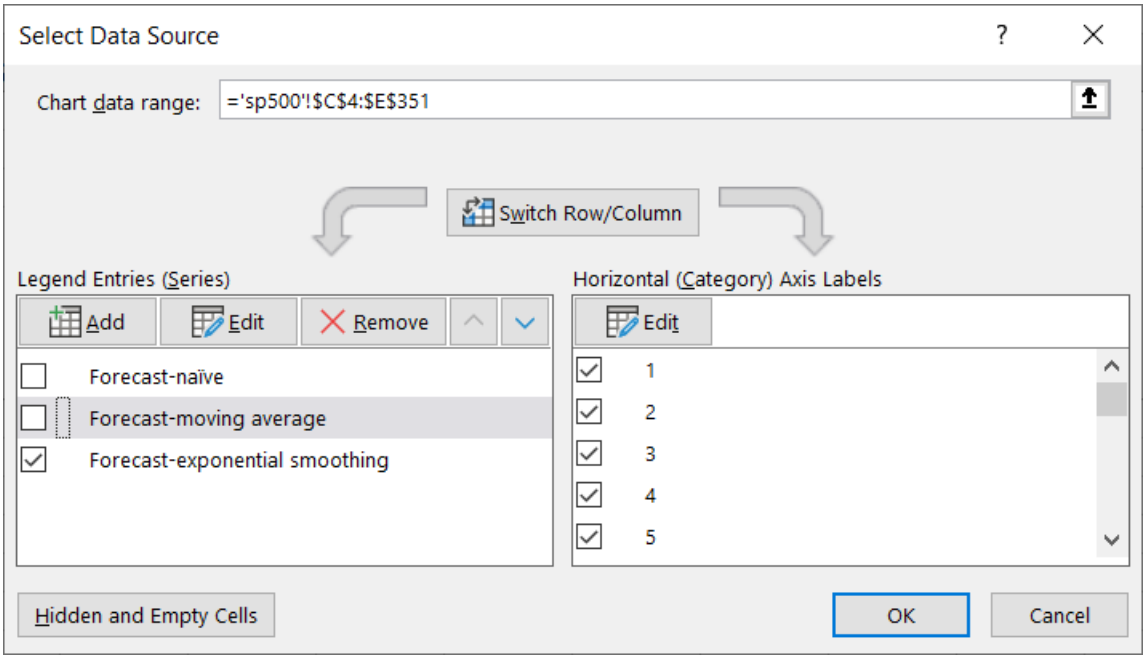
d. You will now see the resulting formulas used for exponential smoothing. Our damping factor is hard-coded into the formula.

	A	B	C	D	E	F	G	H	I	J
1					0.2			MAPE		
2					0.8					
3										
4	Month	SP500 return	Forecast-naïve	Forecast-moving average	Forecast-exponential smoothing		naïve % error	m.a. % error	ES % error	
5	1/1/1981	-0.0117265			#N/A					
6	1/2/1981	0.0024544	-0.0117265	-0.0117265	-0.0117265					
7	1/3/1981	0.0110516	0.0024544	-0.00463605	=0.8*B6+0.2*E6					
8	1/4/1981	0.0190512	0.0110516	0.000593167	0.00876492					
9	1/5/1981	-0.0055657	0.0190512	0.005207675	0.01699394					
10	1/6/1981	-0.0043148	-0.0055657	0.006747875	-0.00105377					
11	1/7/1981	-0.0126518	-0.0043148	0.005055575	-0.00366259					
12	1/8/1981	0.0061444	-0.0126518	-0.000870275	-0.01085396					
13	1/9/1981	0.0059467	0.0061444	-0.004096975	0.00274473					

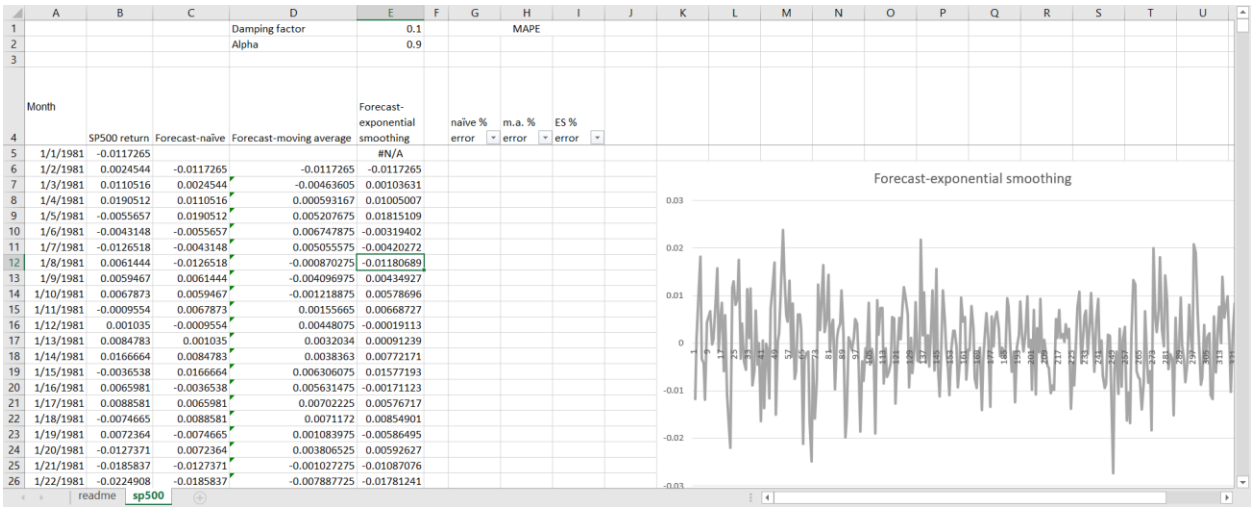
e. Let's make this more dynamic by substituting our .2 and .8 with cell references. That way we can change the damping factor and see what happens to our curve.



f. To make it easier to see the exponential smoothing forecast, you can right-click on the chart, click Select Data, and un-check the other forecasts from showing up on the chart.



