Operations

Forecasting

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Announcements

- Hubspot setup
- NSA research assistant

Why Forecast?

- Assess long-term capacity needs
- Develop budgets, hiring plans, etc.
- Plan production or order materials
- Get agreement within firm and across supply chain partners

Types of Forecasts

- **Demand**
  - Firm-level
  - Market-level
- **Supply**
  - Materials
  - Labor supply
- **Price**
  - Cost of supplies and services
  - Cost of money — interest rates, currency rates
  - Market price for firm's product or service

Forecasting at Disney World

- Global portfolio includes parks in Hong Kong, Paris, Tokyo, Orlando, and Anaheim
- Revenues are derived from people – how many visitors and how they spend their money
- Daily management report contains only the forecast and actual attendance at each park

Forecasting at Disney World

- Disney generates daily, weekly, monthly, annual, and 5-year forecasts
- Forecast used by labor management, maintenance, operations, finance, and park scheduling
- Forecast used to adjust opening times, rides, shows, staffing levels, and guests admitted

Forecasting at Disney World

- 20% of customers come from outside the USA
- Economic model includes gross domestic product, cross-exchange rates, arrivals into the USA
- A staff of 35 analysts and 70 field people survey 1 million park guests, employees, and travel professionals each year

Forecasting at Disney World

- Inputs to the forecasting model include airline specials, Federal Reserve policies, Wall Street trends, vacation/holiday schedules for 3,000 school districts around the world
- Average forecast error for the 5-year forecast is 5%
- Average forecast error for annual forecasts is between 0% and 3%

Forecasting Approaches

Qualitative Methods

- Used when situation is vague and little data exists
  - New products
  - New technology
- Involves intuition, experience

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- E.g., forecasting sales to a new market

Quantitative Methods

- Used when situation is ‘stable’ and historical data exists
  - Existing products
  - Current technology
- Heavy use of mathematical techniques

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- E.g., forecasting sales of a mature product

Principles of Forecasting

Many types of forecasting models
- Differ in complexity
- Differ in amount of data they incorporate

Common features include:
- Forecasts are rarely perfect
- Forecasts are more accurate for grouped data than for individual items

Time Series Models

- Forecaster looks for data patterns as
  - Data = historic pattern + random variation
- Historic pattern to be forecasted:

PATTERN

  - **Level** (long-term average) – data fluctuates around a constant mean
  - **Trend** – data exhibits an increasing or decreasing pattern
  - **Seasonality** – any pattern that regularly repeats itself and is of a constant length
  - **Cycle** – patterns created by economic fluctuations
- Random variation cannot be predicted

Time Series Models

- **Naive:**

$$F_{t+1} = A_t$$

- **Simple Mean:**

$$F_{t+1} = \sum A_t / n$$

- **Simple Moving Average:**

$$F_{t+1} = \sum A_t / n$$

Time Series Models cont'd

- **Weighted Moving Average:** $F_{t+1} = \sum C_t A_t$
  - Method in which "n" of the most recent observations are averaged and past observations may be weighted differently
  - All weights must add to 100% or 1.00

    e.g. $\mathbf{C_t}$ **.5**, $\mathbf{C_{t-1}}$ **.3**, $\mathbf{C_{t-2}}$ **.2** (weights add to 1.0)
  - Allows emphasizing one period over others; above indicates more weight on recent data (C_t=.5)
  - Differs from the simple moving average that weighs all periods equally - more responsive to trends

Time Series Models cont'd

- **Exponential Smoothing:** $\mathbf{F_{t+1} = \alpha A_t + (1-\alpha)F_t}$
  - Most frequently used time series method because of ease of use and minimal amount of data needed
  - Need just three pieces of data to start: α
    - Last period's forecast (**Ft**)
    - Last periods actual value (**At**)
    - Select value of smoothing coefficient, α ,between 0 and 1.0
  - If no last period forecast is available, average the last few periods or use naive method
  - Higher α values (e.g. .7 or .8) place a lot of weight on current periods actual demand and influenced by random variation

Time Series Problem

- **Determine forecast for periods 7 & 8**
- **2-period** moving average
- **4-period** moving average
- **2-period** weighted moving average with t-1 weighted 0.6 and t-2 weighted 0.4
- **Exponential smoothing** with alpha=0.2 and the period 6 forecast being 375

