Package ‘SCperf’

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Title Supply Chain Perform

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Description The package implements different inventory models, the bullwhip effect and other supply chain performance variables.

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`bullwhip` *bullwhip effect*

Description

`bullwhip` computes the increase of the demand variability (the bullwhip effect) for a simple two-stage supply chains consisting of a single retailer and a single manufacturer using three forcasting methods: Minimum Mean Square Error (MMSE), Simple Moving Average (SMA) and Exponential Smoothing (ES) when the demand follows a known stationary AR(1) stochastic process.

Usage

```
bullwhip(method = c("MMSE", "SMA", "ES"), phi, L, p, alpha)
```

Arguments

`method`	character string specifing which method to use,
`phi`	a vector of autoregressive parameters,
`L`	a positive lead-time,
`p`	the order to be used in the SMA method,
`alpha`	smoothing factor to be used in the ES method (0 < alpha < 1).

Details

The bullwhip effect is commonly defined as the ratio between the unconditional variance of the order process to that of the demand process, $Var(O_t)/Var(d_t)$. If this ratio is equal to one there is no variance amplification, while a ratio greater than one means that the bullwhip effect is present. On the other hand, a ratio less than one means that the orders are smoothed if compared with the demand.

Value

The measure for the bullwhip effect.

Author(s)

Marlene Silva Marchena <marchenamarlene@gmail.com>

References

Chen, F.; Drezner, Z.; Ryan, J. ; Simchi-Levi, D. (2000a) Quantifying the bullwhip effect in a simple supply chain: the impact of forecasting, lead times and information. Management Science, v.46, n.3, p. 436-443.

Silva Marchena, M. (2010) Measuring and implementing the bullwhip effect under a generalized demand process. http://arxiv.org/abs/1009.397

Zhang, X. (2004a) The impact of forecasting methods on the bullwhip effect, International Journal of Production Economics.l, v.88, n.1, p. 15-27.

See Also

SCperf

Examples

```
bullwhip("SMA",0.9,2,4)

bullwhip("ES",0.9,2,0,0.6)

bullwhip("MMSE",0.9,2)
```

EOQ *Economic Order Quantity model*

Description

Implements the classical Economic Order Quantity (EOQ) model and the EOQ model with planned shortages.

Usage

```
EOQ(d, k, h, b = 0)
```

Arguments

d	demand per unit time,
k	ordering or setup cost per unit time,
h	holding cost per unit time,
b	shortage penalty cost per unit time (default:0).

Details

The classical EOQ model assumes that the demand rate of units per time unit is constant and each new order is delivered in full when inventory reaches zero. Also a cost for each unit held in storage and a fixed cost for each order placed are considered. No shortages are allowed.

The optimal (the economic order) quantity that minimize the total cost associated with the purchase, delivery and storage is defined by $Q = \sqrt{2Dk/h}$. When we relax the last assumption, that is, $b \neq 0$ we have the EOQ model with backorders.

Value

`EOQ()` returns a list containing:

Q	batch quantity,
T	time between orders (cycle length or time),
S	maximum backorder in units,
TVC	total variable cost.

Author(s)

Marlene Silva Marchena <marchenamarlene@gmail.com>

References

Hillier, F. and Lieberman, G. (2001). *Introduction to operational research.* New York: McGraw-Hill, 7th.

See Also

EPQ, Newsboy, WW

Examples

```
# Classical EOQ model#
# Given demand d=8000 items per year; set up cost k=12000; and holding cost h=0.3
# per unit we find that the optimal solution is to order 25298 units every 3.2
# months with a total variable cost of $7589.5

EOQ(8000,12000,0.3)

# EOQ model with planned shortages#
# Consider now that backorders are allowed with a backorder cost b=1.1 per
# unit and year. Then the optimal solution is to order 28540 units every 3.6 months.
# The total variable cost is $6727.3 and the maximum shortage is 6116 units.

EOQ(8000,12000,0.3,1.1)
```

EPQ *Economic Production Quantity model*

Description

Implements the Economic Production Quantity (EPQ) model.

Usage

```
EPQ(d, p, k, h)
```

Arguments

d	demand rate,
p	production rate,
k	ordering or setup cost,
h	holding cost.

Details

The EPQ model is an extension of the EOQ model. It considers finite production rate, that is, the inventory is replenished gradually as the order is produced. Note that this assumption requires the production rate to be greater than the demand rate (p>d) otherwise there would be no inventory at any time.

The model considers that a new order is produced incrementally when the inventory reaches zero. During the time that production run, $t = Q/p$, inventory is accumulated at rate $p - d$, which implies that when the production of the batch Q is finished the inventory will reach its maximum level I.

Value

`EPQ()` returns a list containing:

`Q`	batch quantity,
`t`	time required to produce the batch quantity,
`T`	time between orders (cycle length or time),
`I`	maximum inventory level,
`TC`	total cost.