g. You will see that the more of a damping factor that is included, the more jagged the forecast is. We are weighting the current datapoint more highly.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1				Damping factor	0.1			MAPE													
2				Alpha	0.9																
3																					
4	Month	SP500 return	Forecast-naïve	Forecast-moving average	Forecast-exponential smoothing		naïve % error	m.a. % error	ES % error												
5	1/1/1981	-0.0117265			#N/A																
6	1/2/1981	0.0024544	-0.0117265	-0.0117265	-0.0117265																
7	1/3/1981	0.0110516	0.0024544	-0.00463605	0.00103631																
8	1/4/1981	0.0190512	0.0110516	0.000593167	0.01005007																
9	1/5/1981	-0.0055657	0.0190512	0.005207675	0.01815109																
10	1/6/1981	-0.0043148	-0.0055657	0.006747875	-0.00319402																
11	1/7/1981	-0.0126518	-0.0043148	0.005055575	-0.00420272																
12	1/8/1981	0.0061444	-0.0126518	-0.000870275	-0.01180689																
13	1/9/1981	0.0059467	0.0061444	-0.004096975	0.00434927																
14	1/10/1981	0.0067873	0.0059467	-0.001218875	0.00578696																
15	1/11/1981	-0.0009554	0.0067873	0.00155665	0.00668727																
16	1/12/1981	0.001035	-0.0009554	0.00448075	-0.00019113																
17	1/13/1981	0.0084783	0.001035	0.0032034	0.00091239																
18	1/14/1981	0.0166664	0.0084783	0.0038363	0.00772171																
19	1/15/1981	-0.0036538	0.0166664	0.006306075	0.01577193																