Period	Actual
1	300
2	315
3	290
4	345
5	320
6	360
7	375
8	

Time Series Problem Solution

Period	Actual	2-Period	4-Period	2-Per.Wgted.	Exponential Smoothing
1	300				
2	315				
3	290				
4	345				
5	320				
6	360				
7	375	**340.0**	**328.8**	**344.0**	**372.0**
8		**367.5**	**350.0**	**369.0**	**372.6**

Linear Trend Line

- A time series technique that computes a forecast with trend by drawing a straight line through a set of data using this formula:

$$y = a + bx$$

where

y= forecast for period X

x = the number of time periods from X = 0

a = value of y at X = 0 (Y intercept)

b = slope of the line

Correlation Coefficient - How Good is the Fit?

- Correlation coefficient **(r)** measures the direction and strength of the linear relationship between two variables. The closer the r value is to 1.0 the better the regression line fits the data points.

$$r = \frac{n\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{n\left(\sum X^2\right) - \left(\sum X\right)^2} * \sqrt{n\left(\sum Y^2\right) - \left(Y\right)^2}}$$

$$r = \frac{4(28{,}202) - 189(589)}{\sqrt{4(9253) - (189)^2} * \sqrt{4(87{,}165) - (589)^2}} = .992$$

$$r^2 = (.982)^2 = .964$$

- Coefficient of determination (r^2) measures the amount of variation in the dependent variable about its mean that is explained by the regression line. Values of (r^2) close to 1.0 are desirable.

Techniques for Seasonality

- Seasonality – regularly repeating movements in series values that can be tied to recurring events
  - Expressed in terms of the amount that actual values deviate from the average value of a series
  - Models of seasonality
    - Additive
      - Seasonality is expressed as a quantity that gets added to or subtracted from the time-series average in order to incorporate seasonality
    - Multiplicative
      - Seasonality is expressed as a percentage of the average (or trend) amount which is then used to multiply the value of a series in order to incorporate seasonality

Seasonal Relatives

- **Seasonal relatives**
  - The seasonal percentage used in the multiplicative seasonally adjusted forecasting model
- Using seasonal relatives
  - To *deseasonalize* data
    - Done in order to get a clearer picture of the nonseasonal components of the data series
    - **Divide each data point by its seasonal relative**
  - To *incorporate seasonality* in a forecast
    - Obtain trend estimates for desired periods using a trend equation
    - Add seasonality by **multiplying these trend estimates by the corresponding seasonal relative**

Seasonal Relatives Example

- A coffee shop owner wants to predict **quarterly demand** for hot chocolate for **periods 9 and 10,** which happen to be the **1st and 2nd quarters** of a particular year**. The sales data consist of both trend and seasonality. The trend portion of demand is projected using the equation $F_t = 124 + 7.5\,t$. Quarter relatives are**

  $Q_1 = 1.20$, $Q_2 = 1.10$, $Q_3 = 0.75$, $Q_4 = 0.95$,

Seasonal Relatives Example (cont'd)

- Use this information to deseasonalize sales for Q1 through Q8.

Period	Quarter	Sales	÷	Quarter Relative	=	Deseasonalized sales
1	1	158.4	÷	1.20	=	132.0
2	2	153.0	÷	1.10	=	139.1
3	3	110.0	÷	0.75	=	146.7
4	4	146.3	÷	0.95	=	154.0
5	1	192.0	÷	1.20	=	160.0
6	2	187.0	÷	1.10	=	170.0
7	3	132.0	÷	0.75	=	176.0
8	4	173.8	÷	0.95	=	182.9

Seasonal Relatives Example (cont'd)

- Use this information to predict for periods 9 and 10.
- $F_9 = 124 + 7.5(9) = \mathbf{191.5}$

$F_{10} = 124 + 7.5(10) = \mathbf{199.0}$

Multiplying the trend value by the appropriate quarter relative yields a forecast that includes both trend and seasonality.

Given that **t =9** is a **1st quarter** and **t = 10** is a **2nd quarter**.

