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Werner Jammernegg und Peter Kischka

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Schriftleitung:

Prof. Dr. Hans-Walter Lorenz
h.w.lorenz@wiwi.uni-jena.de

Prof. Dr. Armin Scholl
a.scholl@wiwi.uni-jena.de

Performance Measurement for Inventory Models with Risk Preferences

Werner Jammernegg [(a)]
Peter Kischka [(b)]

Abstract:
In financial economics in general the objective function expresses the risk preferences of the decision maker, see for example the mean variance approach in portfolio theory. Only recently in inventory management instead of maximizing expected profit or minimizing expected cost risk-averse objective functions have been used for determining the optimal order quantity. Examples are the exponential utility function and the conditional value at risk criterion. We use the well-known newsvendor model to determine the optimal performance measures for an objective function with two risk parameters, which can describe risk neutral, risk averse as well as risk taking behaviour of the inventory manager. We provide for this approach a complete characterization with respect to the performance measures expected profit and service level. We show that a risk averse inventory manager can not dominate a risk neutral or a risk taking inventory manager. Finally, we provide a managerial guideline for selecting the appropriate risk parameters of the objective function.

Keywords:
Performance Measurement; Risk Preferences; Newsvendor Model

1 Introduction

In operations management traditionally risk neutral decision makers are considered optimizing the expected value of the cost function or the profit function. Only recently inventory models, e. g. the newsvendor model, have been analyzed for objective functions which do not exhibit risk neutrality. Examples are the expected utility and the Conditional Value at Risk of the profit or the cost.

Eeckhoudt et al. (1995) consider inventory models from an expected utility point of view. The optimal order quantity is given by maximizing the expected utility of a profit function. The decision is based on a subjective utility function of the decision maker. For certain utility functions the solution within this framework is larger or smaller than the solution in the risk neutral case; also the fraction of losses may be reduced. The expected utility approach itself can be criticized since it relies on an independence axiom which may be violated (see e. g. Kischka/Puppe (1992)). Moreover, from a more pragmatic point of view the application of the expected utility is made more difficult since the decision maker has to specify a utility function. This is possible, e. g. by comparing lotteries with certainty equivalents, but it seems doubtful that decision making in inventory management always can be based on such a procedure.

(a) Vienna University of Economics and Business Administration, Department of Production Management, A-1090 Wien, Nordbergstrasse 15, Austria, Email: werner.jammernegg@wu-wien.ac.at
(b) Friedrich Schiller University Jena, Department of Statistics, D-07743 Jena, Carl Zeiß Strasse 3, Germany, Email: p.kischka@wiwi.uni-jena.de

Another criterion used in inventory management is the Conditional Value at Risk (CVaR) (Chen et al. (2004) and the literature cited there). The CVaR is based on the well known Value at Risk (VaR), the quantile of the profit distribution for a prespecified level α. The CVaR is the conditional expected profit given profit is below the α-quantile. Thus, CVaR encompasses the amount of loss; moreover, CVaR is – contrary to VaR – a coherent risk measure (see Artzner et al. (1999)).

In our view the main disadvantage of the CVaR as a single decision criterion is the fact that it describes – at least for small α - extreme risk aversion. This is the consequence that only the worst outcomes are considered. On the other hand for growing α the CVaR criterion converges to decision making in the risk neutral case. Therefore, the CVaR criterion either describes risk aversion and neglects a large part of the profit distribution or it encompasses a large part of the profit distribution and approaches risk neutrality. Our approach to decision making in inventory management avoids this conflict.

Clearly, a basic motivation to use the CVaR as an objective function is – again – that the fraction of losses is reduced compared to the risk neutral decision maker in the newsvendor model (Chen et al. (2004)). But this has to be traded off with lower expected profits and also lower levels of customer service.

Inventory management is one of the most important topics in supply chain management because it deals with one of basic tradeoffs of the operations strategy, namely the tradeoff between supply chain costs and customer service. “Increasing supply chain inventories typically increases customer service and consequently revenue, but it comes at a higher cost” (Neale et al.(2003), p. 32).

