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Salient Compromises in the Newsvendor Game*

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Abstract

The newsvendor problem denotes the puzzle that a retailer facing an uncertain demand for some product underreacts to profit margins, and hence adjusts the order quantity toward the expected demand. Due to its range of applications in operations management, this problem has drawn much interest in recent years. Various articles have tried to reconcile the newsvendor problem with loss aversion under ad hoc assumptions on the underlying reference point. We, instead, argue that the newsvendor problem is an application of the well-studied *compromise effect*. As the compromise effect is based on violations of the IIA axiom, we argue that models of context-dependent behavior, such as salience theory, better explain newsvendor-like behavior than loss aversion-based models. We conduct a novel experiment which allows us to clearly distinguish between the role of loss aversion and salience, and find strong support for the latter. Thereby, we also add to the agenda of comparing loss aversion-based models and salience theory.

JEL-Classification: D03.
Keywords: Newsvendor Problem; Loss Aversion; Salience; Compromise Effects.

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1 Introduction

In the newsvendor game, a retailer orders a certain quantity of a perishable good before she can observe the factual demand for that product. Determining the expected profit-maximizing order quantity is straightforward (Arrow *et al.*, 1951), but various experimental studies, starting with Schweitzer and Cachon (2000), have shown that agents' ordering decisions are systematically biased. While it is optimal to order a quantity in excess of (below) the expected demand if a newspaper's profit margin is high (low), agents tend to underreact to profit margins, thereby adjusting their order quantity toward the mean demand ("pull-to-the-center effect"). This phenomenon, typically denoted the "newsvendor problem," is a strong and robust effect which has been detected in many variants of the original experimental setup (e.g., Bolton and Katok, 2008, or Kremer *et al.*, 2010). Not only students, but also experienced managers are prone to the newsvendor problem (Bolton *et al.*, 2012), and neither experience nor different feedback conditions suffice to overcome this decision bias (Bolton and Katok, 2008; Bostian *et al.*, 2008). As Schweitzer and Cachon (2000) point out, the newsvendor puzzle cannot be explained by standard approaches such as risk-seeking or risk aversion as each of these suggests that agents consistently order too much or too little, regardless of whether the optimal order quantity is below or above the expected demand.

More recently, various studies have derived equilibrium order quantities of a loss-averse newsvendor who evaluates outcomes as gains or losses relative to some reference point as suggested by prospect theory (Kahneman and Tversky, 1979). While Schweitzer and Cachon (2000) or Nagarajan and Shechter (2013) argue that prospect theory cannot account for the newsvendor problem, Long and Nasiry (2015) as well as Uppari and Hasija (2014) propose ad-hoc assumptions of the decision maker's reference point via which prospect theory can explain this phenomenon. Also the most fruitful modeling of loss aversion, according to which reference points are endogenously shaped by an agent's rational expectations (see Kőszegi and Rabin, 2007) cannot account for the newsvendor problem (Herweg, 2013). To sum up, loss aversion seems to play only a minor role in the newsvendor game.

Essentially, loss aversion-based theories capture behavior that is insensitive to the choice context. Whether unchosen alternatives are available or not should not affect the choices of a loss-averse agent. But as the newsvendor problem precisely denotes the effect that choices are biased toward middle options in the choice set, it may be regarded as an application of the well-studied *compromise effect* (Simonson, 1989). According to the compromise effect, subjects avoid extreme options, and choose alternatives which represent a compromise in a given choice context. This, in turn, implies that the composition of the choice environment has a crucial impact on an agent's decision making. Models of loss aversion, in contrast, can only account for context-independent compromise effects according to which agents limit the loss in each dimension by choosing an option with moderate outcomes in each attribute. Thereby, loss aversion-based models cannot account for context-dependent behavior and violations of the axiom of the independence of irrelevant alternatives (IIA).

Context-dependent behavior such as a tendency to choose in favor of compromising options can be explained by a novel behavioral theory – *salience theory* (Bordalo *et al.*, 2012). In general, salience theory challenges the prevalence of loss aversion-based theories in behavioral economics by explaining a broad range of decision biases via the assumption that agents overemphasize features which stand out in a certain context. In this paper, we analyze the newsvendor game in light of salience distortions, and test for compromise effects as predicted by the salience mechanism, but not by models of loss aversion.

In order to test whether context-dependent compromise effects indeed drive behavior in the newsvendor game, we have designed a novel laboratory experiment: we investigate whether a certain order quantity is chosen more frequently if it appears to be a compromise ceteris paribus. For illustrative reasons, we denote the largest quantity which lies in the support of the demand distribution as the *large* order quantity. In virtually all newsvendor games, the subject's choice set equals the support of the demand distribution. Here, the large order quantity is an extreme alternative which, according to a preference for compromises, subjects avoid choosing. If, however, an excessive quantity which exceeds the large order quantity broadens the choice set, the large quantity becomes a compromise itself. Therefore, subjects should more likely choose the large order quantity with the excessive quantity being available. According to any theory which satisfies the IIA axiom, however, the excessive order quantity should have no effect on the evaluation of the other options.

Our findings are fully in line with the predictions by salience theory. First, we replicate the "pull-to-the-center effect" in a standard newsvendor game where the choice set coincides with the support of the demand distribution. Second, as predicted by salience theory, the introduction of the dominated option enhances the proportion of subjects who order the large quantity. Thus, we document violations of the IIA axiom which loss aversion-based models such as prospect theory cannot account for.

By integrating the newsvendor problem into the salience framework, we contribute to the growing literature which compares models of loss aversion and salience theory (for instance, Bordalo *et al.*, 2012; Dertwinkel-Kalt and Köhler, 2016; Dertwinkel-Kalt *et al.*, 2016). While both approaches can account for various decision biases such as the Allais paradox or preference reversals, the salience model yields novel predictions on how the context affects choice. In order to decide whether salience theory is the superior model, we regard the analysis of the newsvendor problem as an important step since newsvendor-like decisions have a wide range of applications in operations management.

We do not claim that salience theory gives the best fit among all behavioral approaches to the newsvendor problem. In fact, other models may explain newsvendor behavior in a more general setup which would not be tractable with our salience approach. We, however, point out that salience theory can *also* explain the newsvendor problem, given that it can account for a wider range of decision biases than most other behavioral approaches.

In particular, we show that the salience-based explanation, that is, subjects tend to choose compromising options, is supported by our novel manipulation of the newsvendor game. Here, we document relevant effects (see Section 7 for a discussion of the practical relevance for operations management) which—to the best of our knowledge—only salience theory can account for.

Finally, we qualify the "pull-to-the-center effect" which has been assumed to be the driver of the newsvendor problem. While this effect states that quantities are adjusted in the direction of the center of the demand distribution, we show that the center of the choice set also serves as a focal point which affects the newsvendor's orders. In our experiment, we therefore observe rather a "pull-to-the-center-of-the-choice-set effect" than a "pull-to-the-center-of-the-demand-distribution effect." This is fully in line with the rationale of the compromise effect as alternatives located in the center of the choice set represent compromising options. In more general setups, we assume that both effects interact.

We proceed as follows. In Section 2, we define and discuss the newsvendor problem. Subsequently, we introduce salience theory and apply it to a simplified newsvendor game (Section 3). Section 4 reinvestigates the predictions of loss aversion-based theories. Then Section 5 describes the design of our laboratory experiment. In Section 6, we present our experimental results before Section 7 concludes.

2 The Newsvendor Problem

In this section, we provide a general definition of the newsvendor problem. For that, we first introduce the continuous newsvendor game. Second, we introduce a simple discrete version of the newsvendor game which our subsequent analysis builds on. Third, we review the related literature.

The Newsvendor Game. Consider a probability space $(\Omega, \mathcal{F}, P)$ and a measurable space $(\mathbb{R}, \mathcal{B})$, where $\mathcal{B}$ denotes the Borel-σ-algebra. Let $X : \Omega \to \mathbb{R}_+$ be the random variable which determines the demand for newspapers. We assume that its cumulative distribution function F is differentiable with the probability density function f. The newsvendor chooses an order quantity q from her strategy space $Q = \{x \in \mathbb{R}_+ | f(x) > 0\}$, which is assumed to contain all feasible demand realizations.

A newspaper is acquired at cost w and sold at price p, where $p \geq w \geq 0$. In the following, we characterize the order quantities as a function of the *cost price ratio* $z := w/p$. The newsvendor's payoff derived from demand realization $x = X(\omega)$ and order quantity q equals

$$u(x, q) := p \min\{q, x\} - wq. \tag{1}$$

For each quantity q we denote the newsvendor's expected payoff as

$$U(X, q) := \int_0^\infty u(x, q) f(x) dx.$$

Arrow *et al.* (1951) have already shown that there is a unique solution to the newsvendor's optimization problem which is monotonic in the cost price ratio z.

Proposition 1. *The optimal order quantity* $q^* := \arg\max_{q \in Q} U(X, q)$ *exists and is unique. Moreover, its inverse exists and equals*

$$z(q^*) = 1 - F(q^*). \tag{2}$$

Finally, the optimal order quantity strictly decreases in the cost price ratio z, that is,

$$dq^*(z)/dz = -1/f(q^*) < 0. \tag{3}$$

The proof is relegated to the Online Appendix Part A.

Example. In many studies, demand X follows a uniform distribution (Schweitzer and Cachon, 2000; Bolton and Katok, 2008; Bostian *et al.*, 2008; Bolton *et al.*, 2012; Ockenfels and Selten, 2014). If we consider a uniform distribution with support $[0, 1]$, the newsvendor has an expected profit of

$$U(X, q) = p\left(\int_0^q x dx + \int_q^1 q dx\right) - wq = p\left(q - \frac{q^2}{2}\right) - wq,$$

so that the optimal order quantity equals

$$q^* = 1 - z.$$

The Newsvendor Problem. Typically, agents fail to make the optimal inventory decision, but deviate systematically. The frequently observed choice pattern is denoted the *newsvendor problem*.[1]

Definition 1 (The Newsvendor Problem)**.** *Let $z \in (0, 1)$, then strategy $q = q(z)$ represents the newsvendor problem if it satisfies the following three properties:*

i) The newsvendor will place the optimal order if and only if the optimal order quantity q^* meets the expected demand $E(X)$. That is, $q(z) = q^*(z)$ holds if and only if $z = 1 - F(E(X))$.

ii) Order quantity q monotonically decreases in the cost price ratio z.

iii) Order quantity q is insufficient if and only $q^*(z) > E(X)$, while it is excessive if and only if $q^*(z) < E(X)$.

According to the newsvendor problem, order quantity q does not optimally correspond to profit margins as represented by the cost price ratio. Instead, the newsvendor

[1] Our definition of the newsvendor problem ignores the trivial cases for $z \in \{0, 1\}$, where we expect the newsvendor to order optimally. That is, $q(z) = q^*(z)$ holds if and only if $z \in \{0, 1 - F(E(X)), 1\}$.

tends to adjust her ordered quantity toward the expected demand so that she orders less than q^* if the cost price ratio is low (i.e., the profit margin is high) and more than the optimal order quantity if the cost price ratio is high (i.e., the profit margin is low). This effect has also been denoted the "pull-to-the-center effect" since agents' order quantities are biased toward the center of the demand distribution (see Schweitzer and Cachon, 2000; Bolton and Katok, 2008; Bostian *et al.*, 2008). In this sense, the newsvendor problem can be interpreted as an application of the compromise effect according to which agents' choices are biased toward intermediate options that constitute a compromise between more extreme alternatives.

