Agribusiness Analysis and Forecasting

Seasonality and Cycles

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Uses for Seasonal Models

A **seasonal** pattern is a recurring pattern of variability in a time series that occurs of the course of each year.

- Prices usually differ from one season to another.
  - Tomatoes, avocados, grapes, lettuce
  - Wheat, corn, hay
  - 450-550 pound Steers
  - Gasoline
- Many quantity series have seasonal patterns (e.g., production)
- To forecast seasonal data you must explicitly incorporate variables in the model to reflect the seasonality.

Seasonal Forecasts

- Multiple observations per year are needed to observe a seasonal pattern.
- Seasonal patterns repeat each year due to
  - Seasonal production due to climate or weather.
  - Seasonal demand (holidays, summer, etc.).
- A cycle may also be present, with a seasonal pattern mapped on the top of the cycle.

Seasonal Forecasts

Example of monthly prices showing seasonal variability on top of a multi-year cycle.

Econometric Models for Forecasting Seasonal Patterns

- Seasonal indices
- Composite forecast models
- Harmonic regression model
- Dummy variable regression model

Steps for Estimating a Seasonal Index

- Graph the data.
- Check for a trend and seasonal pattern.
- Develop and use a seasonal index if no trend is present.
- Develop a composite forecast model that includes trend and seasonal components.

Two kinds of Seasonal Indices

- Price Index
  - The traditional index value shows the relative relationship of price between months or quarters.
  - It is ONLY used with price data.

- Fractional Contribution Index
  - If the variable is a quantity, calculate a fractional contribution index to show the relative contribution of each month to the annual total quantity.
  - It is ONLY used with quantities.

Seasonal Price Index Model

- Seasonal price index is a simple way to forecast a monthly or quarterly series.
- Index represents the fraction that each month's price is above or below the annual mean.
  - If the seasonal index for June is 1.10 it means the June price averages 110% of the annual average price.
  - If the seasonal index for December is 0.85 it means the December price averages 85% of the annual average price.
- A function in Simetar estimates the seasonal price index for time series with a few simple steps, so it is very easy to use this type of forecasting model.

Seasonal Price Index Model Estimated by Simetar

Years	1	2	3	4	5	6	7	8	9	10	11	12
1	71.06	71.47	70.06	70.31	68.75	67.08	64.8	63.12	59.44	63.94	66.62	64.12
2	65.12	65.25	62.72	59.15	60.19	60	64.5	65.25	66.13	64.7	64.94	64.68
3	66.88	72.6	73.66	75.43	76.38	75.63	77.53	81.5	85.4	78.81	80.71	79.5
4	83.66	88	88.3	89.75	89.5	82.8	81.5	84.1	84.25	87.5	85.7	85.33
5	89.13	90.88	90.5	88.25	88.4	92.83	93.83	90.7	86.5	87	85.1	88.08
6	89.85	89.63	95.13	95.25	95.8	94.63	94.38	99.2	94.75	93.3	91.88	98.17
7	96.25	101.75	102.75	103.3	103.19	102.69	99.63	92.94	92.19	91.85	89.38	88.25
8	87.44	87.69	91.15	93.88	90	89.4	89.25	88.01	85.75	85.44	84.25	84.13
9	88.63	92.88	94.35	98.32	97.44	96.45	96.34	95.07	90.5	88.82	86.5	87.67
10	89.57	89.5	92.4	91.88	87.55	84	84.34	83.1	79.32	76.57	77.85	80.08
11	82.45	80.51	78.88	78.19	75.9	73.87	71.83	67.4	65	63.5	62.5	61.5
12	56.9	60.07	56.49	54.94	58.3	57.28	62.67	63.94	60.47	59.14	62.31	63.01
13	71.99	75.8	81.49	85.48	85.15	86.6	86.63	82.98	84	78.79	79.14	81.32
14	90.83	93.17	91.86	89.43	83.85	77.815	72.92	70.915	67.275	71.63	70.445	72.835
15	79.465	84.82	84.405	86.25	81.755	81.16	83.04	81.215	81.52	80.805	84.18	90.25
16	93.675	94.99	96.125	100.36	93.265	95.245	100	87.925	87.22	90.31	96.63	98.975
17	97.72	103.825	103.47	107.545	99.585	107.5	99	96	95	91.16	95.135	96.14
SUM	1400.62	1442.835	1453.74	1467.715	1435.005	1424.98	1422.19	1393.365	1364.715	1353.265	1363.27	1384.04
AVERAGE	82.38941	84.87265	85.51412	86.33618	84.41206	83.82235	83.65824	81.96265	80.27735	79.60382	80.19235	81.41412
ST DEV	11.57589	11.9041	12.96476	14.22	12.60769	13.73284	12.45774	11.46838	11.57323	10.96217	10.82638	11.95711
INDEX	0.994	1.024	1.032	1.042	1.019	1.011	1.009	0.989	0.969	0.961	0.968	0.982
FRAC. CONT. INDEX	0.083	0.085	0.086	0.087	0.085	0.084	0.084	0.082	0.081	0.080	0.081	0.082
INDEX LCI	0.719	0.749	0.735	0.719	0.726	0.690	0.718	0.715	0.686	0.691	0.703	0.695
INDEX UCI	1.270	1.299	1.329	1.365	1.311	1.333	1.301	1.263	1.251	1.230	1.232	1.270
STOCHASTIC INDICES	0.944	0.989	1.023	1.110	1.034	1.033	0.991	0.938	0.999	0.928	0.944	0.969
STOCHASTIC FRACTIONA	0.083	0.089	0.088	0.083	0.083	0.086	0.084	0.081	0.080	0.077	0.081	0.086
ADJ. STOCH.INDICES	0.952	0.997	1.031	1.119	1.042	1.041	0.999	0.946	1.008	0.935	0.952	0.977
ADJ. STOCH.FRACTIONAL	0.083	0.089	0.087	0.083	0.083	0.086	0.084	0.081	0.080	0.077	0.081	0.086