We explicitly consider the tradeoff between cost and service by proposing a model where risk neutral, risk averse as well as risk taking behaviour of the inventory manager can be represented. Instead of a utility function the inventory manager must specify only two risk parameters. In contrast to CVaR models we do not restrict to low performance values of the optimal order quantity, the optimal product availability and the optimal expected profit.

We present within the newsvendor framework a model where the risk preferences are expressed by two parameters; the risk neutral model as well as the CVaR model is included as special case. The objective function is given by a convex combination of two conditional expected values of the profit. The convex combination is described by a risk parameter λ. As in the expected utility setting and in contrast with the CVaR approach the complete probability distribution of the profits is used in the decision model. In the objective function one conditional expected value of the profit is the CVaR taking into account low profits whereas the other one takes into consideration high profits. Low profits and high profits are discriminated by the α-quantile of the profit distribution; α is the other risk parameter.

For given risk parameters we derive the optimal order quantities, the optimal levels of product availability (cycle service level, fill rate) as well as the optimal expected profits. We characterize the optimal performance measures in dependence of the risk parameters α and λ. Furthermore we give a complete description of the risk preferences (risk averse, risk neutral, risk taking) with respect to the expected profit and the cycle service level. A risk averse inventory manager orders less than the classical, risk neutral newsvendor whereas a risk taking manager orders more than the risk neutral newsvendor. For the performance measures expected profit and cycle service level (or fill rate) the risk averse inventory manager can not dominate the risk neutral and the risk taking manager.

In the next section we briefly review the classical newsvendor model. Section 3 introduces the newsvendor model with risk preferences and presents the main results. For matter of comparison between our model, the classical newsvendor model and the newsvendor model with CVaR criterion we provide numerical analyses in section 4. Finally, in section 5 we give a managerial guideline how to specify the risk parameters of our model for given price and cost parameters and for a specified level of product availability. Section 6 concludes the paper by discussing also possible extensions to our model.

2 The Classical Newsvendor Model

The location of stocking points and the determination of the inventory level is one of the most important theoretical as well practical topics in supply chain management. Of course the inventory model must be chosen in accordance with the respective supply chain processes. In an efficient supply chain mainly standard products are produced, stored and delivered. In order to be able to earn a small contribution margin the order winner are the costs of products sold. A necessary qualifying criterion is high product availability. Contrary, for high tech and fashion products or more general products with short life cycles the order winning criterion is customer service (short delivery times and high product availability or delivery reliability) whereas supply chain costs is a typical qualifier for potential customers (Fisher(1997)).

In this paper we concentrate on products in responsive supply chains because products with life cycles shorter than the replenishment leadtime of the supply chain are an increasingly common phenomenon. A prominent inventory model for this framework is the newsvendor model where a retailer has a single opportunity to order the product for the selling season from the supplier. In this model fixed costs are not relevant (Neale et al.(2003), p.39-40).

The inventory manager of the retailer has to place the order for a product to the supplier before the actual demand is known. The random demand $\tilde{d}$ is characterized by the distribution function F. The purchase price per unit of the product is c. The product is sold to the customers during the regular selling season with a price per unit p. Unsatisfied demand is lost and leftover inventory of the product at the end of the selling season is sold in another distribution channel with the salvage price per unit z. p - c describes the cost of understocking by one unit, whereas c - z describes the cost of overstocking by one unit. It is assumed that $p > c > z$ holds.

Let y denote the order quantity and g denote the profit. g depends on y and the stochastic demand and is given by

$$g(y,\tilde{d}) = (p-c)\, y - (p-z)\, (y-\tilde{d})^{+} .$$

In the classical newsvendor model the optimal order quantity y* is derived by maximizing the expected profit E(g(y,d)). The optimality condition is given by (see e. g. Chopra/Meindl (2004)):

$$F(y^*) = (p-c)/(p-z) .$$

Therefore, for the optimal order quantity y* the level of product availability is $(p-c)/(p-z)$. The quantile $(p-c)/(p-z)$ is the cycle service level (CSL); for the order quantity y* we denote it by CSL*. As an alternative measure of product availability the fill rate fr can be used which is defined by

$$fr = E(Min\{1, y^* / \tilde{d}\}).$$

3 The Newsvendor Model with Risk Preferences

In the newsvendor framework customer service usually is an important order winning criterion of a company. Therefore, the company selling the product should have the possibility to control the level of the product availability. Perhaps the cycle service level or the fill rate is communicated to the customers by delivery contracts or simply via advertisements.