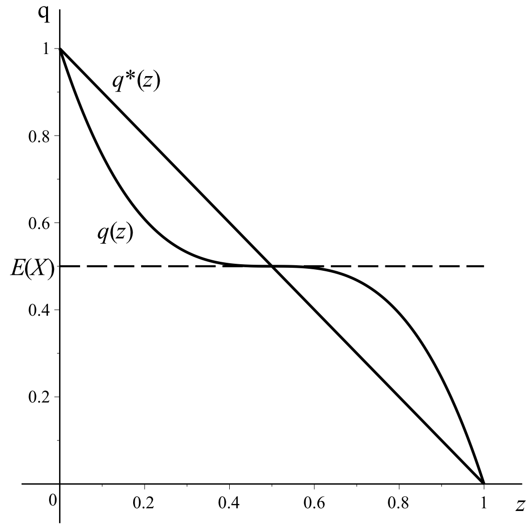

Figure 1: *Optimal order quantities, $q^*(z)$, and order quantities according to the newsvendor problem, $q(z)$, for uniformly distributed demand on* $[0,1]$ *and cost-price ratio z.*

A Discretization of the Newsvendor Game. The newsvendor problem also occurs in discrete newsvendor games with very few feasible demand realizations. Bolton and Katok (2008) provide evidence that the newsvendor problem will persist even if the subjects' choice set is reduced to three options.

The remainder of the paper is built on the following discretization of the newsvendor game. Suppose the decision maker faces a stochastic demand represented by the lottery $X = (x_i, Pr(x_i))_{0 \leq i \leq n}$ with $x_i \in \mathbb{N}_0$ and corresponding probability $0 \leq Pr(x_i) \leq 1$ so that $\sum_{i=0}^{n} Pr(x_i) = 1$. We specify $n = 2$ and $x_0 = 0$, $x_1 = 1$, and $x_2 = 2$, where $Pr(x_i) = 1/3$ for $0 \leq i \leq 2$. The decision maker's choice set equals the support of the demand distribution, that is, $Q = \{0, 1, 2\}$. Each demand realization x_i defines a *state of the world* i. For retail price p, marginal cost w, and demand x_i the newsvendor's payoff from order quantity $q_j \in Q$ equals $u(x_i, q_j) = p \min\{x_i, q_j\} - wq_j$. In order to decide which quantity to acquire, the newsvendor evaluates her options in all feasible states of the world. In Table 1, we provide an overview of the payoffs earned in the different states.

A rational decision maker chooses a quantity q_j in order to maximize her expected

	$x_0 = 0$	$x_1 = 1$	$x_2 = 2$
$q_0 = 0$	0	0	0
$q_1 = 1$	$-w$	$p - w$	$p - w$
$q_2 = 2$	$-2 \cdot w$	$p - 2 \cdot w$	$2 \cdot (p - w)$

Table 1: *Payoffs derived from order quantities q_j in state i where $i, j = 0, 1, 2$.*

payoff $U(X, q_j) = \sum_{i=0}^{2} Pr(x_i)u(x_i, q_j)$. Therefore, she chooses

$$q^*(z) = \begin{cases} 0 & \text{if } 2/3 < z \leq 1, \\ 1 & \text{if } 1/3 < z \leq 2/3, \\ 2 & \text{if } \quad 0 \leq z \leq 1/3. \end{cases}$$

Hence, if costs are relatively high, a rational newsvendor orders zero units. If the cost price ratio is at an intermediate level, she orders one unit, and if costs are relatively low, she orders a large quantity; that is, two units. Note that the rational valuation of an option is independent of the choice context and the other available options.

Experimental Evidence on the Newsvendor Problem. In their seminal experimental study on the newsvendor game, Schweitzer and Cachon (2000) test the explanatory power of several theories (risk aversion, prospect theory, waste aversion, stockout aversion) and heuristics (anchoring with insufficient adjustments, minimization of ex-post inventory errors). Two experiments are conducted in which subjects face a discrete and uniformly distributed demand and make repeated inventory decisions. While negative profits are feasible in the first experiment, the second one ensures strictly positive profits.[2] Each experiment involves a high- and a low-marginal profit condition (arranged in a within-subjects design) such that the optimal order quantities are either $E(X)/2$ or $3E(X)/2$. Observed order quantities accord with the newsvendor problem in both experiments and both profit conditions.

The newsvendor problem has been reproduced in many further experiments. It arises under various feedback conditions and experience only slightly improves choices over time (Bolton and Katok, 2008). Interestingly, professional managers who are familiar with related decisions do not perform significantly better than undergraduate students (Bolton *et al.*, 2012). According to Bostian *et al.* (2008), the newsvendor problem is independent of the payoff level as doubling outcomes does not alter inventory decisions by much.

Other studies have found that the newsvendor problem is not universal. Gavirneni and Xia (2009) observe that not only individual newsvendors but also groups of newsvendors are prone to an anchoring bias, but they suggest that the focal point is not necessarily the expected demand. If informational cues, such as past decisions or consultant suggestions, are presented, agents tend to adjust their ordering decisions in the direction of the

[2]This admits to testing for diverging perceptions of gains and losses as predicted by prospect theory.

additional information instead. Similarly, Kremer *et al.* (2010) find that the wording used to describe the newsvendor game impacts on a newsvendor's ordering decisions. Their setup allows to rule out random errors as the sole explanation for the newsvendor problem. Furthermore, Rudi and Drake (2014) find that demand observability is crucial for the emergence of the newsvendor problem. If demand realizations are censored, subjects tend to order less, ceteris paribus. Thus, their study replicates the "pull-to-the-center effect" only if demand is perfectly observable ex-post.

To the best of our knowledge, the newsvendor problem has not been studied in the field. The main complication for a field study is the ex-ante uncertainty regarding future demand. Therefore, suboptimal ordering decisions could rather be driven by insufficient information on future demand than by a decision bias such as salience. Only in the lab can experimenters precisely control for the distribution of demand and the information the agent receives.

Compromise Effects and the Newsvendor Problem. Most decisions involve a trade-off between different choice dimensions. In case of inventory decisions, for instance, the agent has to trade off the risk of running out of stock against the risk of demand falling short of the stock. Simonson (1989) first demonstrated that subjects tend to choose intermediate options which constitute a compromise in order to avoid extreme outcomes. The rationale behind this compromise effect perfectly applies to the newsvendor problem: adjusting the order quanitity toward the mean demand gives a compromise between the extremes of under- and overstocking, respectively. Thus, the "pull-to-the-center effect" can be interpreted as a preference for compromises. Moreover, Dhar and Simonson (2003) suggest that a compromising option appears particularly attractive in an uncertain environment as given in the newsvendor game. Compromise effects are not an artefact of the lab, but are highly relevant in field contexts (Pinger *et al.*, 2016).

3 Salience Theory and the Newsvendor Problem

In this section, we introduce the salience model and apply it to the newsvendor game. Salience theory (Bordalo *et al.*, 2012, 2013) represents a model of context-dependent decision making according to which a decision maker's probability weight is inflated for more salient states and deflated for less salient states. The salience model can account for a wide range of decision biases and has been supported by recent empirical (Hastings and Shapiro, 2013) and experimental (Dertwinkel-Kalt *et al.*, 2017) studies.

The Salience Mechanism. According to salience theory of choice under risk (Bordalo *et al.*, 2012), a decision maker evaluates an option by assigning the outcome in each state a subjective probability that depends on the state's true probability and on its salience. In line with Bordalo *et al.* (2012), we denote an agent who is susceptible to the salience bias a *local thinker* (LT). A local thinker maximizes the *salience-weighted expected payoff*

$$U(X, q_j|Q) := \sum_{i=0}^{2} w_{ij}\ Pr(x_i)\ u(x_i, q_j),$$

where w_{ij} depends on the salience of option q_j's outcome in state i within choice set Q. We will refer to $U(X, q_j|Q)$ as the local thinker's decision utility.

Salience is determined by a symmetric and continuous mapping $\sigma : \mathbb{R}^2 \to \mathbb{R}_+$ which satisfies *ordering*, that is, $\sigma(x + \mu\epsilon, y - \mu\epsilon') > \sigma(x, y)$ for $\mu = sgn(x - y)$ and $\epsilon, \epsilon' \geq 0$ with $\epsilon + \epsilon' > 0$, and *homogeneity of degree zero*, that is, $\sigma(\alpha x, \alpha y) = \sigma(x, y)$ for all $\alpha > 0$. The salience of q_j's outcome in state i equals $\sigma\left(u\left(x_i, q_j\right), \overline{u}_i\right)$ where $\overline{u}_i := \frac{1}{3}\sum_{j=0}^{2} u\left(x_i, q_j\right)$ gives the average payoff in state i. Thus, a local thinker compares an option's outcome in a given state to the average outcome in that state.

A salience function σ captures two essential features of sensory perception. Due to ordering, an outcome is the more salient the more it differs from the average payoff in the respective state. This captures the frequently observed *contrast effect* according to which large contrasts attract attention (Schkade and Kahneman, 1998; Dunn *et al.*, 2003). Together with ordering, homogeneity of degree zero implies diminishing sensitivity according to which a uniform increase (decrease) of positive (negative) outcomes in a given state decreases the attention they attract.[3] Formally, diminishing sensitivity is defined as $\sigma(x, y) > \sigma(x + \epsilon, y + \epsilon)$ for any $x, y \geq 0$ and $\epsilon > 0$ or any $x, y \leq 0$ and $\epsilon < 0$. This property captures the *level effect*, a phenomenon which is well-known in psychology as *Weber's law* of perception (for a discussion of this property see also Kahneman and Tversky, 1979).

We use the standard salience function $\sigma\left(x, y\right) := |x - y|/(|x| + |y|)$ with $\sigma(0, 0) := 0$ proposed by Bordalo *et al.* (2013) that satisfies the preceding properties.

Definition 2 (Salience)**.** *The salience of state i for option q_j is given by*

$$\sigma\left(u\left(x_i, q_j\right), \overline{u}_i\right) = \frac{|u\left(x_i, q_j\right) - \overline{u}_i|}{|u\left(x_i, q_j\right)| + |\overline{u}_i|},$$

where $\overline{u}_i$ gives the average payoff in state i for $i \in \{0, 1, 2\}$.

Decision weights w_{ij} are defined as follows. For each option q_j states are ranked by their salience where $\sigma\left(u\left(x_i, q_j\right), \overline{u}_i\right) > \sigma\left(u\left(x_l, q_j\right), \overline{u}_l\right)$ indicates that for q_j state i is more salient than state l. Let r_{ij} denote the salience rank of outcome $u(x_i, q_j)$. Formally, let $r_{ij} = k - 1$ if state i is the k^{th} most salient state for option q_j. Equally salient states obtain the same salience rank. If there are two most salient states they both obtain salience rank 0, and if there are two states with salience rank $k - 1$ the next state in the salience ranking obtains salience rank k. Then,

$$w_{ij} := \frac{\delta^{r_{ij}}}{\sum_{k=0}^{2} \delta^{r_{kj}} Pr(x_k)},$$

[3] Bordalo *et al.* (2013) prove that ordering and homogeneity of degree zero imply diminishing sensitivity.

where parameter $\delta \in (0, 1)$ gives the strength of the salience bias, and the denominator represents a normalization which ensures that the distorted probabilities $w_{ij}\ Pr(x_i)$ sum up to one. While the limit case $\delta = 1$ captures the rational decision maker, for $\delta \to 0$ the local thinker takes only the most salient outcome into account when evaluating an option.

Salience and the Newsvendor Problem. We investigate a local thinker's inventory decision in the discrete newsvendor game introduced in the previous section. Throughout the paper, we denote a local thinker's order quantity as q^{LT}. In this paragraph we sketch the predictions of salience theory, while we provide a detailed derivation in the Online Appendix Part B.