The forecast demand for period 9 = **191.5**(1.20) = 229.8
The forecast demand for period 10 = **199.0**(1.10) = 218.9

Measuring Forecast Error

- Forecasts are never perfect
- Need to measure over time
- Need to know how much we should rely on our chosen forecasting method
- Measuring forecast error: $$\mathbf{E_t = A_t - F_t}$$
- Note that over-forecasts = negative errors and under-forecasts = positive errors

Measuring Forecasting Accuracy

- Mean Absolute Deviation (MAD)
  - measures the total error in a forecast without regard to sign

$$\mathbf{MAD} = \frac{\sum \left|\mathbf{actual} - \mathbf{forecast}\right|}{\mathbf{n}}$$

- Cumulative Forecast Error (CFE)
  - Measures any bias in the forecast

$$\text{CFE} = \sum \left(\text{actual} - \text{forecast}\right)$$

- Mean Square Error (MSE)
  - Penalizes larger errors

$$\mathbf{MSE} = \frac{\sum \left(\mathbf{actual - forecast}\right)^2}{\mathbf{n}}$$

Accuracy & Tracking Signal Problem: A company is comparing the accuracy of two forecasting methods. Forecasts using both methods are shown below along with the actual values for January through May. The company also uses a tracking signal with ±4 limits to decide when a forecast should be reviewed. Which forecasting method is best?

Month	Actual sales	Method A				Method B			
		F'cast	Error	Cum. Error		F'cast	Error	Cum. Error	
Jan.	**30**	**28**	**2**	**2**		**27**	**3**	**3**	
Feb.	**26**	**25**	**1**	**3**		**25**	**1**	**4**	
March	**32**	**32**	**0**	**3**		**29**	**3**	**7**	
April	**29**	**30**	**-1**	**2**		**27**	**2**	**9**	
May	**31**	**30**	**1**	**3**		**29**	**2**	**11**	
MAD			**1**				**2.2**		
MSE			**1.4**				**5.4**		

Selecting the Right Forecasting Model

1. The amount & type of available data
   - Some methods require more data than others
2. Degree of accuracy required
   - Increasing accuracy means more data
3. Length of forecast horizon
   - Different models for 3 month vs. 10 years
4. Presence of data patterns
   - Lagging will occur when a forecasting model meant for a level pattern is applied with a trend

Collaborative Planning Forecasting & Replenishment (CPFR)

- Establish collaborative relationships between buyers and sellers
- Create a joint business plan
- Identify exceptions for sales forecast
- Resolve/collaborate on exception items
- Create order forecast
- Identify exceptions for order forecast
- Resolve/collaborate on exception items
- Generate order

CPFR is an iterative process.

Example 9.4 – Seasonal Adjustments

Based on the results of the regression model, develop a seasonal index for each month and reforecast months 1 through 24 (January 2016 – December 2017) using the seasonal indices.

MONTH	DEMAND	MONTH	DEMAND
January 2016	51	January 2017	112
February	67	February	137
March	65	March	191
April	129	April	250
May	225	May	416
June	272	June	487
July	238	July	421
August	172	August	285
September	143	September	235
October	131	October	222
November	125	November	192
December	103	December	165