In inventory models based on concave utility functions or on the CVaR the optimal order quantity is smaller than y* of the classical newsvendor. Of course the corresponding optimal cycle service level is also smaller than CSL* = (p - c)/(p - z). E.g., for the newsvendor model with the CVaR criterion the optimal cycle service level is α CSL* where $0 < \alpha < 1$ (Chen et al. (2004), p. 7); this model is a special case of our approach (see below).

In our newsvendor model incorporating risk preferences we use two risk parameters α and λ to be able to derive optimal order quantities for cycle service levels that can be larger or smaller than the classical newsvendor service level CSL*.

The objective is to find the optimal order quantity which maximizes

$$\lambda \cdot E\{g(y,\tilde{d}) \mid g(y,\tilde{d}) \le z_\alpha(y)\} + (1-\lambda) \cdot E\{g(y,\tilde{d}) \mid g(y,\tilde{d}) \ge z_\alpha(y)\}$$

where $z_\alpha(y)$ is the α-quantile of the distribution of the random profit $g(y,\tilde{d})$, $0 < \alpha < 1$, and λ is a weighting factor, $0 \le \lambda \le 1$. Thus, the objective function is a convex combination of two conditional expected values.

The conditional value at risk $\text{CVaR}_\alpha(y)$ of the order quantity y at level α is given by

$$\text{CVaR}_\alpha(y) := E\{g(y,\tilde{d}) \mid g(y,\tilde{d}) \le z_\alpha(y)\}.$$

Therefore, we can rewrite our objective function in the following way:

$$\lambda\ \text{CVaR}_\alpha(y) + \frac{1-\lambda}{1-\alpha}\ [E(g(y,\tilde{d})) - \alpha\ \text{CVaR}_\alpha(y)] =$$
$$= \frac{\lambda-\alpha}{1-\alpha}\ \text{CVaR}_\alpha(y) + \frac{1-\lambda}{1-\alpha}\ E(g(y,\tilde{d}))$$

As a consequence, if λ = α our objective function reduces to that of the classical newsvendor model. On the other hand, if λ = 1 then we have the special case of the CVaR criterion.

In a companion paper we derive the optimal cycle service level, the optimal order quantity and the optimal expected profit in dependence of the risk parameters α and λ (Jammernegg and Kischka(2004)). In the following we give the main results.

For $0 < \alpha < 1$ the optimal cycle service level CSL(λ) is given by:

$$\mathrm{CSL}(\lambda) = \begin{cases} \dfrac{p-c}{p-z} + \left(1 - \dfrac{p-c}{p-z}\right)\dfrac{\alpha-\lambda}{1-\lambda}, & \lambda \le \dfrac{p-c}{p-z} \\[2ex] \dfrac{p-c}{p-z}\,\dfrac{\alpha}{\lambda}, & \lambda \ge \dfrac{p-c}{p-z} \end{cases}$$

Note that for $\lambda = (p-c)/(p-z)$ the two functions in the above formula coincide.

For $\lambda = \alpha$ the cycle service level $\mathrm{CSL}(\lambda)$ equals $\mathrm{CSL}^* = (p-c)/(p-z)$. CSL(1) = αCSL* is the cycle service level for the CVaR criterion, $\mathrm{CSL}(0) = \alpha + (1-\alpha)\mathrm{CSL}^*$ is the cycle service level for the extreme risk seeking case $\lambda = 0$.

As an immediate consequence of these special cases we have that CSL(λ) is decreasing in λ for all $0 < \alpha < 1$. Also the fill rate fr(λ) is a decreasing function of λ for $0 < \alpha < 1$.