Using a Seasonal Price Index for Forecasting

- Seasonal index has an average of 1.0
- Use seasonal index to forecast monthly prices from annual average price forecast

$$P_{Jan} = \text{Annual Average Price} * Index_{Jan}$$

$$P_{Mar} = \text{Annual Average Price} * Index_{Mar}$$

- Suppose you have a trend forecasted annual average price of \$125, you can develop monthly forecasts using the seasonal price indices, as:

$$\text{January Price} = \$125 * 0.88 = \$110.0$$

$$\text{March Price} = \$125 * 1.08 = \$135.0$$

- The forecast can include risk by using a stochastic forecast of annual price.

Probabilistic Monthly Forecasts

We use the Adjusted Stochastic Indices at the bottom of the Simetar output

	1	2	3	4	5	6	7	8	9	10	11	12
1	71.06	71.47	70.06	70.31	68.75	67.08	64.8	63.12	59.44	63.94	66.62	64.12
2	65.12	65.25	62.72	59.15	60.19	60	64.5	65.25	66.13	64.7	64.94	64.68
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INDEX UCI	1.270	1.299	1.329	1.365	1.311	1.333	1.301	1.263	1.251	1.230	1.232	1.270
STOCHASTIC INDICES	1.021	0.986	1.006	1.054	0.963	1.046	1.013	0.970	1.006	0.937	0.952	1.058
STOCHASTIC FRACTIONAL IND	0.081	0.084	0.088	0.083	0.083	0.085	0.083	0.083	0.084	0.082	0.080	0.085
ADJ.STOCH.INDICES	1.020	0.985	1.005	1.053	0.962	1.045	1.012	0.969	1.005	0.936	0.951	1.057
ADJ.STOCH.FRACTIONAL INDIC	0.081	0.084	0.088	0.083	0.083	0.085	0.083	0.083	0.084	0.082	0.080	0.085

Probabilistic Monthly Forecasts

- Develop probabilistic forecast of the annual price. In this case a trend forecast is used of the annual average prices and 18th period is forecasted.
- Use the stochastic indices to simulate stochastic monthly forecasts.