20	1/16/1981	0.0065981	-0.0036538	0.005631475	-0.00171123																
21	1/17/1981	0.0088581	0.0065981	0.00702225	0.00576717																
22	1/18/1981	-0.0074665	0.0088581	0.0071172	0.00854901																
23	1/19/1981	0.0072364	-0.0074665	0.001083975	-0.00586495																
24	1/20/1981	-0.0127371	0.0072364	0.003806525	0.00592627																
25	1/21/1981	-0.0185837	-0.0127371	-0.001027275	-0.01087076																
26	1/22/1981	-0.0224908	-0.0185837	-0.007887725	-0.01781241																

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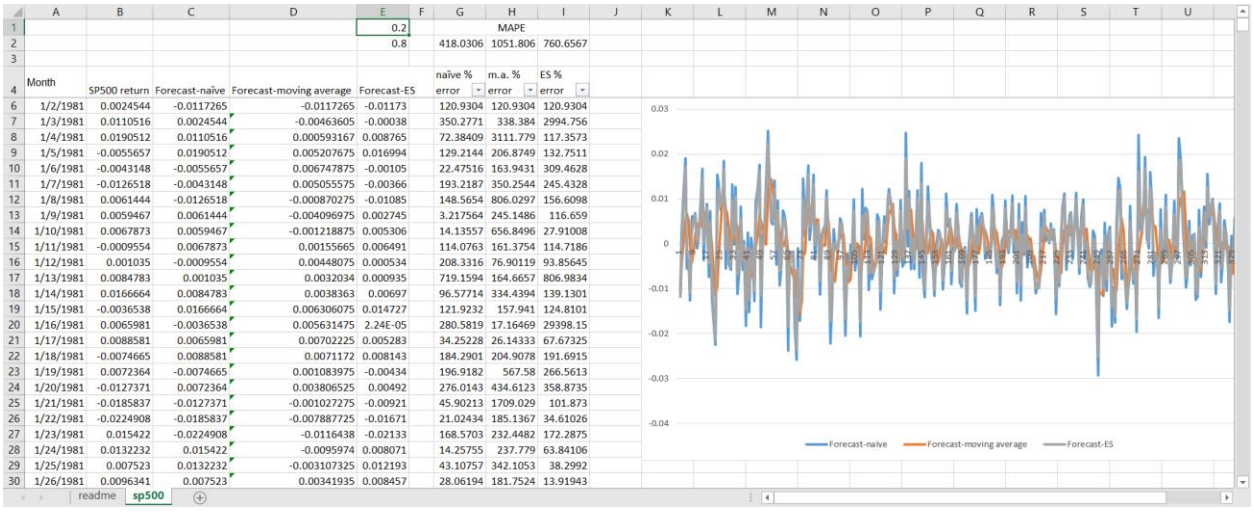
2. Now let's evaluate the accuracy of our forecasts using the mean absolute percentage error, MAPE. I have the formulas for MAPE at the bottom of the columns, so paste them, fill them down the rows and then take the average for each one. Your model should look something like this. I have turned the other forecasts back on in the chart below.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1					0.2			MAPE													
2					0.8		418.0306	1051.806	760.6567												
3																					
4	Month	SP500 return	Forecast-naïve	Forecast-moving average	Forecast-ES		naïve % error	m.a. % error	ES % error												
6	1/2/1981	0.0024544	-0.0117265	-0.0117265	-0.01173		120.9304	120.9304	120.9304												