Therefore, the optimal order quantity y(λ) for $0 < \alpha < 1$ is given by:

$$y(\lambda) = \begin{cases} F^{-1}\left(\dfrac{p-c}{p-z} + \dfrac{\alpha-\lambda}{1-\lambda}\cdot\dfrac{c-z}{p-z}\right), & \lambda \le \dfrac{p-c}{p-z} \\[2ex] F^{-1}\left(\dfrac{p-c}{p-z}\cdot\dfrac{\alpha}{\lambda}\right), & \lambda \ge \dfrac{p-c}{p-z} \end{cases}$$

As the optimal cycle service level CSL(λ) is decreasing in λ the optimal order quantity y(λ) is also a decreasing function of λ. For λ = α the optimal order quantity is equal to the optimal order quantity y* in the classical newsvendor model.

This means that for λ = α the inventory manager exploits risk neutral behaviour. If λ < α then the optimal order quantity y(λ) is larger than y*. In such a situation the manager behaves as a risk taker. On the other hand for λ > α the optimal order quantity y(λ) is smaller than in the risk neutral case meaning that the inventory manager is a risk averse decision maker.

Finally we show the optimal expected profit in dependence of the risk parameter λ for $0 < \alpha < 1$. Let EP(λ) bet the expected profit for $0 < \alpha < 1$. Then the optimal expected profit EP(λ)in dependence of the optimal order quantity y(λ) is given by:

$$\mathrm{EP}(\lambda) = (p-c)\, y(\lambda) - (p-z) \int_0^{y(\lambda)} (y(\lambda) - d)\, dF(d)$$

Note that y(λ)is defined differently for λ larger or smaller than $\frac{p-c}{p-z}$.

We can conclude that EP(λ) is increasing for $0 \le \lambda \le \alpha$ and decreasing for $\alpha \le \lambda \le 1$. The maximal value EP* is attained for $\lambda = \alpha$.

With these results it is possible to show the traditional inventory-service trade-off in dependence of the risk parameters λ and α. In Figure 1 the trade-off between the optimal expected profit and the optimal cycle service level is presented.

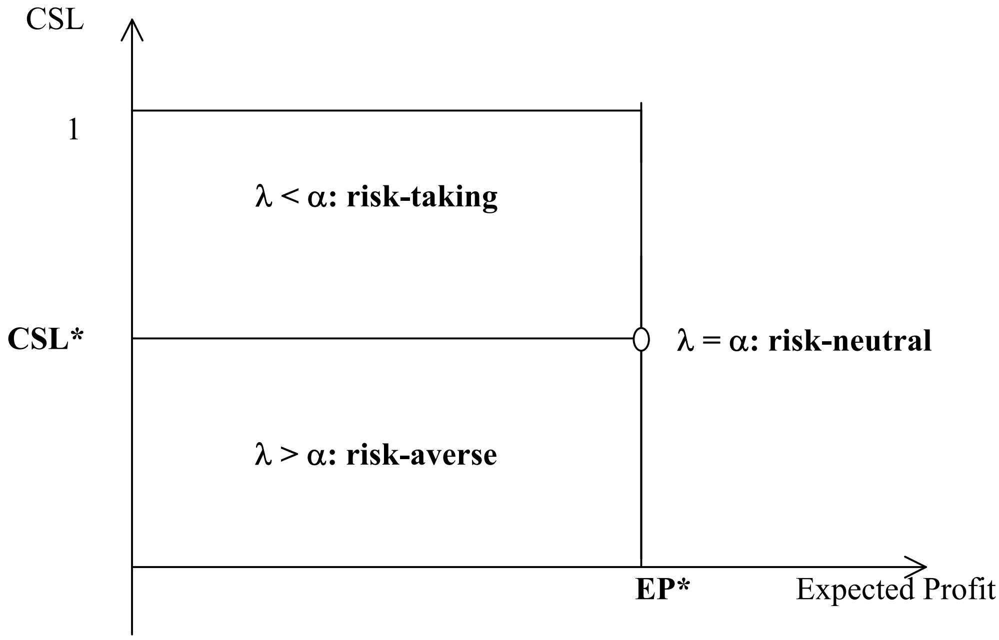

Figure 1: Risk preferences in dependence of expected profit and service level

From Figure 1 we conclude that a risk averse inventory manager, characterized by λ > α, can not dominate an inventory manager with risk taking behaviour, i.e. λ < α. The risk-averse manager orders less than the risk-taking colleague resulting also in a lower cycle service level and fill rate, respectively.