	F	G	H	I	J	K	L	M	N	O	P	Q	R
33													
34	STOCHASTIC INDICES	0.951	1.031	1.006	1.104	1.084	0.993	0.982	1.020	0.945	0.990	0.944	1.030
35	STOCHASTIC FRACTIO	0.082	0.082	0.085	0.084	0.085	0.087	0.088	0.081	0.081	0.082	0.076	0.084
36	**ADJ.STOCH.INDICES**	**0.945**	**1.024**	**0.999**	**1.097**	**1.076**	**0.986**	**0.976**	**1.013**	**0.939**	**0.983**	**0.938**	**1.023**
37	ADJ.STOCH.FRACTION	0.082	0.082	0.085	0.084	0.086	0.087	0.088	0.081	0.081	0.082	0.077	0.084
38													
39	**Simualte a Monthly Stochastic Price give a Stochastic Annual Forecast**												
40	**Stochastic Annual Price**												
41		**97.59261**	=Y48+Z48*18+NORM(0,Y57)										
42		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
43		**92.23**	**99.94**	**97.50**	**107.06**	**105.06**	**96.26**	**95.22**	**98.84**	**91.63**	**95.94**	**91.54**	**99.88**
44		=$G$41*G36		=$G$41*I36		=$G$41*K36		=$G$41*M36		=$G$41*O36		=$G$41*Q36	

Simetar Simulation Results for 500 Iterations.

Variable	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde	'Price Inde
Mean	88.83	91.52	92.23	93.09	91.03	90.40	90.23	88.40	86.58	85.86	86.50	87.79
StDev	11.11	11.51	11.78	11.80	11.67	11.60	11.54	11.27	11.06	10.96	11.09	11.08
CV	12.50	12.58	12.78	12.67	12.82	12.83	12.79	12.75	12.77	12.77	12.82	12.62
Min	56.46	57.42	58.01	60.49	59.10	58.23	57.92	54.15	55.61	54.51	54.63	51.63
Max	117.61	123.98	124.45	131.95	125.98	129.61	123.03	127.56	121.12	121.55	120.66	119.62
Iteration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Seasonal Price Index Model Estimated by Simetar

[demo]

Seasonal Fractional Contribution Index

- Fractional Contribution Index sums to 1.0 to represent 100% of annual quantity of sales.
- Each month's value is the fraction of total sales that month.
- Use a trend or structural model to forecast annual sales.

$$Sales_{Jan} = \text{Total Annual Sales} * Index_{Jan}$$

$$Sales_{Jun} = \text{Total Annual Sales} * Index_{Jun}$$

- For an annual sales forecast at 340,000 units

$$Sales_{Jan} = 340,000 * 0.050 = 17,000.0$$

$$Sales_{Jun} = 340,000 * 0.076 = 25,840.0$$

- This forecast is useful for input procurement and inventory management.
- The forecast can include risk by using a stochastic forecast of annual sales.

Harmonic Regression for Seasonal Models

- Add sin and cos functions in OLS regression to isolate seasonal variation.
- Define a variable N to represent the number of observations per year
  - Ex.: Monthly observations: $N = 12$
  - Ex.: Weekly observations: $N = 52$
- Create the X Matrix for OLS regression.

$$X_1 \text{ indexes obervations : } T = 1, 2, 3, 4, 5, \ldots.$$

$$X_2 = \sin\left(\frac{2\pi T_t}{N}\right)$$

$$X_3 = \cos\left(\frac{2\pi T_t}{N}\right)$$

- Fit the regression equation as:

$$Y_t = \beta_0 + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \beta_3 X_{3,t}$$

Harmonic Regression for Seasonal Models

This is what the X matrix looks like for a Harmonic Regression.