In a first step we have to determine the salience ranking of the outcomes for options q_1 and q_2. Note that the small option q_0 pays zero in any state so that the expected payoff $U(X, q)$ and the salience-weighted expected payoff $U(X, q|Q)$ coincide. We observe that for the middle option q_1 demand realization x_1 is the most salient, while demand realizations x_0 and x_2 are equally salient. Precisely, applying Definition 2 yields

$$\underbrace{\sigma\left(u\left(x_1, q_1\right), \overline{u}_1\right)}_{=\sigma(p-w, 2/3\cdot p-w)} > \underbrace{\sigma\left(u\left(x_0, q_1\right), \overline{u}_0\right)}_{=\sigma(-w,-w)} = \underbrace{\sigma\left(u\left(x_2, q_1\right), \overline{u}_2\right)}_{=\sigma(p-w,p-w)},$$

where the above ranking follows from the facts that q_1 provides the highest payoff among all three options in state 1, and exactly the respective average outcome in each of the other states. Next, we derive the salience ranking for the large option q_2. First note that states 0 and 2 are equally salient, which follows from homogeneity of degree zero and Definition 2. Now it depends on the cost price ratio $z = w/p$ whether state 1 is more or less salient than the other states. Intuitively, if the cost price ratio is low, option q_2 yields the intermediate payoff in state 1. Hence, for low values of z, q_2's payoff in state 1 is close to the average outcome in this state, and therefore not salient. If the cost price ratio is sufficiently high, however, option q_2 yields the lowest payoff in state 1. In this case, q_2's payoff in state 1 stands in sharp contrast to the average outcome in this state, and is therefore salient. Formally, Definition 2 yields $\sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right) = \sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right) > \sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right)$ for any $0 \leq z \leq 4/9$, and $\sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right) > \sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right) = \sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right)$ for any $4/9 < z \leq 1$.

Given these salience rankings, a local thinker maximizes her decision utility by choosing

$$q^{LT}(z) = \begin{cases} 0 & \text{if } \frac{1+\delta}{1+2\delta} < z \leq 1, \\ 1 & \text{if } \frac{\delta}{1+2\delta} \leq z \leq \frac{1+\delta}{1+2\delta}, \\ 2 & \text{if } \quad 0 \leq z < \frac{\delta}{1+2\delta}. \end{cases}$$

As $\delta < 1$ and therefore $(1 + \delta)/(1 + 2\delta) > 2/3$, the local thinker orders more than q^* at high cost price ratios. Due to $\delta/(1 + 2\delta) < 1/3$ she orders less than a rational agent at low cost price ratios. The table below documents the optimal choices for the rational decision maker and the local thinker as a function of the cost price ratio z. For $z \in (0, 1/3] \cup (2/3, 1)$ a local thinker's inventory decision depends on her salience parameter δ. The smaller the local thinker's δ the more likely it is that she reveals the newsvendor problem. For any $z \in (0, 1)$, all order quantities listed in Table 2 are supported by a considerable parameter range. Note that, for $z \in \{0, 1\}$, a local thinker orders optimally.

cost price ratio	**rational**	**local thinker**
$2/3 < z \leq 1$	$q^* = 0$	$q^{LT} \in \{0, 1\}^\star$
$1/3 < z \leq 2/3$	$q^* = 1$	$q^{LT} = 1$
$0 \leq z \leq 1/3$	$q^* = 2$	$q^{LT} \in \{1, 2\}^{\star\star}$

* $q^{LT} = 1$ if $\delta < (1-z)/(2z-1)$.

** $q^{LT} = 1$ if $\delta < z/(1-2z)$.

Table 2: *Optimal vs. a local thinker's order quantities given choice set Q.*

Intuitively, by incorporating homogeneity of degree zero, the salience mechanism represents a way to model relative thinking. Accordingly, a local thinker opts for an alternative which performs relatively well in each state. Thereby, the decision maker is deterred by q_2's large negative payoff in state zero and by q_0's small payoff in state two, but attracted by q_1's relatively good performance in all three states. Apparently, the local thinker wants to avoid extreme outcomes and opts for the compromising alternative q_1. Therefore, salience theory predicts the "pull-to-the-center effect."

Prediction (ST-1). *Given the choice set $Q = \{0, 1, 2\}$, a local thinker's order quantity q^{LT} (weakly) exceeds q^* for high cost price ratios, while it is (weakly) below q^* for low cost price ratios. Hence, a local thinker's choices reveal the newsvendor problem.*

Salience and Choice Set Effects. Crucially, a local thinker's choices depend on the exact composition of the choice set. The presence of dominated options may shift attention to different payoffs of the available options and may therefore affect choices. According to rational choice, loss aversion (Kahneman and Tversky, 1979; Kőszegi and Rabin, 2006, 2007) and most other behavioral models, dominated alternatives should not affect decisions. We exploit this fact in order to test salience theory against alternative models of economic decision making.

	$x_0 = 0$	$x_1 = 1$	$x_2 = 2$
$q_0 = 0$	0	0	0
$q_1 = 1$	$-w$	$p - w$	$p - w$
$q_2 = 2$	$-2 \cdot w$	$p - 2 \cdot w$	$2 \cdot (p - w)$
$q_3 = 3$	$-3 \cdot w$	$p - 3 \cdot w$	$2 \cdot p - 3 \cdot w$

Table 3: *Payoffs derived from order quantities q_j in state i where $i, j = 0, 1, 2$.*

Suppose the agent chooses from the enlarged choice set $Q^L := Q \cup \{q_3 = 3\}$ in the simplified newsvendor game. Table 3 provides an overview of the attainable payoffs in the different states. Option q_3 is first-order stochastically dominated by q_2 as it exceeds maximum demand. Therefore, q_3 should not affect a newsvendor's order pattern. According to salience theory, however, q_3 can alter the perception of the other alternatives and therefore affect choices. In fact, the presence of q_3 shifts attention from q_2's downside (i.e., its outcome if demand is zero) to its upside (i.e., its payoff if demand is two). If demand is zero, q_2 does not yield the lowest outcome anymore. If demand equals two, q_2's high payoff becomes especially pronounced through the introduction of the dominated option. Indeed, option q_2 becomes a compromise if the dominated option is available. Note that q_1 represents a compromise independent of whether q_3 is available or not. Altogether, it can be shown that the introduction of q_3 increases a local thinker's order quantity for all $z \in (0, 1)$ if the salience bias is sufficiently strong (for a formal derivation see the Online Appendix Part B).

cost price ratio	**rational**	**local thinker**
$2/3 < z \leq 1$	$q^* = 0$	$q^{LT} \in \{0, 1, 2\}$
$1/3 < z \leq 2/3$	$q^* = 1$	$q^{LT} \in \{1, 2\}$
$0 \leq z \leq 1/3$	$q^* = 2$	$q^{LT} = 2$

Table 4: *Optimal vs. a local thinker's order quantities given the broader choice set Q^L.*

Prediction (ST-2). *For any $z \in (0, 1)$, adding the first-order stochastically dominated option $q_3 = 3$ to the choice set increases a local thinker's order quantity if the salience bias is sufficiently strong.*

It is important to note that adding a different dominated option to the subject's choice set, such as $q = 5$, has a similar effect on a local thinker's choices as adding $q = 3$. Salience does not predict that this effect will become stronger the larger the dominated quantity is as it is simply the fact that q_2 becomes a compromising option which drives a local thinker's behavior. The same holds true if several larger (dominated) quantities were added to the choice set. This limits the extent to which dominated options can distort a local thinker's behavior. In fact, the dominated option has to substantially change the average payoff in a state in order to affect a local thinker's salience ranking. For illustrative reasons, suppose that the support of demand and the choice set had a larger range than in our simplified version of the newsvendor game, for instance, all integers between zero and 100. Then, adding a slightly larger dominated option such as 101 can be expected to have only a very small effect, if any. This is completely in line with the salience model as the additional option results only in a small change of the average payoff in each state.

Our predictions rely on the specific salience function introduced in Definition 2. This salience function, however, is the standard salience function which Bordalo *et al.* have proposed. Even more importantly, the intuition we provide for our predictions, that is, a preference for compromising options, follows from the basic properties of the salience function and not only from the specific functional form that we have used.

4 Loss Aversion and the Newsvendor Problem

Models built on loss aversion can explain a wide range of behavioral anomalies. Accordingly, decision makers evaluate outcomes with respect to a reference point and put more weight on outcomes below the reference point (losses) than on outcomes above it (gains). Prospect theory (Kahneman and Tversky, 1979) incorporates loss aversion as one major assumption, but does not explicitly define the reference point. Typically, it has been assumed that the reference point reflects the decision maker's status quo at the moment she makes her choice (see Kahneman and Tversky, 1979, and Tversky and Kahneman, 1992). In the newsvendor game, the status quo corresponds to a payoff of zero. Other specifications of the reference point, however, may yield very different predictions in general. This problem has been addressed in models by Kőszegi and Rabin (2006, 2007). According to their approach, the reference point is shaped by the decision maker's rational expectations on the state of the world she will face given her decision. Numerous applications imply that this endogenization of the reference point represents a fruitful approach (Knetsch and Wong, 2009; Sydnor, 2010; Abeler *et al.*, 2011; Crawford and Meng, 2011; Pope and Schweitzer, 2011; Gill and Prowse, 2012).

Loss Aversion and the Newsvendor Game. Prospect theory can or cannot explain the newsvendor problem, depending on the specification of the reference point. As we will show, Kőszegi and Rabin's (2007) approach with an endogenous reference point cannot account for the newsvendor problem. Instead, their solution concept of a *choice-acclimating equilibrium* prescribes order quantities below the rational level q^*, both in the low- and in the high-margin case.

In general, according to loss aversion-based models, an agent's utility $u(x, q)$ from ordering quantity q and facing demand x is adjusted by a gain-loss utility $\mu(\cdot)$ which is a function of the difference between the factual payoff, given the ordered quantity q, and a *reference payoff*. If this difference is positive (negative), we say that the agent experiences a *gain* (*loss*). The function $\mu(\cdot)$ is piecewise linear with slope $\eta > 0$ if the argument is positive and with slope $\eta\lambda$ for some $\lambda > 1$ if the argument is negative; that is, $\mu(v) = \eta v$ if $v \geq 0$ and $\mu(v) = \eta\lambda v$ otherwise. While η gives the relative weight on gain-loss utility, λ captures the decision maker's degree of loss aversion. For reference payoff r (where r can depend on various variables), the agent receives *reference-dependent utility*

$$u(x, q|r) := u(x, q) + \mu(u(x, q) - r),$$

where $u(x, q) = p \min\{q, x\} - wq$ as before. In the following we present different approaches of how the reference payoff can be specified.

4.1 Prospect Theory and the Newsvendor Problem

The order quantities of a loss-averse newsvendor crucially depend on the specification of the reference point relative to which outcomes are evaluated. If the reference point is given by the agent's status quo of having zero payoff, the newsvendor problem cannot be explained as long as negative profits are ruled out (Schweitzer and Cachon, 2000; Nagarajan and Shechter, 2013). If negative profits are ruled out and if the agent has an s-shaped value function (which is a typical assumption in prospect theory), the agent will perceive all profits as gains and therefore behave as though risk averse, ordering a quantity below q^* for any profit margin (see Eeckhoudt *et al.*, 1995). Taking all features of prospect theory into account, that is, loss aversion with respect to the status quo, an s-shaped value function, and probability distortions, Nagarajan and Shechter (2013) show that prospect theory predicts insufficient orders for low profit margins, but excessive order quantities for high profit margins. Hence, they verify that prospect theory might predict the reverse of the "pull-to-the-center effect," namely, a "push-from-the-center-effect."

Long and Nasiry (2015) propose a different specification of the reference point which allows prospect theory to account for the newsvendor problem. They assume that the decision maker's reference point equals a convex combination of the maximum and the minimum attainable payoff associated with a particular quantity choice. Uppari and Hasija (2014) use a related approach according to which the reference payoff equals the payoff earned under ordering mean demand. Also in this case, prospect theory can explain the newsvendor problem as long as loss aversion is sufficiently strong. Even though Uppari and Hasija argue that the mean demand is focal and represents, therefore, a natural reference point, both the specifications by Long and Nasiry and Uppari and Hasija appear to be ad hoc as they are neither shared by other established behavioral models nor, to the best of our knowledge, supported by much experimental or empirical evidence.