In the following section we investigate these trade-offs of the performance measures by means of a numerical study.

4 Numerical Analyses

In our numerical study we choose a so-called newsvendor distribution for the random demand of a selling period. Such a distribution can deal with exact data and with censored data which happens to be the case in dynamic newsvendor models. The inventory manager can only observe the sales of the product. If the sales are lower than the order quantity y then an exact observation can be made, i.e. sales equals demand. If instead the whole order quantity y is sold during the selling season, then of course in general demand will exceed sales. For a newsvendor distribution there exists a one-dimensional sufficient statistic for an unknown parameter of the distribution that is a function of the exact demand data (sales smaller than or equal to the order quantity) and of the censored demand data (demand is larger than the order quantity). Such a newsvendor distribution is the Weibull distribution with distribution function

$$F(d) = 1 - \exp(\delta d^{\gamma})$$

with parameters $\gamma > 0$ and $\delta > 0$, where δ represents the above mentioned unknown parameter of the newsvendor distribution (Braden/Freimer (1991), p. 1395 – 1397).

Generally, the Weibull distribution is very flexible because it shows positive or negative skewness depending on the value of the shape parameter γ. Moreover, a Weibull distribution with shape parameter $\gamma > 1$ has an increasing failure rate ($\gamma = 1$ represents the special case of the exponential distribution). In inventory management the demand distribution is often assumed to have an increasing failure rate.

In a dynamic environment the parameter δ can be estimated by the newsvendor statistic and the shape parameter γ can be adjusted depending on the level of product availability in previous selling seasons. E.g. no lost sales in previous periods may lead to a right-shift of the demand distribution which is expressed by an increase of the shape parameter γ and perhaps a negative skewness.

For reference we choose the following parameters for the newsvendor model. The selling price per unit of the product is $p = 10$, the purchasing cost per unit $c = 6$ and the salvage price per unit is $z = 5$. Observe that the cycle service level of the classical newsvendor is $CSL^* = (p – c) / (p – z) = 0.8$.

The demand distribution is specified as Weibull distribution with parameters $\gamma = 2$ and $\delta = 0.0001$. Thus, the expected demand is 88.6 units, the coefficient of variation is 0.52 and the skewness is 0.63.

In Table 1a, 1b, 1c and 1d the optimal cycle service level CSL, the corresponding optimal fill rate fr, the optimal order quantity y and the optimal expected profit is computed for different values of the risk parameters α and λ. For parameter α we use the values 0.1, 0.3, 0.5, 0.7 and 0.9, the values of parameter λ are 0, 0.1, …, 0.9 and 1.

	α				
λ	**0.1**	**0.3**	**0.5**	**0.7**	**0.9**
0	82.0	86.0	90.0	94.0	98.0
0.1	80.0	84.4	88.9	93.3	97.8
0.2	77.5	82.5	87.5	92.5	97.5
0.3	74.3	80.0	85.7	91.4	97.1
0.4	70.0	76.7	83.3	90.0	96.7
0.5	64.0	72.0	80.0	88.0	96.0
0.6	55.0	65.0	75.0	85.0	95.0
0.7	40.0	53.3	66.7	80.0	93.3
0.8	10.0	30.0	50.0	70.0	90.0
0.9	8.9	26.7	44.4	62.2	80.0
1	8.0	24.0	40.0	56.0	72.0

Table 1a: Cycle Service Level [%]

	α				
λ	0.1	0.3	0.5	0.7	0.9
0	96.9	97.8	98.6	99.3	99.8
0.1	96.4	97.4	98.4	99.2	99.8
0.2	95.7	97.0	98.1	99.0	99.7
0.3	94.8	96.4	97.7	98.8	99.7
0.4	93.5	95.5	97.2	98.6	99.6
0.5	91.4	94.1	96.4	98.2	99.6
0.6	87.7	91.8	95.0	97.6	99.4
0.7	79.5	86.9	92.4	96.4	99.2
0.8	47.2	72.2	85.3	93.5	98.6
0.9	44.9	69.2	82.3	90.7	96.4
1	43.0	66.6	79.5	88.1	94.1