	A	B	C	D	E
7			**Let SL =**	**12**	
8	**Formulas for Period 1:**			**=SIN(2*PI()*C10/$D$7)**	**=COS(2*PI()*C10/$D$7)**
9		Price	T	Sin(2PiT/SL)	Cos(2PiT/SL)
10	Jan	71.06	1	0.5000000	0.8660254
11	Feb	71.47	2	0.8660254	0.5000000
12	Mar	70.06	3	1.0000000	0.0000000
13	Apr	70.31	4	0.8660254	-0.5000000
14	May	68.75	5	0.5000000	-0.8660254
15	Jun	67.08	6	0.0000000	-1.0000000
16	Jul	64.8	7	-0.5000000	-0.8660254
17	Aug	63.12	8	-0.8660254	-0.5000000
18	Sep	59.44	9	-1.0000000	0.0000000
19	Oct	63.94	10	-0.8660254	0.5000000
20	Nov	66.62	11	-0.5000000	0.8660254
21	Dec	64.12	12	0.0000000	1.0000000
22	Jan	65.12	13	0.5000000	0.8660254
23	Feb	65.25	14	0.8660254	0.5000000

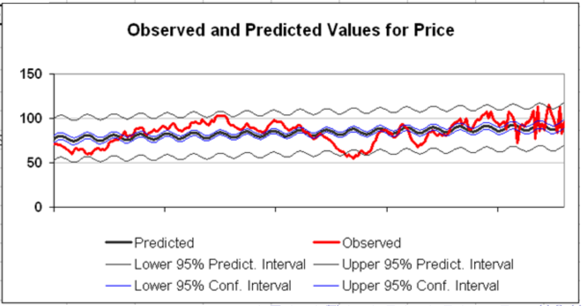
Harmonic Regression for Seasonal Models

- Note that the cos term is not statistically significant, but it MUST be included when using the model to forecast.
- sin and cos are creating the wave effect in the forecast.
- *T* is creating the positive trend in the forecast.
- The model needs more terms to capture the underlying cycle.

OLS Regression Statistics for Price,

F-test	8.147	Prob(F)	0.000	Unrestrict
MSE^1/2	11.835	CV Regr	14.281	F-test
R^2	0.109	Durbin-W	0.068	R^2
$RBar^2$	0.096	Rho	0.967	$RBar^2$
Akaike Inf	4.952	Goldfeld-(	0.360	Akaike Inf
Schwarz I	5.001			Schwarz I

95%	Intercept	T	Sin(2PiT/$	Cos(2PiT/$
Beta	76.714	0.060	2.735	-1.572
S.E.	1.665	0.014	1.173	1.172
t-test	46.083	4.265	2.331	-1.342
Prob(t)	0.000	0.000	0.021	0.181
Elasticity at Mean		0.074	0.000	0.000
Variance Inflation Fa		1.002	1.002	1.000
Partial Correlation		0.289	0.163	-0.094
Semipartial Correlat		0.284661	0.155613	-0.08955



Recap of Harmonic Regression

$$Y_t = \beta_0 + \beta_1 Z_t + \beta_2 T_t + \beta_3 \sin\left(\frac{2\pi T_t}{N}\right) + \beta_4 \cos\left(\frac{2\pi T_t}{N}\right)$$

- The T variable captures the trend in the Y variable.
- The sin and cos capture the seasonal variability in Y.
- The Z variable represents structural variables that could explain changes due to income, population, tastes and preferences, policy shifts.

Harmonic Regression Demo

[demo]

Cycles

- Business cycle
- Beef cycle
- Hog cycle
- Earnings season

Analyzing and Forecasting Cycles

- Cyclical analysis involves analyzing data for underlying cycles.
- Estimate the length of an average cycle and forecast Y variable in part based on cycle length.
- May still include trend, seasonal, and structural variables to be removed with other parts of your model.
- Need adequate data to reflect several cycles

Rules for Cyclical Analysis Models

- Note that a cycle is simply a generalization of the seasonal concept
- Seasonal pattern: one cycle per year
- More general: cyclic pattern that repeats with an arbitrary frequency
- Now define N as the number of observations *per cycle* (previously number of obs per year)
- Example: to reflect a quarterly cycle with weekly obs, $N = 13$
- Example: to a reflect a five-year cycle with monthly obs, $N = 60$

Cyclical Analysis Models

The regression model, including a possible trend, is still just

$$Y = \beta_0 + \beta_1 T + \beta_2 \sin\left(\frac{2\pi T}{N}\right) + \beta_3 \cos\left(\frac{2\pi T}{N}\right)$$

where N = number of observations per cycle.