Author(s)

Marlene Silva Marchena <marchenamarlene@gmail.com>

References

Gallego, G. "IEOR4000: Production Management" (Lecture 2), Columbia (2004).

See Also

EOQ, Newsboy, WW

Examples

```
# Suppose k = 100, h = 5, d = 200, p = 1000. Then the production run at
# t=0.1, the optimal order interval is T = 0.5, the optimal order quantity
# is Q = 100, the maximum inventory level is I=80 and the total cost is
# TC = $400.

EPQ(d=200,p=1000,k=100,h=5)
```

`Newsboy`	*The Newsboy model*

Description

Implements the Newsboy (or Newsvendor) model with normal demand.

Usage

```
Newsboy(m, sd, p, c, s = 0)
```

Arguments

`m`	mean demand during the period,
`sd`	standard deviation of demand during the period,
`c`	the unit cost,
`p`	the selling price, where p > c
`s`	the salvage value (default:0), where s < c.

Details

When the demand is a random variable with normal distribution, the optimal stocking quantity that minimize the expected cost is: $Q = m + z * sd$, where $z = \Phi^{-1}(p - c)/(p - s)$, the inverse of the standard normal cumulative density function of the demand, is known as the safety factor and $Q - m = z * sd$ is known as the safety stock.

Note that the Newsboy problem is not formulated in terms of per unit holding cost $h = c - s$ and penalty cost $b = p - c$.

Value

`Newsboy()` returns a list containing:

`Q`	optimal order-up-to quantity,
`SS`	safety stock,
`ExpC`	expected cost,
`ExpP`	expected profit,
`CV`	coefficient of variation of the demand,
`CR`	$= (p - c)/(p - s) = b/(b + h)$, critical ratio,
`FR`	fill rate, the fraction of demand served from stock,
`z`	safety factor.

Author(s)

Marlene Silva Marchena `<marchenamarlene@gmail.com>`

References

Porteus E. L. (2002) Foundations of Stochastic Inventory Theory, Stanford University Press, Stanford, CA.

Gallego G. (1995) Newsvendor Problem. IEOR 4000 Production Management.

Ayhan, Hayriye, Dai, Jim, Foley, R. D., Wu, Joe, (2004): Newsvendor Notes, ISyE 3232 Stochastic Manufacturing & Service Systems.

See Also

EOQ, EPQ, WW

Examples

```
# Example Porteus #
# Suppose demand is normally distributed with mean 100 and standard
# deviation 30. If p = 4 and c = 1, then CR = 0.75 and Q=120.23.
# Note that the order is for 20.23  units (safety stock) more than the
# mean. Note also that ExpC(120.23) = 38.13 and ExpP(120.23)=261.87,
# with FR=0.96.

Newsboy(100,30,4,1)

# Example Gallego #
# Suppose demand is normal with mean 100 and standard deviation 20. The
# unit cost is 5, the holding and penalty cost are 1 and 3
# respectively. From the definition of the holding and penalty
# cost we find that p=4, then CR = 0.75 and Q = 113.49. Notice that the
# order is for 13.49 units (safety stock) more than the mean,
# ExpC(113.49) = 25.42 and ExpP(113.49) = 274.58, with fill rate of
# 97 percent.

Newsboy(100,20,4,1)
```

SCperf *Supply Chain Perform*

Description

SCperf computes the bullwhip effect for an stationary ARMA(p,q) demand process and other supply chain performance variables.

Usage

```
SCperf(phi, theta, L = L, SL = 0.95)
```

Arguments

`phi`	a vector of autoregressive parameters,
`theta`	a vector of moving-average parameters,
`L`	positive lead-time,
`SL`	service level, (default:0.95).

Details

The bullwhip effect for a stationary ARMA(p,q) demand process is defined as:

$$M = \frac{1 + 2\sum_{i=0}^{L}\sum_{j=i+1}^{L}\psi_i\psi_j}{\sum_{j=0}^{\infty}\psi_j^2}$$

where the ψ-weights solve the equations $\psi(z)\theta(z) = \phi(z)$. If $M = 1$ there is no variance amplification, while $M > 1$ means that the bullwhip effect is present. On the other hand, $M < 1$ means that the orders are smoothed if compared with the demand.

Two safety stock measures are presented as well: $SS = z\sqrt{L * VarD}$ and $SSL = z\sqrt{VarDL}$. SSL is calculated using an estimate of the standard deviation of L periods forecast error $\sqrt{VarDL} = \sqrt{Var(D_t^L - \hat{D}_t^L)}$ where $\hat{D}_t^L = \sum_{\tau=1}^{L}\hat{d}_{t+\tau}$ is an estimate of the mean demand over L periods after period t.

Value

`SCperf()` returns a list containing:

`M`	measure for the bullwhip effect,
`VarD`	variance of the demand,
`VarDL`	variance of forecasting error for lead-time demand,
`SS`	safety stock calculated using the standard deviation of the demand,
`SSL`	safety stock calculated using the standard deviation of L periods forecast error,
`z`	safety factor.