In order to show that loss aversion can account for the newsvendor problem in our discrete newsvendor game if a suitable specification of the reference point is used, we will illustrate the interpretation of prospect theory by Long and Nasiry (2015). Similarly, other models of loss aversion can be applied to our setup. While some other approaches (such as the model by Uppari and Hasija) also predict the newsvendor problem, in contrast to salience theory, none of the loss aversion-based models predicts that dominated options will affect the newsvendor's choice pattern.

Long and Nasiry (2015). We delineate the model by Long and Nasiry (2015) in more detail. For order quantity $q \in Q$ let the reference payoff $r(q)$ be determined by a convex combination of the minimum possible payoff $-wq$ and the maximum possible payoff $(p-w)q$, that is,

$$r(q) := \beta(-w)q + (1-\beta)(p-w)q = (1-\beta)pq - wq$$

for some $\beta \in (0,1)$.[4] Then, a decision maker's reference-dependent utility $u(x,q|r(q))$ for demand x, order quantity q, and the corresponding reference point $r(q)$ equals

$$\begin{aligned} u\left(x,q|r(q)\right) &= p\min\{x,q\} - wq \\ &+ \begin{cases} \eta(p\min\{x,q\} - wq - r(q)) & \text{if } p\min\{x,q\} > wq + r(q), \\ \eta\lambda(p\min\{x,q\} - wq - r(q)) & \text{if } p\min\{x,q\} < wq + r(q). \end{cases} \end{aligned} \tag{4}$$

The agent chooses q in order to maximize her expected reference-dependent utility

$$U(X,q|r(q)) = \sum_{x \in X} u\left(x,q|r(q)\right) Pr(x).$$

Thus, a loss-averse agent orders

$$q^{LN}(z) = \begin{cases} 0 & \text{if } \tau_1 < z \leq 1, \\ 1 & \text{if } \tau_2 < z \leq \tau_1, \\ 2 & \text{if } \ 0 \leq z \leq \tau_2, \end{cases}$$

with threshold values $\tau_1 := \big(2 + \eta(2\beta - \lambda(1-\beta))\big)/3$, and $\tau_2 := \big(1 + \eta\lambda(3\beta - 2)\big)/3$ for $0 < \beta < 1/2$ and $\tau_2 := \big(1 + \eta(2\beta - 1 - \lambda(1-\beta))\big)/3$ for $1/2 \leq \beta < 1$. By definition, the newsvendor problem arises if and only if $\tau_2 < 1/3$ and $2/3 < \tau_1$. In the Online Appendix, Part C, we show that this is the case if and only if the following assumption is satisfied.

Assumption 1. *Suppose one of the following statements holds.*

(A) The reference payoff does not take an extreme value, that is, $1/3 < \beta \leq 2/3$, and the agent is not too loss averse, that is, $\lambda < \frac{2\beta}{1-\beta}$.

(B) The reference payoff is low, that is, $2/3 < \beta < 1$, and the agent's loss aversion parameter satisfies $\frac{2\beta-1}{1-\beta} < \lambda < \frac{2\beta}{1-\beta}$.

Prediction (LN-1). *If and only if Assumption 1 holds, an agent's order quantity is above q^* for high cost price ratios and below q^* for low cost price ratios. Hence, under Assumption 1, an agent's choices reveal the newsvendor problem.*

Note that Long and Nasiry (2015) do not impose an analogue to Assumption 1 as they analyze the newsvendor problem only with a continuous, and not with a discrete demand. Assumption 1 ensures that the agent's order quantity is not only marginally different from the optimal order quantity, but also discretely as required in our setup. Intuitively, the upper bound on the loss aversion parameter decreases in the reference payoff since a loss becomes more likely for a higher reference point. In addition, if the reference payoff is sufficiently low (i.e., losses are sufficiently unlikely), the newsvendor problem occurs only if the loss aversion parameter is also bounded from below.

[4]Note that for any order quantity q that exceeds the maximum demand of two units the reference payoff equals $r(q) = \beta(-w)q + 2(1-\beta)(p-w) = 2(1-\beta)p - wq$.

4.2 Expectation-based Loss Aversion and the Newsvendor Problem

Several empirical findings support the view that the reference point is endogenously shaped by a decision maker's rational expectations. This approach has been formalized in two seminal papers by Kőszegi and Rabin (2006, 2007). For instance, their approach provides a compelling reinterpretation of the controversial finding that wages and labor supply are negatively related for taxi drivers in New York City (see Camerer *et al.*, 1997; Farber, 2005, 2008). Crawford and Meng (2011) confirm that the model by Kőszegi and Rabin gives an accurate description of the data. Moreover, Knetsch and Wong (2009) or Ericson and Fuster (2011) strongly support this novel approach by showing that it can explain under which conditions people are subject to an endowment effect. Altogether, a substantial body of empirical literature questions traditional assumptions on the reference point, and instead supports the expectation-based specification of the reference point.

Kőszegi and Rabin (2007). According to the model by Kőszegi and Rabin (2007), an agent evaluates an outcome with respect to a reference lottery $R(q)$. More specifically, for a given order quantity q, each feasible demand realization y determines a reference payoff $r(q,y) = p\min\{q,y\} - wq$. The agent's reference lottery then assigns to each reference payoff the probability with which the corresponding demand occurs.

Formally, if quantity q is chosen, demand realization x is valued as

$$u(x,q|R(q)) = \sum_{y\in X} u(x,q|r(q,y))Pr(y), \tag{5}$$

where $u(x,q|r(q,y))$ is defined in (4). An agent chooses q in order to maximize her expected reference-dependent utility

$$U(X,q|R(q)) = \sum_{x\in X} u(x,q|R(q))Pr(x).$$

Definition 3 (Choice-acclimating equilibrium). *The order quantity $q \in Q$ denotes a choice-acclimating equilibrium if and only if $U(X,q|R(q)) \geq U(X,q'|R(q'))$ for all $q' \in Q$.*

Proposition 2. *If q denotes a choice-acclimating equilibrium then $q \leq q^*$.*

Proposition 2 has been proven by Herweg (2013). In the Online Appendix Part D, we provide a simpler proof, and show why an agent who is loss averse with respect to her rational expectations generally orders a quantity below the optimal order quantity. Intuitively, the agent chooses a rather low order quantity in order to dampen her payoff expectations, to reduce the probability of excess supply, and to therefore limit the expected losses in size and probability.

Prediction (KR-1). *For all cost price ratios, an agent who is loss averse with respect to her rational expectations orders weakly less than q^*.*

4.3 Loss Aversion and Compromise Effects

Models of loss aversion satisfy the axiom of the independence of irrelevant alternatives as long as these irrelevant alternatives do not affect the agent's reference point. As a consequence, the models introduced in the previous subsections predict that choices should be insensitive to the kind of choice set effects which we are investigating in this study. In order to understand why this is the case, note that both models assume that reference points are invariant to the composition of the choice set. Hence, it remains to show that first-order stochastically dominated options are indeed irrelevant (i.e., will never be chosen by a loss-averse agent) in our simplified newsvendor game.

In general, loss-averse agents might choose dominated lotteries, but only if such lotteries reduce the probability and magnitude of loss sensations (see, for instance, Proposition 7 in Kőszegi and Rabin, 2007), which is not the case in our setup. By construction, an order quantity q is first-order stochastically dominated if and only if $q > 2$. According to the model by Long and Nasiry (2015), gain-loss utility is independent of the unit cost w (see Equation 4), and therefore the same for any order quantity $q \geq 2$. This implies that any order quantity $q > 2$ is dominated in terms of reference-dependent utility by $q = 2$. Also the model by Kőszegi and Rabin (2007) predicts that $q > 2$ will never be chosen since an expectation-based, loss-averse newsvendor should order weakly less than a rational agent (Proposition 2), who orders at most two units. Thus, according to both models, any first-order stochastically dominated option is irrelevant for the agent's ordering decision.

Prediction (LN-2, KR-2). *Enlarging the newsvendor's choice set by a first-order stochastically dominated option does not affect her order quantity.*

5 Design

In this section, we delineate and discuss our experimental setting. First, we describe our laboratory implementation of the simplified newsvendor game. Subsequently, we present our treatments and also the hypotheses to test. Finally, we discuss several appeals of our experimental design.

Procedures. Students were invited to our laboratory via ORSEE (Greiner, 2015) and the experiment was implemented with z-Tree (Fischbacher, 2007). After arriving at the laboratory, students were randomly assigned to one of four treatments. Once all students were seated, the participants received the instructions (for a translation, see the Online Appendix Part E). Participants were informed that they would play the newsvendor game repeatedly for five rounds, one of which would be randomly selected to be payoff-relevant.

During the experiment subjects could earn an experimental currency (ECU). At the end of the experiment, earnings were converted at an exchange rate of 2 ECU= 1 Euro. In addition, subjects received a show-up fee of 7 Euros. Gains in the payoff-relevant period would be added to this endowment while losses would be deducted.

After having read the instructions, subjects responded to non-incentivized control questions at the computer. This gave the participants the opportunity to familiarize themselves with the game before making payoff-relevant decisions.

Then, the subjects played five rounds of the simplified newsvendor game (for details, see below). In each round, they chose an order quantity before they were informed of the demand and their profits in that round. In all treatments, all subjects faced the identical sequence of demand realizations (randomly drawn upfront).[5] Following Bolton and Katok (2008) and Bolton *et al.* (2012), a table informed each participant of her previous choices and profits after each stage (see the Online Appendix Part E for a screenshot). After the final round, subjects had to answer a questionnaire on personal characteristics (field of study, sex, and age) before they were privately paid.

Treatments and Hypotheses. We conducted four treatments (using a between-subjects design) to test for the newsvendor problem at a low/high margin and with a small/large choice set (Table 5). Demand was uniformly distributed on the set $\{0, 1, 2\}$. While the small choice set equaled $\{0, 1, 2\}$, the large choice set also contained the dominated order quantity 3. We set $w = 3$ ECU for all treatments and the selling price to $p = 4$ ECU for the low-profit margin, and to $p = 10$ ECU for the high-profit margin. Thus, the optimal order quantity is $q^* = 0$ if the profit margin is low, that is, in treatments LS and LL, and $q^* = 2$ if the profit-margin is high, that is, in treatments HS and HL.

	Small Choice Set	Large Choice Set
Low Margin	**LS**	**LL**
High Margin	**HS**	**HL**

Table 5: 2×2 *treatments.*

In this experimental setup, we test for the two predictions of salience theory which we derived in Section 3. That is, we test for the newsvendor problem (H ST-1) and for the specific choice-set effects (H ST-2).[6]

Hypothesis (H ST-1). *The average order quantity is above zero in LS, but below two in HS.*

Hypothesis (H ST-2). *The average order quantity is larger in LL (HL) than in LS (HS).*

Participants and Sessions. Fifteen sessions were conducted in August and September 2015 at the DICE experimental laboratory at the Heinrich-Heine-University Düsseldorf.

[5]This is in line with several other studies (for instance, Bolton and Katok, 2008, or Bolton *et al.*, 2012) as it ensures comparability between the treatments. Otherwise changes in the participants' order patterns might be driven rather by a different sequence of demand realizations than by variations of the selling price or the composition of the choice set.

[6]When choosing from $\{0, 1, 2\}$, a local thinker chooses a quantity of one if $\delta < 0.50$ and the profit margin is low or if $\delta < 0.87$ and the profit margin is high. When choosing from $\{0, 1, 2, 3\}$, a local thinker opts for a quantity of one (two) if the profit margin is low and $0.10 < \delta < 0.77$ ($\delta < 0.10$) while she opts for a quantity of two if the profit margin is high.