Steps to estimate a cycle length:

1. Enter N in a cell.
2. Reference the cell with N to calculate all of the sin and cos values in the X matrix.
3. Estimate regression model.
4. Change the value for N, observe the F ratio, $MAPE$, R^2, or information criterion
5. Repeat process for numerous N values and choose the N with the best value for your chosen fit metric

Multiple Simultaneous Cycles

OLS regression model:

$$Y = \beta_0 + \beta_1 T + \beta_2 \sin\left(\frac{2\pi T}{N_1}\right) + \beta_3 \cos\left(\frac{2\pi T}{N_1}\right) + \beta_4 \sin\left(\frac{2\pi T}{N_2}\right) + \beta_5 \cos\left(\frac{2\pi T}{N_2}\right)$$

where: N_1 = Number of obs per cycle for the first cycle and N_2 = Number of obs per cycle for the second cycle

For example: make N_1 the number of observarions per year to reflect a seasonal/annual cycle, and N_2 some larger number to reflect a multi-year cycle.

Results from a combined seasonal and multi-year cycle model

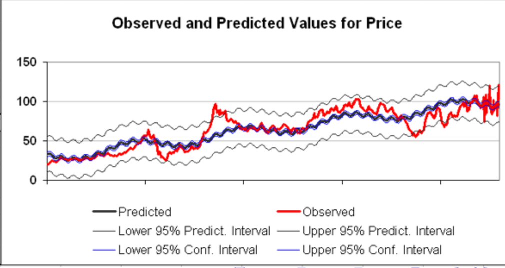
- Monthly data
- Slightly different notation than above: here "cycle length" is the of *years* (not obs) in the multi-year cycle, chosen based on maximum *MAPE*.

	Test Alt. Cycles							
Cycle leng	5	6	7	8	9	10	11	12
R Squared	0.752	0.748	0.759	0.748	0.78	0.811	**0.813**	0.798
MAPE	16.41	16.7239	16.551	16.3628	**15.1482**	15.221	15.8022	17.2846

OLS Regression Statistics for Price,

F-test	311.284	**Prob(F)**	0.000	**Unrestricted Model**	
MSE^1/2	11.453	**CV Regr**	18.022	**F-test**	311.284
R²	0.780	**Durbin-Wa**	0.057	**R²**	0.780
RBar²	0.778	**Rho**	0.970	**RBar²**	0.778
Akaike Inf	4.886	**Goldfeld-Q**	1.026	**Akaike Inf**	4.886
Schwarz I	4.932			**Schwarz I**	4.932

95%	Intercept	T	Sin(2PiT/S	Cos(2PiT/S	Sin(2PiT/C	Cos(2PiT/
Beta	**28.857**	**0.156**	**2.041**	-1.074	**-6.204**	**3.563**
S.E.	1.102	0.004	0.769	0.769	0.787	0.764
t-test	26.180	36.162	2.655	-1.398	-7.887	4.663
Prob(t)	0.000	0.000	0.008	0.163	0.000	0.000
Elasticity at Mean		0.546	0.000	0.000	-0.001	0.001
Variance Inflation Fa		1.032	1.001	1.000	1.028	1.005
Partial Correlation		0.866	0.126	-0.067	-0.353	0.217
Semipartial Correlati		0.80973	0.05944	-0.0313	-0.1766	0.104414



Cycle Demo

[demo]

Seasonal Forecast Using Dummy Variable Models

- Dummy variable regression model can forecast trend and seasonal variability.
- Include a trend if one is present.
- Regression model can be estimate as:

$$Y = \beta_0 + \beta_1 Jan + \beta_2 Feb + ... + \beta_{11} Nov + \beta_{13} T + \beta_{14} Z$$

- Jan–Nov are individual dummy variable 0's and 1's.
- Effect of Dec is captured in the intercept.
- If the data are quarterly, use 3 dummy variables, for first 3 quarters and intercept picks up affect for fourth quarter.

$$Y = \beta_0 + \beta_1 Qt1 + \beta_2 Qt2 + \beta_3 Qt3 + \beta_4 T + \beta_5 Z$$

- The Z variable represents other structural variables that can be included in the model.