7	1/3/1981	0.0110516	0.0024544	-0.00463605	-0.00038		350.2771	338.384	2994.756												
8	1/4/1981	0.0190512	0.0110516	0.000593167	0.008765		72.38409	3111.779	117.3573												
9	1/5/1981	-0.0055657	0.0190512	0.005207675	0.016994		129.2144	206.8749	132.7511												
10	1/6/1981	-0.0043148	-0.0055657	0.006747875	-0.00105		22.47516	163.9431	309.4628												
11	1/7/1981	-0.0126518	-0.0043148	0.005055575	-0.00366		193.2187	350.2544	245.4328												
12	1/8/1981	0.0061444	-0.0126518	-0.000870275	-0.01085		148.5654	806.0297	156.6098												
13	1/9/1981	0.0059467	0.0061444	-0.004096975	0.002745		3.217564	245.1486	116.659												
14	1/10/1981	0.0067873	0.0059467	-0.001218875	0.005306		14.13557	656.8496	27.91008												
15	1/11/1981	-0.0009554	0.0067873	0.00155665	0.006491		114.0763	161.3754	114.7186												
16	1/12/1981	0.001035	-0.0009554	0.00448075	0.000534		208.3316	76.90119	93.85645												
17	1/13/1981	0.0084783	0.001035	0.0032034	0.000935		719.1594	164.6657	806.9834												
18	1/14/1981	0.0166664	0.0084783	0.0038363	0.00697		96.57714	334.4394	139.1301												
19	1/15/1981	-0.0036538	0.0166664	0.006306075	0.014727		121.9232	157.941	124.8101												
20	1/16/1981	0.0065981	-0.0036538	0.005631475	2.24E-05		280.5819	17.16469	29398.15												
21	1/17/1981	0.0088581	0.0065981	0.00702225	0.005283		34.25228	26.14333	67.67325												