In total, 158 subjects participated: 41 in LS, 40 in LL, 39 in HS, and 38 in HL. The treatments were randomized among all sessions. A session lasted around 20 minutes and subjects earned between €4.00 and €14.00 with an average of €7.40.

Discussion of our Experimental Setup. Besides ensuring tractability, we think that our discretization of the newsvendor game has several appeals. A discrete choice set is a realistic assumption as goods to be ordered, such as newspapers, can only be delivered in full units. It also seems natural that newsvendors order bundles of newspapers rather than single papers, which supports our assumption of a choice set with only a very limited number of options. This reasoning is not restricted to ordering newspapers since demand is discrete for most product categories.

Moreover, loss aversion can explain the newsvendor problem in this setup only under very strong additional assumptions: (1) the reference point has to have a rather unusual specification such as the one used in Long and Nasiry (2015), and (2) additional assumptions on the size of the reference payoff and the strength of loss aversion have to be imposed (see Assumption 1). The fact that salience theory can account for the newsvendor problem without such auxiliary assumptions yields additional support for our salience-based explanation of the newsvendor problem.

The most novel feature of our experiment is the investigation of choice set effects in the newsvendor context. Mainly, we analyze choice set effects as they allow a clear distinction between several behavioral approaches (such as those built on loss aversion) and salience theory. While there may be other behavioral models beside salience theory which predict choice set effects, they cannot account for such a broad range of cognitive biases as the salience approach.

6 Results

First, we test the two hypotheses based on subjects' first-period order quantities. The results are presented in Table 6. In order to test for Hypothesis H ST-1, we compare subjects' order quantities in treatments LS and HS. In order to test for Hypothesis H ST-2, we compare order quantities in LS (HS) with those in LL (HL). Second, we build our analysis on subjects' order quantities during the entire five periods in order to investigate whether learning mitigates the newsvendor problem or choice set effects.

In treatment LS, the average of first-period order quantities exceeds the optimal quantity of zero units at a significance level of 1 percent. We can reject the according null hypothesis by running a Tobit regression of first-period order quantities on a constant which yields an estimate of the average order quantity.[7] This average order quantity is significantly larger than zero as we obtain a 99%-confidence interval of $[0.54, 1.13]$. In treatment HS, the average order quantity lies significantly below the optimal quantity of two units (i.e., below its theoretical maximum) as the 99%-confidence interval of a Tobit

[7] We cannot use a simple average test as we test the average quantity against its theoretical minimum.

	LS		LL		HS		HL	
	Choice		Choice		Choice		Choice	
$q = 0$	8	19.51%	4	10.00%	1	2.56%	0	0.00%
$q = 1$	30	73.17%	23	57.50%	31	79.49%	23	60.53%
$q = 2$	3	7.32%	13*	32.50%	7	17.95%	15*	39.47%
# of participants	41		40		39		38	
average order $\overline{q}$	0.88		1.25		1.15		1.42	

* Including one subject who has chosen $q = 3$.

Table 6: *Distribution of first-period order quantities.*

regression on a constant is given by $[0.96, 1.42]$. As illustrated in Table 6, regardless of the profit margin, a majority of subjects go for the middle option in the first period, that is, 73.2% of the subjects (30 out of 41 subjects) in LS and 79.5% of the subjects (31 out of 39 subjects) in HS. Hence our results are fully in line with H ST-1.

Result 1. *Subjects underreact to profit margins. Their choices represent the newsvendor problem.*

Order quantities significantly increase if the dominated option $q_3 = 3$ extends the set of alternatives. More specifically, in the low margin condition the presence of the dominated option (three units) increases the share of subjects choosing the large quantity (two units) by roughly 25 percentage points. Similarly, if the profit margin is high, the share of subjects ordering two units increases by around 20 percentage points. Formally, the average order quantity is significantly higher in LL than in LS ($p < 0.01$, Wilcoxon rank-sum test) and in HL than in HS ($p < 0.05$, Wilcoxon rank-sum test). Our results strongly support H-ST 2.

Result 2. *Adding the dominated option to the choice set increases subjects' order quantities as predicted by salience theory.*

We do not think that our results are driven by random choice. First, note that choices are much more biased toward the center of the demand distribution than random choice would suggest. Second, expanding the choice set—which should have no impact—even has a weakly stronger impact on choices than the increase in the profit margin—which should have a substantial impact. Third and most importantly, randomness cannot explain why a particular option (i.e., $q = 2$) is chosen more frequently if the choice set becomes larger.

As the salience predictions are agnostic with respect to learning from repeated actions we regard our analysis of first-period data as the cleanest test of salience theory. In order to investigate the robustness of the predictions, however, we also test our hypotheses for the subjects' average order quantities over the five periods (Table 7 and Figure 2). In the Online Appendix, Part F, we further present a more detailed analysis of time trends and learning.

	LS		LL		HS		HL	
	Choice		Choice		Choice		Choice	
$q \leq 0.5$	9	21.95%	5	12.50%	1	2.56%	0	0.00%
$0.5 < q \leq 1.0$	19	46.34%	16	40.00%	23	58.97%	16	42.11%
$1.0 < q \leq 1.5$	9	21.95%	10	25.00%	8	20.52%	13	34.21%
$1.5 < q$	4	9.76%	9	22.50%	7	17.95%	9	23.68%
# of participants	41		40		39		38	
average order $\overline{q}$	0.87		1.12		1.18		1.32	

Table 7: *Distribution of the average order quantities over the five periods.*

As we can see from Table 7 and Figure 2, the newsvendor problem persists over time.[8] This is remarkable as the choice set contains only three options so that learning to make better decisions should be easily possible. Nevertheless, this result is in line with previous findings on the persistency of the newsvendor problem (Bolton and Katok, 2008). In contrast, the impact of the dominated option on the average order quantity declines, but stays significant at a 10 percent level ($p = 0.075$ for the low margin and $p = 0.079$ for the high margin, Wilcoxon rank-sum tests). This is intuitive for two reasons: first, we have so far abstracted from the distinction between a subject's choice set and her *consideration set*, that is, the set of options a subject actively considers. Typically, both are assumed to coincide. Actually, in the salience model options are compared not within the choice set but within the consideration set. In our setup it seems reasonable to assume that agents actively consider the dominated option at least in the first period, which is also strongly supported by Result 2. Once the agent realizes that the dominated option is irrelevant, however, it may be discarded from her consideration set for later periods. As soon as it is discarded, according to the salience model the choice set effect should disappear.[9] Second, if the presence of the dominated option tempts a subject to choose a large quantity in an early period (especially in treatment LL), the potentially large loss may prevent the subject from again choosing a large quantity. We can sum up that salience effects are present and persist at least partly even in very transparent environments.

7 Conclusion

While loss aversion seems to play only a minor role in the newsvendor game, we have shown that a novel model of context-dependent decision making, salience theory, yields an intuitive explanation for the newsvendor problem. More specifically, we have hypothesized that the newsvendor problem results from a preference for compromising options which can be explained by the salience model. We have tested this hypothesis in a novel laboratory experiment. Our results yield strong support for the relevance of compromise

[8] For the small choice set, Tobit regressions on a constant yield a 99%-confidence interval of $[0.60, 1.09]$ in case of the low margin and a 99%-confidence interval of $[1.02, 1.37]$ in case of the high margin.

[9] An experiment which precisely allows us to determine which options a subject actively considers when making a choice is beyond the scope of this paper as it might need eye tracking devices or similar techniques.

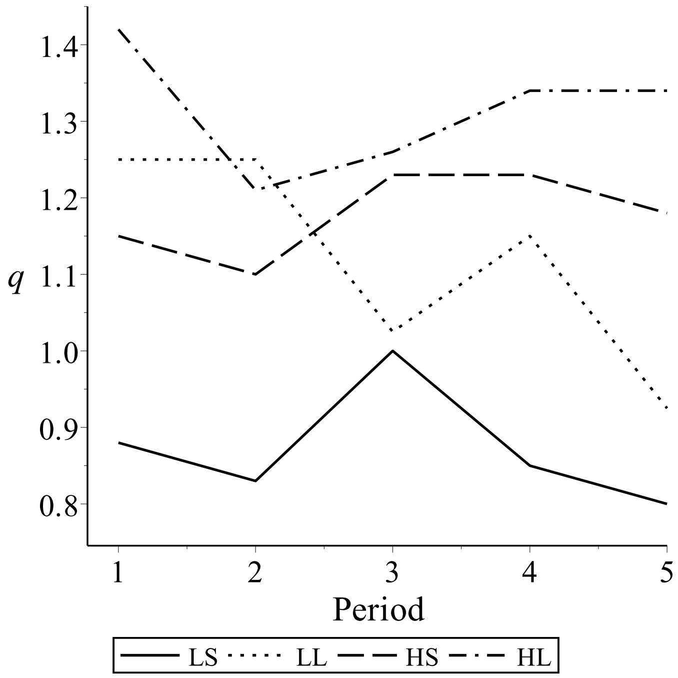

Figure 2: *Average order quantities per period and treatment.*

effects in the newsvendor context, while loss aversion cannot explain our experimental findings.

In our experiment, we have investigated how inventory decisions are affected by the presence of a dominated option. According to the axiom of the *independence of irrelevant alternatives* dominated options should not affect a rational agent's choices. Also most other behavioral theories, such as loss aversion-based models, cannot account for these kinds of choice set effects. But through the introduction of an excessive order quantity, a large order becomes an (attractive) compromise. Salience theory explains why larger order quantities are chosen more frequently in the presence of an excessive quantity. By revealing that inventory decisions are context-dependent, we extend the scope of salience theory toward the field of operations management.

Altogether, our results make the "pull-to-the-center effect"—which has been regarded as the driver of the newsvendor problem—more precise. In line with salience theory, but in contrast to most other behavioral theories, we rather observe a "pull-to-the-center-of-the-choice-set effect" than a "pull-to-the-center-of-the-demand-distribution effect." In general, we think that both effects play a role.

This distinction may have important practical implications. We suggest that choice set effects, previously neglected in the newsvendor literature, can reinforce or mitigate the newsvendor problem. We have shown that introducing excessive, dominated quantities into the choice set increases order quantities. Interestingly, introducing an insufficient, dominated option does not have to decrease overall order quantities, but might instead mitigate the newsvendor problem (we provide an example in the Online Appendix Part

G). Thus, choice set effects could be exploited, either to push order quantities toward the optimum or to pull order quantities even further away from the optimum. Given a fixed final demand, a manufacturer, for instance, may tempt the retailer to increase its order by offering excessive quantities, thereby raising his and decreasing the retailer's profit. On the other hand, a manager, aware of context-sensitive order patterns, might frame the choice set for his inventory analysts differently in order to improve their choices. We expect the role of the choice set to be larger if only a few options are available, for instance, if products are offered only in large bundles. The seller or manager may even intentionally restrict the choice set to few options in order to strengthen possible salience effects.

For future work, it may be interesting to investigate whether the choice set effects which we observe can be replicated by real data from wholesale markets. First, it may be tested whether larger quantity offers induce larger orders, given fixed demand and linear wholesale prices. And as a further step, it may be interesting to investigate whether there are manufacturers that are already exploiting these effects. Due to the possibility to learn, we would suggest that these choice set effects are most likely to be present if the interactions between the upstream and the downstream firms are sparse (in the textile industry, for instance, a retailer's orders follow a seasonal pattern).

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Online Appendix to
Salient Compromises in the Newsvendor Game

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The appendix is organized as follows: In Part A we provide a proof of Proposition 1. Part B formally derives the salience predictions for our simplified newsvendor game. In Part C we delineate the order quantity of a loss-averse newsvendor with a reference point as proposed by Long and Nasiry (2015). In Part D we derive the optimal order quantity of an expectation-based, loss-averse newsvendor (Proposition 2). Part E provides information on our experimental implementation, such as the instructions subjects received during the experiment. In Part F we present tables with further experimental results. In Part G we delineate how an insufficient dominated option might affect the order quantity of a local thinker (LT).

