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# On the assessment of costs in a newsvendor environment: Insights from an experimental study

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ABSTRACT

In this paper, we address the question of how the assessment of costs influences decisions in a newsvendor setting. We expect that different cost types lead to different behavior. In our investigation, we consider a newsvendor problem with opportunity costs and a newsvendor problem with penalty costs. In addition, we differentiate between three cases with different margins for each of the two problems. In an experimental study, we observe that the average order quantities in the newsvendor problem with penalty costs exceed the average order quantities in the newsvendor problem with opportunity costs and that a mean anchor effect, familiar from a number of previous studies, exists. A different weighting of costs can be seen as the main driver for the different order quantities. Thus, a biased perception of different cost types exists and decision makers are more sensitive to penalty costs than to opportunity costs. Based on our observations, we can identify situations where the cost weighting and the mean anchor effect compensate for each other and thus lead to "good" decisions as well as situations where the two effects compound and therefore lead to "bad" decisions. As penalty costs are present in many newsvendor situations, our insights allow us to apply the findings from behavioral studies of the newsvendor problem to a broader context.



## 1. Introduction

In the newsvendor problem, a decision maker has to decide on the number of ordered products under stochastic demand. Once the uncertainty is resolved, the costs incurred from the mismatch between the decision and the realization become apparent. The decision maker observes that his decision was too "high" or too "low". The newsvendor model provides a theoretically grounded approach to determine the optimal order quantity, i.e. the order quantity that minimizes the expected mismatch costs.[1] However, experimental studies show that decision makers systematically deviate from the optimal order quantity. In their seminal paper, Schweitzer and Cachon [31] observe a pattern of behavior where subjects order too few high margin products and too many low margin products. According to the anchoring and adjustment heuristic [35], this too low/too high pattern can be explained by the fact that individuals anchor on the mean demand and insufficiently adjust toward the optimal order quantity. A number of follow-up studies have confirmed the too low/too high pattern, e.g. in experimental newsvendor studies considering doubled payoffs and reduced order frequency [5], the effect of learning [3], different demand distributions [2], participants with different educational backgrounds [4], different frames [20,30], multilocation inventory systems [15], different payment schemes [7] as well as cross-cultural differences between Western and Eastern countries [11]. Order decisions in the newsvendor problem tend to be biased towards the anchor of mean demand, which we call the "mean anchor effect". For a recent review considering experimental studies of the newsvendor problem, see Kremer and Minner [19].

Although many studies discuss behavioral aspects in the newsvendor problem, there is hardly any research on the assessment of the different cost types. Since costs are one of the essential influencing variables in the newsvendor problem, the assessment of costs may have a strong effect on human decision making. Depending on the field of application, costs like out-of-pocket costs, opportunity costs, or penalty costs can be relevant when deciding on the order quantities. A detailed definition of the cost types in the context of our study will be given in Section 2. Previous studies have shown that these cost types may have a diverse influence on behavior in several situations. The indirect character of opportunity costs is a reason why they are often neglected in decision making. Northcraft and Neale [27] state that opportunity costs are abstract possibilities which can lead to a biased assessment of the cost/benefit picture of a decision maker. This biased opportunity cost perception is documented in numerous papers. The results of an experimental study by Becker et al. [1] suggest that

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[1] A minimization of the expected mismatch costs is equivalent to a maximization of the expected profit, see Silver et al. [32] or Khouja [18].

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decision makers consider opportunity costs as less important than out-of-pocket costs and even ignore them in some cases. A study by Friedman and Neumann [13] leads to consistent results. They conclude that decision makers underweight opportunity costs when only partial information is available. While Becker et al. [1] as well as Friedman and Neumann [13] investigate a setting with a certain environment, Hoskin [16] considers the assessment of opportunity costs in an uncertain environment. Seventeen years before the seminal paper by Schweitzer and Cachon [31], the experimental study of Hoskin [16] had already addressed human behavior in the newsvendor problem. The results show that decision makers deviate from the order quantities that optimize expected profits. However, the study has a number of technical shortcomings which do not allow for deriving consistent and reliable results.[2] Since previous research has shown that decision makers underweight or even neglect foregone payoffs, Ho et al. [15] hypothesize that the psychological aversion to leftovers is greater than the disutility of stockouts. They develop and experimentally test a newsvendorframework where they add psychological costs of overordering and underordering. A main weakness of their additive approach is that an underweighting of foregone losses is modeled as additional (positive) psychological costs, which seems counterintuitive. Furthermore, the case in which decision makers neglect foregone payoffs is even incompatible. The question why in many situations decision makers underweight opportunity costs compared to out-of-pocket costs is addressed by Thaler [33]. He argues that the endowment effect supports the different weighting of these costs. While opportunity costs are often underweighted, other cost types tend to be overweighted by decision makers. McCaffery and Baron [24] refer to Richard Thaler's real-world observation: "when a gas station charged a 'penalty' for using credit cards ($2.00 versus $1.90, say), people paid cash; when a gas station across the street gave a 'bonus' for using cash ($1.90 versus $2.00), people used credit cards". McCaffery and Baron [24] state that, due to penalty aversion, individuals would rather avoid penalties than obtain bonuses. The tendency of people to avoid penalties is documented in several experimental studies and holds true in diverse economical contexts. For example, tax rules [23] or contracts [21] are less likely to be accepted when they are presented as penalties rather than as bonuses. The consequences of penalty aversion are decisions where penalty costs are higher weighted than out-of-pocket costs – another example that the different assessment of cost types can lead to a different behavior.