22	1/18/1981	-0.0074665	0.0088581	0.0071172	0.008143		184.2901	204.9078	191.6915												
23	1/19/1981	0.0072364	-0.0074665	0.001083975	-0.00434		196.9182	567.58	266.5613												
24	1/20/1981	-0.0127371	0.0072364	0.003806525	0.00492		276.0143	434.6123	358.8735												
25	1/21/1981	-0.0185837	-0.0127371	-0.001027275	-0.00921		45.90213	1709.029	101.873												
26	1/22/1981	-0.0224908	-0.0185837	-0.007887725	-0.01671		21.02434	185.1367	34.61026												
27	1/23/1981	0.015422	-0.0224908	-0.0116438	-0.02133		168.5703	232.4482	172.2875												
28	1/24/1981	0.0132232	0.015422	-0.0095974	0.008071		14.25755	237.779	63.84106												
29	1/25/1981	0.007523	0.0132232	-0.003107325	0.012193		43.10757	342.1053	38.2992												
30	1/26/1981	0.0096341	0.007523	0.00341935	0.008457		28.06194	181.7524	13.91943												

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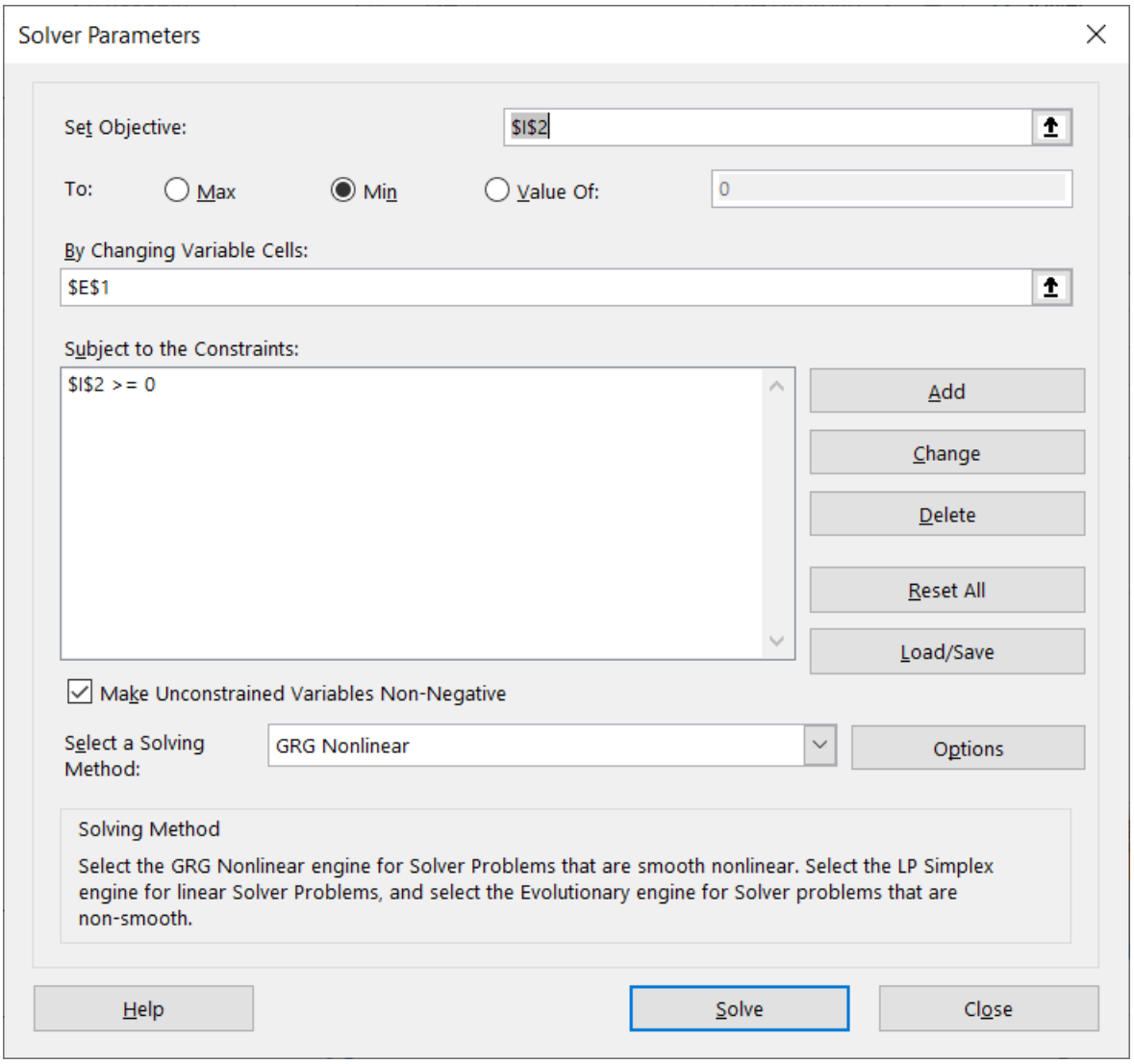
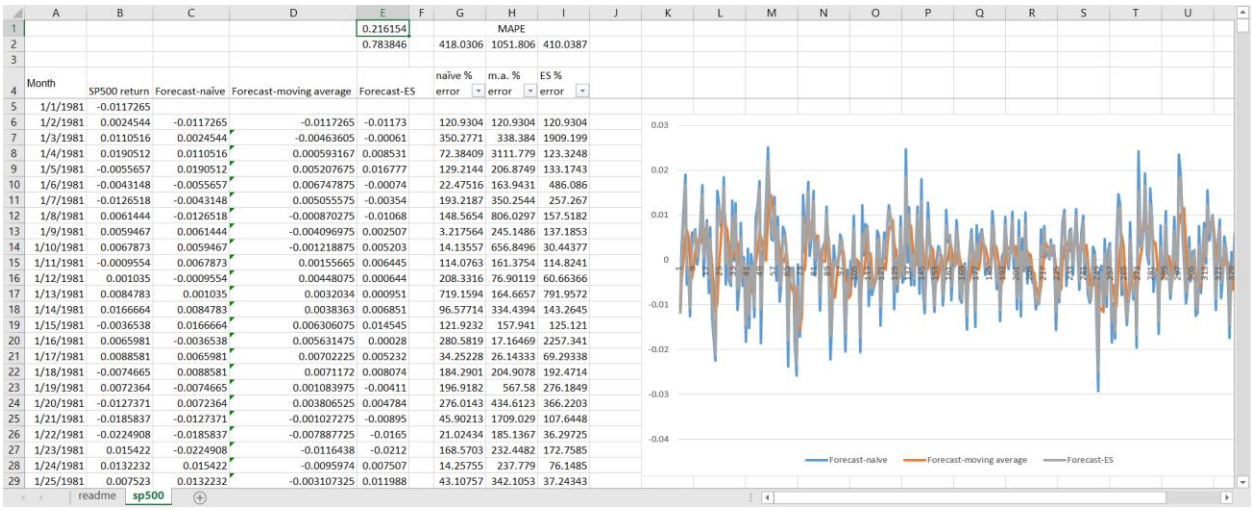
3. It looks like currently the forecast with the lowest MAPE is the naive forecast. But can we do better with the smoothing forecast by re-adjusting our damping factor to minimize MAPE? This sounds like a job for Solver:



4. Turns out that we can do better with exponential smoothing by optimizing the damping factor.
    a. There is a *lot* more you could do to build up on this forecast. This is a good foundation, though.