Part A: Rational Newsvendor

Proof of Proposition 1. By definition, q^* solves

$$\frac{d}{dq}\int_0^\infty (p\min\{q,x\} - wq)\, f(x)dx = 0.$$

Rearranging this equation yields

$$\frac{d}{dq}\left(q\int_q^\infty f(x)dx + \int_0^q xf(x)dx\right) = z,$$

where $z = w/p$, which is equivalent to

$$\frac{d}{dq}\big(q - qF(q)\big) + \frac{d}{dq}\int_0^q xf(x)dx = z.$$

Using Leibniz's rule we obtain

$$1 - F(q^*) = z. \tag{1}$$

As $p \geq w \geq 0$, it follows that $z \in [0,1]$. Since $F : \mathbb{R}_+ \rightarrow [0,1]$ is continuous, $F(0) = 0$, and $\lim_{x\rightarrow\infty} F(x) = 1$, the cumulative distribution function F is onto on $[0,1)$. Due to the intermediate value theorem there exists a solution to Equation (1). In addition, due to our restriction $Q := \{x \in \mathbb{R}_+ | f(x) > 0\}$, $F(q)$ is strictly increasing on Q. Therefore, the solution is unique and its inverse exists. Finally, note that the second-order condition holds. Now, applying the implicit function theorem to Equation (1) gives

$$dq^*(z)/dz = -1/f(q^*). \tag{2}$$

Since $f(q) > 0$ for all $q \in Q$, the RHS of (2) is well-defined on Q and strictly negative. $\square$

Part B: Formal Derivation of Salience Predictions

Salience and the Newsvendor Problem. Here, we derive a local thinker's order quantity if she chooses from the set $Q^S := \{0,1,2\}$ where all feasible demand realizations—namely, $x_0 = 0$, $x_1 = 1$, and $x_2 = 2$—are equally likely. The analysis proceeds in three steps: First, we determine the salience ranking of states for the middle option $q_1 = 1$ and the large option $q_2 = 2$. Note that we do not have to be concerned about the salience ranking of the small option $q_0 = 0$ as it pays zero with certainty so that its distorted and undistorted expected utility coincide. Second, we can compute the local thinker's distorted valuation for either option and determine her optimal order quantity. Third, we argue that a local thinker's order quantity represents the newsvendor problem.

STEP 1 (*Salience ranking*): For the middle option q_1, state 1 is most salient while the remaining states 0 and 2 are equally salient. Formally, applying Definition 2 yields

$$\underbrace{\sigma\left(u\left(x_1, q_1\right), \overline{u}_1\right)}_{=\sigma(p-w, 2/3\cdot p-w)} > 0 = \underbrace{\sigma\left(u\left(x_0, q_1\right), \overline{u}_0\right)}_{=\sigma(-w,-w)} = \underbrace{\sigma\left(u\left(x_2, q_1\right), \overline{u}_2\right)}_{=\sigma(p-w,p-w)};$$

that is, the upside of the middle option q_1 (in state 1) is salient.

Now consider the large option q_2. Since the salience function—introduced in Definition 2—is homogeneous of degree zero, it is straightforward to see that state 0 and state 2 are equally salient. Formally, Definition 2 yields

$$\sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right) = \sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right) = 1/3$$

for state 0 and 2, while the salience value of state 1 for option q_2 is given by

$$\sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right) = \begin{cases} \frac{p-3\cdot w}{5\cdot p-9\cdot w} & \text{if} \quad 0 \leq z < 1/3, \\ \frac{3\cdot w-p}{5\cdot p-9\cdot w} & \text{if} \quad 1/3 \leq z < 1/2, \\ 1 & \text{if} \quad 1/2 \leq z < 2/3, \\ \frac{3\cdot w-p}{9\cdot w-5\cdot p} & \text{if} \quad 2/3 \leq z \leq 1. \end{cases}$$

Accordingly, the salience ranking of states for the large option q_2 equals

$$\begin{cases} \sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right) = \sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right) > \sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right) & \text{if} \quad 0 \le z < 4/9, \\ \sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right) > \sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right) = \sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right) & \text{if} \quad 4/9 \le z \le 1. \end{cases}$$

For small cost price ratios (i.e., $0 \le z < 4/9$), the local thinker's focus lies on states 0 and 2 where q_2 yields either the lowest or the highest payoff among the three options. For large cost price ratios (i.e., $4/9 \le z \le 1$) state 1 is salient for the large order quantity q_2. Note that, if $4/9 \le z \le 1/2$ holds, option q_2 yields the intermediate payoff in this state. For $1/2 < z \le 1$, the large quantity q_2 performs worst among all options in this state.

STEP 2 (*Valuation and choice*): Given the salience rankings above, we can determine a local thinker's valuation for the different options. First, remember that her valuation for the small option q_0 coincides with the option's expected payoff, that is, $U(X, q_0|Q^S) = 0$. Second, a local thinker values the middle option q_1 as

$$U(X, q_1|Q^S) = \frac{\frac{1}{3}\delta \cdot (-w) + \frac{1}{3} \cdot (p-w) + \frac{1}{3}\delta \cdot (p-w)}{\frac{1}{3} + \frac{1}{3}\delta + \frac{1}{3}\delta}.$$

Third, a local thinker's valuation for the large order quantity q_2 equals

$$U(X, q_2|Q^S) = \begin{cases} \frac{\frac{1}{3}\cdot(-2w) + \frac{1}{3}\delta\cdot(p-2w) + \frac{1}{3}\cdot 2(p-w)}{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}\delta} & \text{if} \quad 0 \le z < 4/9, \\ \frac{\frac{1}{3}\delta\cdot(-2w) + \frac{1}{3}\cdot(p-2w) + \frac{1}{3}\delta\cdot 2(p-w)}{\frac{1}{3}+\frac{1}{3}\delta+\frac{1}{3}\delta} & \text{if} \quad 4/9 \le z \le 1. \end{cases}$$

Now straightforward computations yield

$$U(X, q_1|Q^S) \ge U(X, q_0|Q^S) \Leftrightarrow z \le \frac{\delta+1}{2\delta+1}$$

and

$$U(X, q_2|Q^S) \ge U(X, q_0|Q^S) \Leftrightarrow z \le \frac{1}{2}$$

as well as

$$U(X, q_1|Q^S) \ge U(X, q_2|Q^S) \Leftrightarrow z \ge \frac{\delta}{2\delta+1}.$$

Hence, the local thinker maximizes her salience-distorted expected payoff by choosing

$$q^{LT}(z) = \begin{cases} 0 & \text{if} \quad \frac{1+\delta}{1+2\delta} < z \le 1, \\ 1 & \text{if} \quad \frac{\delta}{1+2\delta} \le z \le \frac{1+\delta}{1+2\delta}, \\ 2 & \text{if} \quad 0 \le z < \frac{\delta}{1+2\delta}. \end{cases}$$

STEP 3 (*Newsvendor problem*): First, remember that q_0 is the expected utility maximizing choice for any $2/3 < z \le 1$. As $\delta < 1$, it holds $\frac{1+\delta}{1+2\delta} > \frac{2}{3}$ and the local thinker orders more than is rational at high cost prices ratios. Second, remember that q_2 is the expected utility maximizing choice for any $0 \leq z \leq 1/3$. Since $\frac{\delta}{1+2\delta} < \frac{1}{3}$ for any $\delta \in (0,1)$, the local thinker orders less than is rational at low cost price ratios. Altogether, the local thinker's order quantity represents the newsvendor problem. Note that, for $z \in \{0,1\}$, a local thinker orders optimally.

Salience and Choice Set Effects. Next, we delineate a local thinker's order quantity if she chooses from the set $Q^L := \{0,1,2,3\}$. The analysis proceeds in three steps: First, we need to determine the salience ranking of states for the middle option $q_1 = 1$ and the large option $q_2 = 2$. Note that we do not have to determine the salience ranking for the small option $q_0 = 0$ and the excessive option $q_3 = 3$. The former pays zero independent of the salience ranking while the latter is never chosen by a local thinker as salience theory satisfies first-order stochastic dominance. Second, we compute $U(X, q_1|Q^L)$ and $U(X, q_2|Q^L)$ and determine a local thinker's optimal order quantity. Third, we argue that the presence of the dominated option q_3 strictly increases a local thinker's order quantity for any $z \in (0,1)$ if the salience bias is sufficiently strong (i.e., if δ is small enough). Here, we have to distinguish between several cases (depending on z) and subcases (depending on δ). Note that in any case the small option q_0 gives $U(X, q_0|Q^k) = 0$ for $k \in \{S, L\}$ independent of the salience ranking.

STEP 1 (*Salience ranking*): Consider the large order quantity q_2 first. The presence of the excessive quantity q_3 renders state 2 the most salient state for option q_2 at any cost price ratio. Formally, the salience ranking for option q_2 equals

$$\underbrace{\sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right)}_{=\sigma(2\cdot(p-w), 5/4\cdot p-3/2\cdot w)} > \underbrace{\sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right)}_{\sigma(-2\cdot w, -3/2\cdot w)} = \underbrace{\sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right)}_{\sigma(p-2\cdot w, 3/4\cdot p-3/2\cdot w)}.$$

The equality above follows from the fact that the salience function introduced in Definition 2 is homogeneous of degree zero (we can factor out $-2w$ on the left-hand side of the equality and $p - 2w$ on the right-hand side). Precisely, applying Definition 2 yields

$$\sigma\left(u\left(x_0, q_2\right), \overline{u}_0\right) = 1/7 = \sigma\left(u\left(x_1, q_2\right), \overline{u}_1\right).$$

Moreover, the inequality follows directly from Definition 2 which yields

$$\sigma\left(u\left(x_2, q_2\right), \overline{u}_2\right) = \begin{cases} \frac{3\cdot p-2\cdot w}{13\cdot p-14\cdot w} & \text{if} \quad 0 \leq z < 5/6, \\ 1 & \text{if } 5/6 \leq z \leq 1. \end{cases}$$

Next, consider the middle option q_1. Applying Definition 2 yields $\sigma\left(u\left(x_0, q_1\right), \overline{u}_0\right) = 1/5$ as well as

$$\sigma\left(u\left(x_1, q_1\right), \overline{u}_1\right) = \begin{cases} \frac{p+2\cdot w}{7\cdot p-10\cdot w} & \text{if} \quad 0 \leq z < 1/2, \\ 1 & \text{if } 1/2 \leq z \leq 1, \end{cases}$$

and

$$\sigma\left(u\left(x_2,q_1\right),\overline{u}_2\right)=\begin{cases}\frac{p-2\cdot w}{9\cdot p-10\cdot w} & \text{if} \quad 0\leq z<1/2,\\ \frac{2\cdot w-p}{9\cdot p-10\cdot w} & \text{if } 1/2\leq z<5/6,\\ 1 & \text{if } 5/6\leq z\leq 1.\end{cases}$$

Accordingly, the salience ranking of states for the middle option q_1 equals

$$\begin{cases}\sigma\left(u\left(x_0,q_1\right),\overline{u}_0\right)>\sigma\left(u\left(x_1,q_1\right),\overline{u}_1\right)>\sigma\left(u\left(x_2,q_1\right),\overline{u}_2\right) & \text{if} \quad 0\leq z<1/10,\\ \sigma\left(u\left(x_1,q_1\right),\overline{u}_1\right)>\sigma\left(u\left(x_0,q_1\right),\overline{u}_0\right)>\sigma\left(u\left(x_2,q_1\right),\overline{u}_2\right) & \text{if } 1/10\leq z<7/10,\\ \sigma\left(u\left(x_1,q_1\right),\overline{u}_1\right)>\sigma\left(u\left(x_2,q_1\right),\overline{u}_2\right)>\sigma\left(u\left(x_0,q_1\right),\overline{u}_0\right) & \text{if } 7/10\leq z<5/6,\\ \sigma\left(u\left(x_1,q_1\right),\overline{u}_1\right)=\sigma\left(u\left(x_2,q_1\right),\overline{u}_2\right)>\sigma\left(u\left(x_0,q_1\right),\overline{u}_0\right) & \text{if} \quad 5/6\leq z\leq 1.\end{cases}$$

The presence of the excessive quantity q_3 renders the upside of q_1 salient as long as the cost price ratio is sufficiently high. For sufficiently low cost price ratios it renders the downside of q_1 in state 0 salient.