Table 1b: Fill Rate [%]

	α				
λ	0.1	0.3	0.5	0.7	0.9
0	131.0	140.2	151.7	167.7	197.8
0.1	126.9	136.4	148.2	164.6	195.1
0.2	122.1	132.0	144.2	160.9	192.1
0.3	116.5	126.9	139.5	156.7	188.6
0.4	109.7	120.6	133.9	151.7	184.4
0.5	101.1	112.8	126.9	145.6	179.4
0.6	89.4	102.5	117.7	137.7	173.1
0.7	71.5	87.3	104.8	126.9	164.6
0.8	32.5	59.7	83.3	109.7	151.7
0.9	30.5	55.7	76.7	98.7	126.9
1	28.9	52.4	71.5	90.6	112.8

Table 1c: Order Quantity

	α				
λ	0.1	0.3	0.5	0.7	0.9
0	283.8	281.9	277.2	267.5	243.0
0.1	284.0	282.9	278.9	269.7	245.4
0.2	283.7	283.7	280.6	272.0	248.1
0.3	282.6	284.0	282.1	274.6	251.2
0.4	279.9	283.5	283.4	277.2	254.7
0.5	274.3	281.3	284.0	280.0	258.8
0.6	262.3	275.4	282.9	282.6	263.7
0.7	233.3	259.7	277.0	284.0	269.7
0.8	124.3	206.9	253.9	279.9	277.2
0.9	117.4	196.5	243.1	272.3	284.0
1	111.6	187.4	233.3	263.9	281.3

Table 1d: Expected Profit

The values in the main diagonal, i.e. for $\lambda = \alpha$, represent the performance measures of the classical newsvendor model with a risk neutral inventory manager. The cycle service level is equal to CSL* = 0.8 and the highest optimal expected profit 284 is achieved with respect to all (α ,λ)-combinations.

For given parameter α, the optimal order quantity, the optimal cycle service level and the optimal fill rate are decreasing in parameter λ. The limiting case for λ = 1 shows the performance measures for the CVaR criterion, in this framework it represents the most risk averse inventory manager. E.g. if α = 0.5 the cycle service level of 0.4 is only half of CSL* of the risk neutral newsvendor. Also the fill rate is considerably lower (79.5% versus 96.4%). The optimal order quantity is about 71 units compared with 127 units for the classical newsvendor. And finally the optimal expected profit is about 20% smaller than that of the risk neutral inventory manager.

For given parameter λ the optimal service level measures CSL and fr and the optimal order quantity y are increasing whereas the optimal expected profit is decreasing in parameter α, the quantile of the profit distribution.

In general, from Table 1a to 1d we can discuss the tradeoff between expected profit and service level which is also addressed in Figure 1. For the risk taking inventory manager who is characterised by (α, λ)-combinations above the main diagonal in Table 1a, 1b and 1d indeed a higher expected profit is corresponding with a lower service level CSL or fr. But for parameter combinations below the main diagonal representing the risk averse manager a higher service level is combined with a higher expected profit. At first glance this seems to be the management lever for the resolution of the cost/profit – service tradeoff. But a closer look reveals that this holds only for smaller service levels CSL and fr and smaller expected profits compared with the corresponding performance measures of the classical newsvendor.

5 Managerial Guideline

A managerial guideline for practical decision making can start from the observation that often in the newsvendor framework the order winning performance measure is customer service (cp. the previous chapter). Suppose the price and cost parameters p, c and z already have been specified. In this way also the optimal cycle service level of the risk neutral newsvendor is given, namely CSL* = (p- c) / (p – z). Now the inventory manager can specify that cycle service level CSL which seems to be the appropriate level of product availability for the prospective customers.

In this way the ranges of the risk parameters α and λ can be specified which are compatible with the specified service level CSL. In this way the corresponding optimal order quantity can be derived (see section 3).

Parameter α can be selected from the interval [Max{0, (CSL – CSL*)/(1 – CSL*)}, Min{CSL/CSL*, 1}].