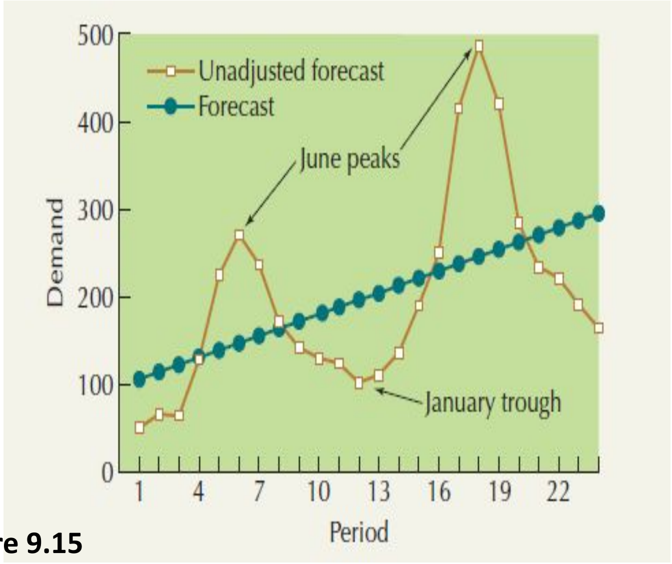

Figure 9.15

Example 9.4 – Seasonal Adjustments

MONTH	PERIOD	DEMAND	UNADJUSTED REGRESSION FORECAST	FORECAST ERROR
January 2016	1	51	106.9	−55.9
February	2	67	115.2	−48.2
March	3	65	123.4	−58.4
April	4	129	131.6	−2.6
May	5	225	139.8	85.2
June	6	272	148.0	124.0
July	7	238	156.3	81.8
August	8	172	164.5	7.5
September	9	143	172.7	−29.7
October	10	131	180.9	−49.9
November	11	125	189.1	−64.1
December	12	103	197.4	−94.4

Example 9.4 – Seasonal Adjustments

MONTH	PERIOD	DEMAND	UNADJUSTED REGRESSION FORECAST	FORECAST ERROR
January 2017	13	112	205.6	−93.6
February	14	137	213.8	−76.8
March	15	191	222.0	−31.0
April	16	250	230.2	19.8
May	17	416	238.5	177.6
June	18	487	246.7	240.3
July	19	421	254.9	166.1
August	20	285	263.1	21.9
September	21	235	271.3	−36.3
October	22	222	279.6	−57.6
November	23	192	287.8	−95.8
December	24	165	296.0	−131.0

Example 9.4 – Seasonal Adjustments

Calculate the (Demand/Forecast) for each of the time periods:

January 2012: (Demand/Forecast) = 51/106.9 = 0.477

January 2013: (Demand/Forecast) = 112/205.6 = 0.545

Calculate the monthly seasonal indices:

Monthly seasonal index, January = (.477 + .545)/2 = .511

Calculate the seasonally adjusted forecasts

Seasonally adjusted forecast = unadjusted forecast x seasonal index

January 2012: 106.9 x .511 = 54.63

January 2013: 205.6 x .511 = 105.06

Example 9.4 – Seasonal Adjustments

Regression forecast model:

Forecasted demand = 98.71 + 8.22 x period

The adjusted forecast is calculated by multiplying the unadjusted forecast by the seasonal index. For January 2016: 106.9 x 0.511 = 54.6.

The percentages for January 2016 and 2017 are averaged to develop the monthly seasonal index for January. The procedure follows the same pattern for other months.

Month	Period	Demand	Unadjusted Regression Forecast	Demand/ Forecast	Monthly Seasonal Index	Adjusted Regression Forecast	New Forecast Error
January 2016	1	51	106.9	0.477	0.511	54.6	−3.6
February	2	67	115.2	0.582	0.611	70.4	−3.4
March	3	65	123.4	0.527	0.694	85.6	−20.6
April	4	129	131.6	0.980	1.033	135.9	−6.9
May	5	225	139.8	1.609	1.677	234.5	−9.5
June	6	272	148.0	1.837	1.906	282.1	−10.1
July	7	238	156.3	1.523	1.587	248.0	−10.0
August	8	172	164.5	1.046	1.064	175.1	−3.1
September	9	143	172.7	0.828	0.847	146.3	−3.3
October	10	131	180.9	0.724	0.759	137.3	−6.3
November	11	125	189.1	0.661	0.664	125.6	−0.6
December	12	103	197.4	0.522	0.540	106.5	−3.5
January 2017	13	112	205.6	0.545	0.511	105.0	7.0
February	14	137	213.8	0.641	0.611	130.7	6.3
March	15	191	222.0	0.860	0.694	154.0	37.0
April	16	250	230.2	1.086	1.033	237.8	12.2
May	17	416	238.5	1.745	1.677	399.9	16.1
June	18	487	246.7	1.974	1.906	470.1	16.9
July	19	421	254.9	1.652	1.587	404.6	16.4
August	20	285	263.1	1.083	1.064	280.1	4.9
September	21	235	271.3	0.866	0.847	229.8	5.2
October	22	222	279.6	0.794	0.759	212.2	9.8
November	23	192	287.8	0.667	0.664	191.1	0.9
December	24	165	296.0	0.557	0.540	159.7	5.3

Figure 9.16

Example 9.4 – Seasonal Adjustments

Plot of Seasonally Adjusted Regression Forecast against a Time Series Showing Seasonality