STEPS 2 & 3 (*Valuation and choice* & *Choice set effect*): Given the salience rankings above, we can determine a local thinker's valuations for the middle option q_1 and the large option q_2. A local thinker values the middle option q_1 as

$$U(X,q_1|Q^L)=\begin{cases}\frac{\frac{1}{3}\cdot(-w)+\frac{1}{3}\delta\cdot(p-w)+\frac{1}{3}\delta^2\cdot(p-w)}{\frac{1}{3}+\frac{1}{3}\delta+\frac{1}{3}\delta^2} & \text{if} \quad 0\leq z<1/10,\\ \frac{\frac{1}{3}\delta\cdot(-w)+\frac{1}{3}\cdot(p-w)+\frac{1}{3}\delta^2\cdot(p-w)}{\frac{1}{3}+\frac{1}{3}\delta+\frac{1}{3}\delta^2} & \text{if } 1/10\leq z<7/10,\\ \frac{\frac{1}{3}\delta^2\cdot(-w)+\frac{1}{3}\cdot(p-w)+\frac{1}{3}\delta\cdot(p-w)}{\frac{1}{3}+\frac{1}{3}\delta+\frac{1}{3}\delta^2} & \text{if } 7/10\leq z<5/6,\\ \frac{\frac{1}{3}\delta\cdot(-w)+\frac{1}{3}\cdot(p-w)+\frac{1}{3}\cdot(p-w)}{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}\delta} & \text{if} \quad 5/6\leq z\leq 1,\end{cases}$$

while her valuation for the large order quantity q_2 equals

$$U(X,q_2|Q^L)=\frac{\frac{1}{3}\delta\cdot(-2w)+\frac{1}{3}\delta\cdot(p-2w)+\frac{1}{3}\cdot 2(p-w)}{\frac{1}{3}+\frac{1}{3}\delta+\frac{1}{3}\delta}.$$

Depending on the cost price ratio we consider five cases. In each case, we first determine a local thinker's order quantity depending on her individual δ (STEP 2). Subsequently, we delineate that the presence of the dominated option q_3 increases a local thinker's order quantity for any $z\in(0,1)$ (STEP 3) if the salience bias is sufficiently strong.

Case 1: Consider cost price ratios $0\leq z\leq 1/3$.

STEP 2 (*Valuation and choice*): We show that a local thinker always goes for the large order quantity q_2 if $z\leq 1/3$. Straightforward calculations yield

$$U(X,q_2|Q^L)>U(X,q_0|Q^L)\Leftrightarrow z<\frac{2+\delta}{2+4\delta},$$

which holds for any $z \leq 1/3$ and any $\delta \in (0,1)$. Moreover, we observe

$$U(X, q_2|Q^L) > U(X, q_1|Q^L) \Leftrightarrow \begin{cases} z < \frac{2+2\delta-\delta^3}{1+3\delta+3\delta^2+2\delta^3} & \text{if} \quad 0 \leq z < 1/10, \\ z < \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} & \text{if } 1/10 \leq z \leq 1/3, \end{cases}$$

where $\frac{2+2\delta-\delta^3}{1+3\delta+3\delta^2+2\delta^3} > \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} > 1/3$ for all $\delta \in (0,1)$. Hence, the local thinker opts for the large order quantity q_2 whenever $0 \leq z \leq 1/3$.

STEP 3 (*Choice set effect*): If the local thinker chooses from the small set Q^S, she orders either q_1 or q_2 for any $0 \leq z \leq 1/3$. Hence, the dominated option weakly increases a local thinker's order quantity for $0 \leq z \leq \frac{\delta}{1+2\delta}$, while it strictly increases her order quantity for $\frac{\delta}{1+2\delta} < z \leq 1/3$.

Case 2: Consider cost price ratios $1/3 < z \leq 2/3$.

STEP 2 (*Valuation and choice*): We show that a local thinker goes either for the middle option q_1 or the large option q_2 if $1/3 < z \leq 2/3$. Straightforward calculations yield

$$U(X, q_1|Q^L) > U(X, q_0|Q^L) \Leftrightarrow z < \frac{1+\delta^2}{1+\delta+\delta^2},$$

which holds for any $1/3 < z \leq 2/3$ and any $\delta \in (0,1)$. Moreover, we observe

$$U(X, q_2|Q^L) > U(X, q_1|Q^L) \Leftrightarrow z < \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3},$$

which holds for any $1/3 < z \leq 2/3$ if $\delta \in (0, a_1)$ with

$$a_1 := \frac{(196+28\sqrt{77})^{2/3}-28}{14(196+28\sqrt{77})^{1/3}} \approx 0.28.$$

Now we have to distinguish two subcases:

(i.) The salience bias is relatively strong, that is, $0 < \delta \leq a_1$.

(ii.) The salience bias is relatively weak, that is, $a_1 < \delta \leq 1$.

In the first subcase, $\frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} \geq 2/3$ holds and the local thinker (weakly) prefers the large order quantity q_2 for any $1/3 < z \leq 2/3$. In the second subcase, we have $1/3 < \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < 2/3$ and the local thinker's order quantity is given by

$$q^{LT}(z) = \begin{cases} 1 & \text{if } \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < z \leq 2/3, \\ 2 & \text{if } \qquad 1/3 < z \leq \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3}. \end{cases}$$

Altogether, we conclude that a local thinker chooses either option q_1 or option q_2 (depending on her individual δ) whenever $1/3 < z \leq 2/3$.

STEP 3 (*Choice set effect*): If the local thinker faces the small choice set Q^S, she chooses the middle option q_1 for any $1/3 < z \leq 2/3$. Hence, the presence of the dominated option strictly increases the local thinker's order quantity (i.) for any $1/3 < z \leq 2/3$ if $\delta \leq a_1$ or (ii.) for any $1/3 < z \leq \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3}$ if $\delta > a_1$.

Case 3: Consider cost price ratios $2/3 < z \leq 7/10$.

STEP 2 (*Valuation and choice*): A local thinker goes for the small option q_0, the middle option q_1, or the large option q_2 if $2/3 < z \leq 7/10$. Straightforward calculations yield

$$U(X, q_1|Q^L) > U(X, q_0|Q^L) \Leftrightarrow z < \frac{1+\delta^2}{1+\delta+\delta^2}.$$

This inequality holds for any $2/3 < z \leq 7/10$ if $\delta \in (0, a_2)$ with $a_2 := \frac{7-\sqrt{13}}{6} \approx 0.57$. Moreover, we observe

$$U(X, q_2|Q^L) > U(X, q_1|Q^L) \Leftrightarrow z < \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3},$$

which holds for any $2/3 < z \leq 7/10$ if $\delta \in (0, a_3)$ with

$$a_3 := \frac{(24515+36\sqrt{845601})^{2/3} - (24515+36\sqrt{845601})^{1/3} - 791}{72(24515+36\sqrt{845601})^{1/3}} \approx 0.24.$$

Here, we have to distinguish four subcases:

(i.) The salience bias is very strong, that is, $0 < \delta \leq a_3$.

(ii.) The salience bias is strong, that is, $a_3 < \delta \leq a_1$.

(iii.) The salience bias is moderate, that is, $a_1 < \delta \leq a_2$.

(iv.) The salience bias is weak, that is, $a_2 < \delta \leq 1$.

In the first subcase,

$$\frac{7}{10} \leq \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{1+\delta^2}{1+\delta+\delta^2}$$

holds and the local thinker (weakly) prefers the large order quantity q_2 for any $2/3 < z \leq 7/10$. In the second subcase, we observe

$$\frac{2}{3} < \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{7}{10} \leq \frac{1+\delta^2}{1+\delta+\delta^2}$$

and the local thinker's order quantity is given by

$$q^{LT}(z) = \begin{cases} 1 & \text{if } \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < z \leq 7/10, \\ 2 & \text{if } \quad 2/3 < z \leq \frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3}. \end{cases}$$

In the third subcase, it holds

$$\frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{2}{3} < \frac{7}{10} \leq \frac{1+\delta^2}{1+\delta+\delta^2}$$

and the local thinker (weakly) prefers the intermediate quantity q_1 for any $2/3 < z \leq 7/10$. In the fourth subcase, we observe

$$\frac{1+\delta+2\delta^2-\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{2}{3} < \frac{1+\delta^2}{1+\delta+\delta^2} < \frac{7}{10}$$

and the local thinker's order quantity is given by

$$q^{LT}(z) = \begin{cases} 0 & \text{if } \frac{1+\delta^2}{1+\delta+\delta^2} < z \leq 7/10, \\ 1 & \text{if } \quad 2/3 < z \leq \frac{1+\delta^2}{1+\delta+\delta^2}. \end{cases}$$

Altogether, we conclude that a local thinker chooses the small option q_0, the middle option q_1, or the large option q_2 (depending on her individual δ) whenever $2/3 < z \leq 7/10$.

STEP 3 (*Choice set effect*): If the local thinker faces the small choice set Q^S, she chooses either the small option q_0 or the middle option q_1 for any $2/3 < z \leq 7/10$. In this case, the presence of the dominated option q_3 strictly increases a local thinker's order quantity for any $2/3 < z \leq 7/10$ if $\delta \leq a_3$. A local thinker's order quantity weakly increases due to q_3 being available for any $2/3 < z \leq 7/10$ if $a_3 < \delta \leq a_2$. In case of weak salience distortions (i.e., $\delta > a_2$) the local thinker orders weakly more if she faces the small choice set Q^S as

$$\frac{1+\delta^2}{1+\delta+\delta^2} < \frac{1+\delta}{1+2\delta}.$$

Case 4: Consider cost price ratios $7/10 < z \leq 5/6$.

STEP 2 (*Valuation and choice*): Straightforward calculations yield

$$U(X, q_1|Q^L) > U(X, q_0|Q^L) \Leftrightarrow z < \frac{1+\delta}{1+\delta+\delta^2},$$

which holds for any $7/10 < z \leq 5/6$ and any $\delta \in (0, a_4)$ with $a_4 := \frac{1+\sqrt{21}}{10} \approx 0.56$. Moreover, we observe

$$U(X, q_2|Q^L) > U(X, q_1|Q^L) \Leftrightarrow z < \frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3}.$$

This inequality holds for any $7/10 < z \leq 5/6$ and any $\delta \in (0, a_5)$ with

$$a_5 := \frac{(71+6\sqrt{177})^{2/3} - 3(71+6\sqrt{177})^{1/3} - 11}{4(71+6\sqrt{177})^{1/3}} \approx 0.06.$$

Here, we have to distinguish five subcases:

(i.) The salience bias is very strong, that is, $0 < \delta \leq a_5$.

(ii.) The salience bias is strong, that is,

$$a_5 < \delta \leq a_6 := \frac{(3475+18\sqrt{44209})^{2/3} - 11(3475+18\sqrt{44209})^{1/3} - 131}{12(3475+18\sqrt{44209})^{1/3}} \approx 0.13.$$

(iii.) The salience bias is moderate, that is, $a_6 < \delta \leq a_4$.