	A	B	C	D	E	F	G	H	I	J
1					0.216154			MAPE		
2					0.783846		418.0306	1051.806	410.0387	
3										
4	Month	SP500 return	Forecast-naïve	Forecast-moving average	Forecast-ES		naïve % error	m.a. % error	ES % error	
5	1/1/1981	-0.0117265								
6	1/2/1981	0.0024544	-0.0117265	-0.0117265	-0.01173		120.9304	120.9304	120.9304	
7	1/3/1981	0.0110516	0.0024544	-0.00463605	-0.00061		350.2771	338.384	1909.199	
8	1/4/1981	0.0190512	0.0110516	0.000593167	0.008531		72.38409	3111.779	123.3248	
9	1/5/1981	-0.0055657	0.0190512	0.005207675	0.016777		129.2144	206.8749	133.1743	
10	1/6/1981	-0.0043148	-0.0055657	0.006747875	-0.00074		22.47516	163.9431	486.086	
11	1/7/1981	-0.0126518	-0.0043148	0.005055575	-0.00354		193.2187	350.2544	257.267	
12	1/8/1981	0.0061444	-0.0126518	-0.000870275	-0.01068		148.5654	806.0297	157.5182	
13	1/9/1981	0.0059467	0.0061444	-0.004096975	0.002507		3.217564	245.1486	137.1853	
14	1/10/1981	0.0067873	0.0059467	-0.001218875	0.005203		14.13557	656.8496	30.44377	
15	1/11/1981	-0.0009554	0.0067873	0.00155665	0.006445		114.0763	161.3754	114.8241	
16	1/12/1981	0.001035	-0.0009554	0.00448075	0.000644		208.3316	76.90119	60.66366	
17	1/13/1981	0.0084783	0.001035	0.0032034	0.000951		719.1594	164.6657	791.9572	
18	1/14/1981	0.0166664	0.0084783	0.0038363	0.006851		96.57714	334.4394	143.2645	
19	1/15/1981	-0.0036538	0.0166664	0.006306075	0.014545		121.9232	157.941	125.121	
20	1/16/1981	0.0065981	-0.0036538	0.005631475	0.00028		280.5819	17.16469	2257.341	
21	1/17/1981	0.0088581	0.0065981	0.00702225	0.005232		34.25228	26.14333	69.29338	
22	1/18/1981	-0.0074665	0.0088581	0.0071172	0.008074		184.2901	204.9078	192.4714	
23	1/19/1981	0.0072364	-0.0074665	0.001083975	-0.00411		196.9182	567.58	276.1849	
24	1/20/1981	-0.0127371	0.0072364	0.003806525	0.004784		276.0143	434.6123	366.2203	
25	1/21/1981	-0.0185837	-0.0127371	-0.001027275	-0.00895		45.90213	1709.029	107.6448	
26	1/22/1981	-0.0224908	-0.0185837	-0.007887725	-0.0165		21.02434	185.1367	36.29725	
27	1/23/1981	0.015422	-0.0224908	-0.0116438	-0.0212		168.5703	232.4482	172.7585	
28	1/24/1981	0.0132232	0.015422	-0.0095974	0.007507		14.25755	237.779	76.1485	