Then

$$\lambda = \begin{cases} \alpha CSL^* / CSL, & CSL \le \alpha \\ (CSL^* - CSL + \alpha(1 - CSL^*)/(1 - CSL), & CSL \ge \alpha \end{cases}$$

If the inventory manager specifies a product availability CSL = 0.9 then for the reference model of section 4 parameter α must be chosen from the interval [0.5, 1]. Then, if α = 0.5 the other parameter has to be λ = 0. The resulting optimal expected profit is 277.2 (see Table 1d). An increase of the cycle service level from 80 % to 90 % leads to a reduction of the optimal expected profit by about 2%.

On the other hand if the inventory manager specifies a service level which is smaller than CSL*, say CSL = 0.7, then risk parameter α can be chosen from the interval [0, 0.875]. For α = 0.1 parameter λ is equal to 0.4. For a product availability of 70 % the optimal expected profit is 279.9.

We compare these two examples with the results for the classical newsvendor in Table 2.

Cycle service level	Fill rate	Expected profit	Order quantity
70 %	93.5 %	279.9	109.7
80 %	96.4 %	284.0	126.9
90 %	98.6 %	277.2	151.7

Table 2: Expected profit and order quantity for different service levels

In this way the inventory manager has a flexible tool available to fix the appropriate performance measures service level and expected profit. By means of the resulting risk parameters α and λ the corresponding optimal quantity of the product can be ordered.

6 Conclusions

In this paper we presented an inventory model with risk preferences. Based on related models with risk-averse objective function (exponential utility, conditional value at risk - CVaR) we use the newsvendor model and analyse it for an objective function with two risk parameters. The classical newsvendor model as well as the model with CVaR - criterion are included as special cases.

In this way it is possible to characterise a risk averse inventory manager who orders less than the classical newsvendor but also a risk taking manager ordering more than the risk-neutral newsvendor. We present a complete description of the risk preferences of the inventory manager in dependence of the performance measures expected profit and service level. With respect to these two measures a risk-averse inventory manager can not dominate a risk-neutral or a risk-taking manager. Furthermore, we describe how the inventory manager can choose appropriate risk parameters based on the specified prices, costs and service level.

The presented model can be extended in several ways. Additionally to the order quantity, the selling price can be chosen as decision variable. The conjecture is that the optimal inventory-pricing policy is an extended base stock list price policy. Furthermore, the dependence of the demand on the price can be described by general demand functions including a reference selling price besides other market parameters. Also in a dynamic version of the model the updating of the demand function is a challenging task. As already mentioned in the text, the parameters of a newsvendor distribution like the Weibull distribution can be updated using past sales but also past service levels to include also lost sales in the past.

References

Artzner, P., Delbaen, F., Eber, J.-M. and Health, D.(1999): Coherent Measures of Risk. Mathematical Finance 9, 203 - 228 .

Braden, D. J. and Freimer, M.(1991): Informational Dynamics of Censored Observations. Management Science 37, 1390 – 1404.

Chen, X., Sim, M., Simchi-Levi, D. and Sun, P.(2004): Risk Aversion in Inventory Management. Working Paper, MIT.

Chopra, S. and Meindl, P.(2004): Supply Chain Management, 2nd edition, Prentice Hall.

Eeckhoudt, L., Gollier, C. and Schlesinger, H.(1995): The Risk-averse (and Prudent) Newsboy. Management Science 41, 786 – 794.

Fisher, M.L.(1997): What is the Right Supply Chain for your Product? Harvard Business Review, March-April, 83 – 93.

Jammernegg, W. and Kischka, P.(2004): Risk Preferences for Inventory Models. Working Paper, Vienna University of Economics and Business Administration.

Kischka, P. and Puppe, C.(1992): Decisions Under Risk and Uncertainty: A Survey of Recent Developments. Zeitschrift für Operations Research 36, 125 - 148.

Neale, J.J., Tomlin, B.T. and Willems, S.P.(2003): The Role of Inventory in Superior Supply Chain Performance. In: Harrison, T., Lee, H. and Neale, J.J.(eds.): The Practice of Supply Chain Management: Where Theory and Application Converge. Kluwer, 31 – 59.

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