Author(s)

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References

Zhang, X. (2004b). Evolution of ARMA demand in supply chains. Manufacturing and Services Operations Management, 6 (2), 195-198.

Silva Marchena, M. (2010) Measuring and implementing the bullwhip effect under a generalized demand process. http://arxiv.org/abs/1009.3977

See Also

bullwhip

Examples

```
#ARMA(1,1) case,

SCperf(phi=0.95,theta=0.1,L=2,SL=0.99)

#AR(2) case,

SCperf(phi=c(0.8,-0.2),theta=0,L=1)
```

`SSL` *Safety stock over lead-time*

Description

`SSL` computes the safety stock level over lead-time for three forecasting methods: Minimum Mean Square Error (MMSE), Simple Moving Average (SMA) and Exponential Smoothing (ES) when the demand follows a stationary AR(1) stochastic process.

Usage

```
SSL(method = c("MMSE", "SMA", "ES"), phi, L, p, alpha, SL)
```

Arguments

`method`	character string specifing which forecasting method to use,
`phi`	a vector of autoregressive parameters,
`L`	a positive lead-time,
`p`	the order to be used in the SMA method,
`alpha`	smoothing factor to be used in the ES method (0 < alpha < 1),
`SL`	service level.

Details

`SSL` is calculated using an estimate of the standard deviation of forecasting error for lead-time demand $\sqrt{Var(D_t^L - \hat{D}_t^L)}$ where $\hat{D}_t^L = \sum_{\tau=1}^{L} \hat{d}_{t+\tau}$ is an estimate of the mean demand over L periods after period t.

Value

The safety stock level over the lead-time.

Author(s)

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References

Silva Marchena, M. (2010) Measuring and implementing the bullwhip effect under a generalized demand process. http://arxiv.org/abs/1009.3977

Zhang, X. The impact of forecasting methods on the bullwhip effect, International Journal of Production Economics.l, v.88, n.1, p. 15-27, 2004a.

See Also

SCperf

Examples

```
SSL("MMSE",0.15,2,4,0.7,0.95)

SSL("SMA",0.15,2,4,0.7,0.95)

SSL("ES",0.15,2,4,0.7,0.95)
```

WW *The Wagner-Whitin algorithm*

Description

WW implements the Wagner-Whitin algorithm. Considering time-varying demand, the algorithm builds production plans that minimizes the total setup and holding costs in a finite horizon of time, assuming zero starting inventory and no backlogging.

Usage

```
WW(x,a,h,method=c("forward","backward"))
## Default S3 method:
WW(x,a,h,method=c("forward","backward"))
## S3 method for class 'WW'
print(x, ...)
```

Arguments

x	a numeric vector containing the demand per unit time,
a	a numeric vector containing the set-up cost per unit time,
h	a numeric vector containing the holding cost per unit time,
method	character string specifing which algorithm to use, must be "forward" (default) or "backward".
...	not used.

Value

WW.default (the function that is called when using WW) returns a list containing:

TVC	total variable cost,
Jt	last period of production for the forward algorithm or the (end of the) period when the inventory reaches a zero level for the backward algorithm,
Solution	matrix of solutions.

Author(s)

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References

Axsäter, S. (2006) Inventory Control. Lund Sweden: Springer, Second Edition.

Hillier, F. and Lieberman, G. (2001). *Introduction to operational research*. New York: McGraw-Hill, Seventh Edition.

See Also

EOQ, EPQ, Newsboy

Examples

```
# Example from Hiller, p.952, reproduced bellow:
# An airplane manufacturer specializes in producing small airplanes. It has just received an
# order from a major corporation for 10 customized executive jet airplanes for the use
# of the corporation's upper management. The order calls for three of the airplanes to be
# delivered (and paid for) during the upcoming winter months (period 1), two more to be delivered
# during the spring (period 2), three more during the summer (period 3),and
# the final two during the fall (period 4). Setting up the production facilities to meet
# the corporation's specifications for these airplanes requires a setup cost of $2 million.
# The manufacturer has the capacity to produce all 10 airplanes within a
#  couple of months, when the winter season will be under way. However, this would necessitate holding
# seven of the airplanes in inventory, at a cost of $200,000 per airplane per period, until their
# scheduled delivery times (...)
# Management would like to determine theleast costly production schedule for filling this order.

x  <- c(3,2,3,2)
a  <- c(2,2,2,2)
h  <- c(0.2,0.2,0.2,0.2)
WW(x,a,h,method="forward") # forward algorithm
WW(x,a,h,method="backward") # backward algorithm

# The optimal production schedules for the forward and backward case is to:
# 1. Produce in period 1 for periods 1, 2, 3 and 4 (3 + 2 + 3 + 2 = 10  airplanes)
# Total variable cost $4.8 million.
# 2. Produce in period 1 for periods 1 and 2 (3 + 2 = 5  airplanes) and in period 3
# for periods 3 and 4 (3 + 2 = 5 airplanes)
# Total variable cost $4.8 million.
```

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