29	1/25/1981	0.007523	0.0132232	-0.003107325	0.011988		43.10757	342.1053	37.24343	

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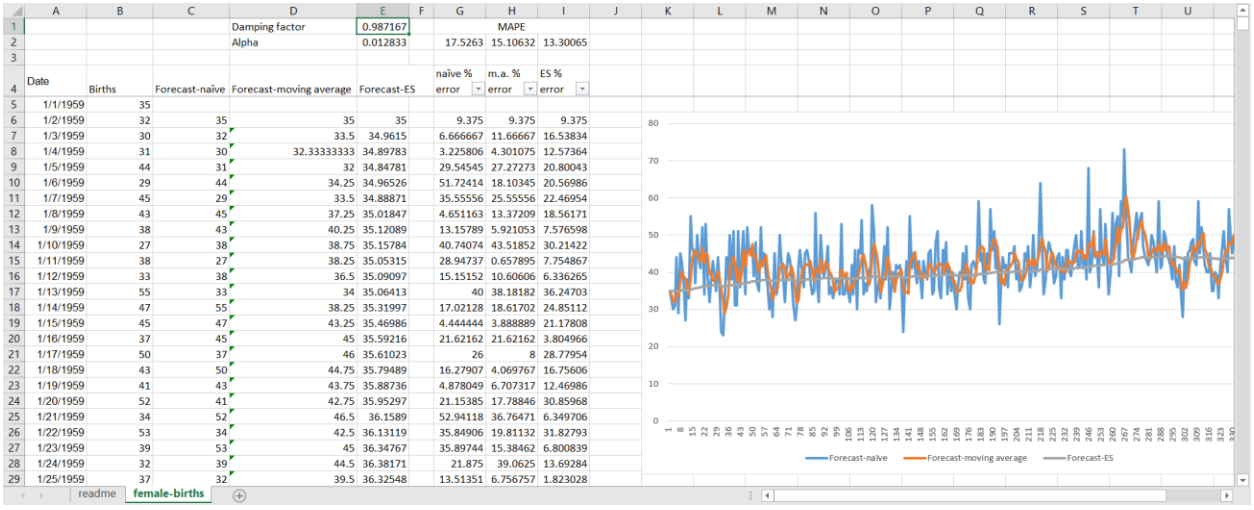
Drill: `female-births.xlsx`

Turns out in this case, a very high damping factor works best. This makes the forecast line look nearly smooth. We do get a better forecast accuracy than the other methods this way.



	A	B	C	D	E	F	G	H	I	J
1				Damping factor	0.987167			MAPE		
2				Alpha	0.012833		17.5263	15.10632	13.30065	
3										
4	Date	Births	Forecast-naïve	Forecast-moving average	Forecast-ES		naïve % error	m.a. % error	ES % error	
5	1/1/1959	35								
6	1/2/1959	32	35	35	35		9.375	9.375	9.375	
7	1/3/1959	30	32	33.5	34.9615		6.666667	11.66667	16.53834	
8	1/4/1959	31	30	32.33333333	34.89783		3.225806	4.301075	12.57364	
9	1/5/1959	44	31	32	34.84781		29.54545	27.27273	20.80043	
10	1/6/1959	29	44	34.25	34.96526		51.72414	18.10345	20.56986	
11	1/7/1959	45	29	33.5	34.88871		35.55556	25.55556	22.46954	
12	1/8/1959	43	45	37.25	35.01847		4.651163	13.37209	18.56171	
13	1/9/1959	38	43	40.25	35.12089		13.15789	5.921053	7.576598	
14	1/10/1959	27	38	38.75	35.15784		40.74074	43.51852	30.21422	
15	1/11/1959	38	27	38.25	35.05315		28.94737	0.657895	7.754867	
16	1/12/1959	33	38	36.5	35.09097		15.15152	10.60606	6.336265	
17	1/13/1959	55	33	34	35.06413		40	38.18182	36.24703	
18	1/14/1959	47	55	38.25	35.31997		17.02128	18.61702	24.85112	
19	1/15/1959	45	47	43.25	35.46986		4.444444	3.888889	21.17808	
20	1/16/1959	37	45	45	35.59216		21.62162	21.62162	3.804966	
21	1/17/1959	50	37	46	35.61023		26	8	28.77954	
22	1/18/1959	43	50	44.75	35.79489		16.27907	4.069767	16.75606	
23	1/19/1959	41	43	43.75	35.88736		4.878049	6.707317	12.46986	
24	1/20/1959	52	41	42.75	35.95297		21.15385	17.78846	30.85968	
25	1/21/1959	34	52	46.5	36.1589		52.94118	36.76471	6.349706	
26	1/22/1959	53	34	42.5	36.13119		35.84906	19.81132	31.82793	
27	1/23/1959	39	53	45	36.34767		35.89744	15.38462	6.800839	
28	1/24/1959	32	39	44.5	36.38171		21.875	39.0625	13.69284	
29	1/25/1959	37	32	39.5	36.32548		13.51351	6.756757	1.823028	

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