What is Each Part of the Equation Doing?

$$Y = \beta_0 + \beta_1 Jan + \beta_2 Feb + ... + \beta_{11} Nov + \beta_{13} T + \beta_{14} Z$$

- The β_0 intercept is capturing the average value of Y when all the other variables are zero.
- The β_1 through β_{11} are capturing the effects of different months on the Y variable, some may be positive and others negative. Some may not be statistically significant but should be left in the model for completeness.
- The "T" variable is trend and effectively "de-trends" the data prior to estimating the seasonal effects.
- The "Z" variable represents other structural variables that can be included in the model, such as income, population, own price and competing prices.

Seasonal Forecast with Dummy Variable Models

- Set up the X matrix with 0's and 1's.
- Easy to forecast as the seasonal effect is assumed to persist forever.
- Note the pattern of 0s and 1s for months.
- December effect is captured in the intercept.

	Price	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Trend
Jan	71.06	1	0	0	0	0	0	0	0	0	0	0	1
Feb	71.47	0	1	0	0	0	0	0	0	0	0	0	2
Mar	70.06	0	0	1	0	0	0	0	0	0	0	0	3
Apr	70.31	0	0	0	1	0	0	0	0	0	0	0	4
May	68.75	0	0	0	0	1	0	0	0	0	0	0	5
Jun	67.08	0	0	0	0	0	1	0	0	0	0	0	6
Jul	64.8	0	0	0	0	0	0	1	0	0	0	0	7
Aug	63.12	0	0	0	0	0	0	0	1	0	0	0	8
Sep	59.44	0	0	0	0	0	0	0	0	1	0	0	9
Oct	63.94	0	0	0	0	0	0	0	0	0	1	0	10
Nov	66.62	0	0	0	0	0	0	0	0	0	0	1	11
Dec	64.12	0	0	0	0	0	0	0	0	0	0	0	12
Jan	65.12	1	0	0	0	0	0	0	0	0	0	0	13
Feb	65.25	0	1	0	0	0	0	0	0	0	0	0	14
Mar	62.72	0	0	1	0	0	0	0	0	0	0	0	15
Apr	59.15	0	0	0	1	0	0	0	0	0	0	0	16
May	60.19	0	0	0	0	1	0	0	0	0	0	0	17
Jun	60	0	0	0	0	0	1	0	0	0	0	0	18

Seasonal Forecast with Dummy Variable Models

- Regression output for a monthly dummy variable model may not have a statistically significant effect for each month, as indicated by the Student t on the betas.
- Monthly forecasts use beta for the month being forecasted.

$$\text{January forecast} = 45.93 + 4.147 * (1) + 1.553 * T$$

$$\text{May forecast} = 45.93 + 4.999 * (1) + 1.553 * T$$

95%	Intercept	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Trend
Beta	**45.930**	4.147	**6.334**	**6.682**	**7.213**	4.999	4.121	3.671	1.689	-0.281	-1.240	-0.936	**1.553**
S.E.	2.973	2.718	2.717	2.716	2.715	2.714	2.714	2.713	2.713	2.712	2.712	2.712	0.095
t-test	15.450	1.525	2.331	2.460	2.656	1.842	1.519	1.353	0.623	-0.104	-0.457	-0.345	16.275
Prob(t)	0.000	0.129	0.021	0.015	0.009	0.067	0.131	0.178	0.534	0.918	0.648	0.730	0.000
Elasticity at Mean		0.004	0.006	0.007	0.007	0.005	0.004	0.004	0.002	0.000	-0.001	-0.001	1.921
Variance Inflation Fa		1.842	1.841	1.839	1.838	1.837	1.836	1.835	1.835	1.834	1.834	1.833	103.050
Partial Correlation		0.110	0.167	0.176	0.190	0.133	0.110	0.098	0.045	-0.008	-0.033	-0.025	0.764
Semipartial Correlat		0.06802	0.103941	0.109692	0.118445	0.082118	0.067719	0.060325	0.027767	-0.00463	-0.02039	-0.0154	0.725712
Restriction													