Involving different types of costs, a wide range of business decisions require that a decision is made before the occurrence of a random event. The underlying trade-off, concerning the costs of the mismatch between the decision and the realization, is captured by the newsvendor model. However, experimental studies of the newsvendor problem typically consider out-of-pocket costs (overage costs) and opportunity costs (underage costs) as mismatch costs. To investigate how the assessment of costs influences a decision maker, we consider two newsvendor situations involving different types of cost. Motivated by the literature, we expect an underweighting of opportunity costs and an overweighting of penalties. Therefore, we consider a situation where penalty costs (respectively additional reorder costs) instead of opportunity costs occur in the underage case. An example is a newsvendor situation involving a second order for an additional premium, as considered by Cachon and Terwiesch [6] where "the second order opportunity eliminates lost sales (…) [but] therefore, the penalty for ordering too little in the first order is that one may be required to purchase additional units in the second order at a higher cost." We refer to this kind of newsvendor problem involving out-of-pocket costs and penalty costs as the"penalty cost problem" whereas the classical newsvendor problem as considered by Schweitzer and Cachon [31] is referred to as the "opportunity cost problem". Since only the type of costs is different, the balancing problem remains mathematically identical and the decision maker is still facing the same underlying tradeoff concerning ordering too little and ordering too much [6]. Gavirneni and Isen [14] show that most people are able to compute the overage and underage costs accurately, but fail to determine the optimal inventory level. Therefore, a different behavior in the penalty cost and the opportunity cost problem implies that the assessment of costs changes for different cost types. Consequently, in order to investigate our research question we set up an experimental study where we differentiate between these two problems. Since previous research has shown that people anchor on the mean demand, we further distinguish between three cases with different margins for each of the two problems.

The main contribution of this paper is twofold. First, we systematically investigate how the assessment of costs influences a decision maker in a newsvendor situation. We propose a behavioral approach, including a higher weighting of penalty costs than of opportunity costs and order decisions which are biased towards the mean. Our model explains large portions of the observed behavior in our experimental study. A different weighting of costs can be seen as the main driver for higher order quantities in the penalty cost problem compared to the opportunity cost problem. Based on our findings, we identify situations in the newsvendor problem which are particularly unfavorable for the performance of a decision maker. Furthermore, our insights allow us to detect situations where the behavioral effects partially compensate for each other and therefore lead to a better performance of decision makers.

Second, our experimental study gives important insights into how people behave in newsvendor situations which are affected by penalty costs. For many business decisions, the underage case of the underlying newsvendor trade-off is influenced by penalty or reorder costs and not by opportunity costs. Typical areas where expensive re-orders, contractual penalties or second production runs occur instead of lost profits are procurement problems if too little was ordered (e.g. [6]), inventory problems if too little was stored (e.g. [10]), or production problems if too little was produced (e.g. [8]).[3,4] In order to apply the findings from behavioral studies of the newsvendor problem to a broad field of business situations, it is important to check validity and to identify limitations. The results of our study clarify that the behavior in a newsvendor situation which is affected by penalty costs is significantly different from the behavior in a situation which is influenced by opportunity costs.

The paper is organized as follows: Section 1 provides an introduction and a literature review before we define our hypotheses in Section 2. The experimental setup and design is described in Section 3, and we discuss the results in Section 4. Finally, in Section 5 we draw conclusions and discuss managerial implications.

## 2. Definitions and research hypotheses

To investigate the influence of different cost types on decision making, we differentiate between two from a mathematical point

[2] The number of participants per experimental setting as well as the number of periods were too small, participants had to estimate the demand distribution based on the past data on demand, and some participants received changed information already after few periods. Furthermore, several product types had to be ordered and the margins of the products were chosen unfavorably.

[3] Identical to the opportunity cost problem, the overage case of the penalty cost problem involves out-of-pocket costs like production costs, holding costs, and purchasing costs.

[4] In a broader context, the penalty cost problem is also inherent in stochastic project management settings, such as the determination of feeding buffers (e.g. [34]) or due dates (e.g. [37]) assuming costs for starting activities earlier and tardiness penalties. Furthermore, a typical application in healthcare management is the reservation of operating room capacity under uncertainty considering costs for operating room time and overtime costs (e.g. [28,36]).