(iv.) The salience bias is weak, that is, $a_4 < \delta \leq a_7 := \frac{3+\sqrt{93}}{14} \approx 0.9$.

(v.) The salience bias is very weak, that is, $a_7 < \delta \leq 1$.

In the first subcase, it holds

$$\frac{5}{6} \leq \frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{1+\delta}{1+\delta+\delta^2}$$

and the local thinker opts for the large order quantity q_2 for any $7/10 < z \leq 5/6$. In the second subcase, we observe

$$\frac{7}{10} < \frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{5}{6} \leq \frac{1+\delta}{1+\delta+\delta^2}$$

and the local thinker's order quantity is given by

$$q^{LT}(z) = \begin{cases} 1 & \text{if } \frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3} < z \leq 5/6, \\ 2 & \text{if } \quad 7/10 < z \leq \frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3}. \end{cases}$$

In the third subcase, we have

$$\frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{7}{10} < \frac{5}{6} \leq \frac{1+\delta}{1+\delta+\delta^2}$$

and the local thinker chooses the middle option q_1 for any $7/10 < z \leq 5/6$. In the fourth subcase, it holds

$$\frac{1+\delta^2+\delta^3}{1+3\delta+3\delta^2+2\delta^3} < \frac{7}{10} < \frac{1+\delta}{1+\delta+\delta^2} < \frac{5}{6}$$

and the local thinker's order quantity is given by

$$q^{LT}(z) = \begin{cases} 0 & \text{if } \frac{1+\delta}{1+\delta+\delta^2} < z \leq 5/6, \\ 1 & \text{if } \quad 7/10 < z \leq \frac{1+\delta}{1+\delta+\delta^2}. \end{cases}$$

In the fifth subcase, we have $\frac{1+\delta}{1+\delta+\delta^2} \leq 7/10$ and the local thinker chooses the small option q_0 for any $7/10 < z \leq 5/6$. Altogether, we conclude that a local thinker chooses the small option q_0, the middle option q_1, or the large option q_2 (depending on her individual δ) whenever $7/10 < z \leq 5/6$.

STEP 3 (*Choice set effect*): If the local thinker faces the small choice set Q^S, she chooses either the small option q_0 or the middle option q_1 for any $7/10 < z \leq 5/6$. The presence of the dominated option q_3 (weakly) increases a local thinker's order quantity for any $7/10 < z \leq 5/6$ since

$$\frac{1+\delta}{1+\delta+\delta^2} > \frac{1+\delta}{1+2\delta}$$

for $\delta \in (0,1)$. In fact, we observe that for any cost price ratio

$$\frac{1+\delta}{1+2\delta} < z \leq \frac{1+\delta}{1+\delta+\delta^2}$$

the local thinker's order quantity strictly increases if the excessive option q_3 broadens the choice set.

Case 5: Consider cost price ratios $5/6 < z \leq 1$.

STEP 2 (*Valuation and choice*): A local thinker goes for the small option q_0, the middle option q_1, or the large option q_2 if $5/6 < z \leq 1$. Straightforward calculations yield

$$U(X, q_1|Q^L) > U(X, q_0|Q^L) \Leftrightarrow z < \frac{2}{2+\delta}$$

and

$$U(X, q_2|Q^L) > U(X, q_1|Q^L) \Leftrightarrow z < \frac{2+\delta^2}{2+5\delta+2\delta^2}.$$

Here, we distinguish three subcases:

(i.) The salience bias is strong, that is, $0 < \delta \leq a_8 := \frac{3\sqrt{73}-25}{8} \approx 0.08$.

(ii.) The salience bias is moderate, that is, $a_8 < \delta \leq 2/5$.

(iii.) The salience bias is weak, that is, $2/5 < \delta \leq 1$.

In the first subcase, we have $5/6 < \frac{2+\delta^2}{2+5\delta+2\delta^2} < \frac{2}{2+\delta} \leq 1$ and a local thinker orders

$$q^{LT}(z) = \begin{cases} 0 & \text{if} \quad \frac{2}{2+\delta} < z \leq 1, \\ 1 & \text{if} \quad \frac{2+\delta^2}{2+5\delta+2\delta^2} < z \leq \frac{2}{2+\delta}, \\ 2 & \text{if} \quad 5/6 < z \leq \frac{2+\delta^2}{2+5\delta+2\delta^2}. \end{cases}$$

In the second subcase, it holds $\frac{2+\delta^2}{2+5\delta+2\delta^2} < 5/6 < \frac{2}{2+\delta} \leq 1$ and we obtain

$$q^{LT}(z) = \begin{cases} 0 & \text{if } \frac{2}{2+\delta} < z \leq 1, \\ 1 & \text{if } 5/6 < z \leq \frac{2}{2+\delta}. \end{cases}$$

In the third subcase, we have $\frac{2}{2+\delta} < 5/6$ and a local thinker chooses quantity q_0 for any $5/6 < z \leq 1$. Altogether, we conclude that a local thinker chooses the small option q_0, the middle option q_1, or the large option q_2 (depending on her individual δ) whenever $5/6 < z \leq 1$.

STEP 3 (*Choice set effect*): If the local thinker faces the small choice set Q^S, she chooses either the small option q_0 or the middle option q_1 for any $5/6 < z \leq 1$. The presence of the dominated option q_3 (weakly) increases her order quantity for any $5/6 < z \leq 1$ since

$$\frac{2}{2+\delta} > \frac{1+\delta}{1+2\delta}$$

for $\delta \in (0,1)$. In fact, we observe that for any cost price ratio

$$\frac{1+\delta}{1+2\delta} < z \leq \frac{2}{2+\delta}$$

the local thinker's order quantity strictly increases if the excessive option q_3 broadens the choice set.

Part C: Prospect Theory and the Newsvendor Problem (Long and Nasiry, 2015)

Long and Nasiry (2015) propose the following specification of the reference point. For order quantity $q \in Q$ let the reference payoff $r(q)$ be determined by a convex combination of the minimum possible payoff $-wq$ and the maximum possible payoff $(p-w)q$, that is,

$$r(q) = \beta(-w)q + (1-\beta)(p-w)q$$

for some $\beta \in (0,1)$. Then, an agent's reference-dependent utility $u(x, q|r(q))$ for demand x, order quantity q, and the corresponding reference point $r(q)$ equals

$$\begin{aligned} u\left(x, q|r(q)\right) &= p\min\{x,q\} - wq \\ &\quad + \begin{cases} \eta(p\min\{x,q\} - wq - r(q)) & \text{if } p\min\{x,q\} > wq + r(q), \\ \eta\lambda(p\min\{x,q\} - wq - r(q)) & \text{if } p\min\{x,q\} < wq + r(q). \end{cases} \end{aligned} \tag{3}$$

The agent chooses q in order to maximize her expected, reference-dependent utility

$$U(X, q|r(q)) = \sum_{x \in X} u\left(x, q|r(q)\right) Pr(x).$$

For our simplified newsvendor game, we obtain the following predictions. If the agent chooses the small option q_0, the minimum and maximum possible payoff coincide with zero. Hence, her reference point is given by $r_0 = 0$, and her expected reference-dependent utility from ordering nothing is $U(X, q_0|r_0) = 0$. If the agent goes for the middle option q_1, her reference point is

$$r_1 = \beta(-w) + (1-\beta)(p-w) = (1-\beta)p - w,$$

and she values option q_1 as

$$U(X, q_1|r_1) = \frac{2}{3}p - w + \frac{1}{3}\eta p\left(2\beta - \lambda(1-\beta)\right).$$

In case she chooses the large option q_2 her reference point is given by

$$r_2 = \beta(-2w) + (1-\beta)2(p-w) = 2(1-\beta)p - 2w,$$

and she values option q_2 as

$$U(X,q_2|r_2)=\begin{cases}p-2w+\frac{1}{3}\eta p\big(2\beta+4\beta\lambda-3\lambda\big) & \text{if } \quad 0<\beta<1/2,\\ p-2w+\frac{1}{3}\eta p\big(4\beta+2\beta\lambda-1-2\lambda\big) & \text{if } 1/2\leq\beta<1.\end{cases}$$

Note that the agent perceives option q_2's payoff in state 1 as a gain if and only if $\beta \geq 1/2$ (i.e., her reference point is rather low). Now, straightforward calculations yield

$$U(X,q_1|r_1)>U(X,q_0|r_0)\Leftrightarrow z<\frac{2+\eta\big(2\beta-\lambda(1-\beta)\big)}{3}=:\tau_1.$$

For $0<\beta<1/2$ we get

$$U(X,q_2|r_2)>U(X,q_1|r_1)\Leftrightarrow z<\frac{1+\eta\lambda\big(3\beta-2\big)}{3}$$

while for $1/2\leq\beta<1$ we get

$$U(X,q_2|r_2)>U(X,q_1|r_1)\Leftrightarrow z<\frac{1+\eta\big(2\beta-1-\lambda(1-\beta)\big)}{3}.$$

Hence, we define

$$\tau_2:=\begin{cases}\frac{1+\eta\lambda(3\beta-2)}{3} & \text{if } \quad 0<\beta<1/2,\\ \frac{1+\eta(2\beta-1-\lambda(1-\beta))}{3} & \text{if } 1/2\leq\beta<1.\end{cases}$$

In order to decide under which conditions the model by Long and Nasiry (2015) predicts the newsvendor problem, we have to distinguish two cases:

(i.) Let $0<\beta<1/2$. Then, the agent chooses

$$q^{LN}(z)=\begin{cases}0 & \text{if } \tau_1<z\leq 1,\\ 1 & \text{if } \tau_2<z\leq\tau_1,\\ 2 & \text{if } \ 0\leq z\leq\tau_2.\end{cases}$$

First, note that $\tau_2<1/3$ for any $0<\beta<1/2$. Hence, the agent orders less than what would maximize expected payoffs if the cost price ratio was low. Second, we observe

$$\tau_1>\frac{2}{3}\quad\text{if and only if}\quad\lambda<\frac{2\beta}{1-\beta}.$$

Since $\lambda>1$ by assumption this inequality can only hold for $\beta>1/3$. We conclude that the model by Long and Nasiry (2015) can account for the newsvendor problem if the agent is not too loss averse (i.e., $\lambda<2\beta/(1-\beta)$ holds) and $1/3<\beta<1/2$.

(ii.) Let $1/2 \leq \beta < 1$. Then, the agent chooses

$$q^{LN}(z) = \begin{cases} 0 & \text{if } \tau_1 < z \leq 1, \\ 1 & \text{if } \tau_2 < z \leq \tau_1, \\ 2 & \text{if } \ 0 \leq z \leq \tau_2. \end{cases}$$

Her choice represents the newsvendor problem if and only if

$$\tau_2 < 1/3 \quad \text{and} \quad 2/3 < \tau_1,$$

or equivalently,

$$\frac{2\beta - 1}{1 - \beta} < \lambda < \frac{2\beta}{1 - \beta}.$$

Note that the first inequality is satisfied for any $1/2 \leq \beta \leq 2/3$ since $\lambda > 1$ by assumption. As argued above, the second inequality might hold for any $1/2 \leq \beta < 1$. Hence, we conclude that the model by Long and Nasiry (2015) can account for the newsvendor problem if either $1/2 \leq \beta \leq 2/3$ and the agent is not too loss averse (i.e., $\lambda < 2\beta/(1-\beta)$ holds) or $2/3 < \beta < 1$ and the agent is sufficiently but not too loss averse (that is, $(2\beta-1)/(1-\beta) < \lambda < 2\beta/(1-\beta)$ holds).

Altogether, the model by Long and Nasiry (2015) predicts the newsvendor problem for our simplified newsvendor game if and only if one of the following statements holds:

(A) The reference payoff does not take an extreme value, that is, $1/3 < \beta \leq 2/3$, and the agent is not too loss averse, that is, $\lambda < \frac{2\beta}{1-\beta}$.

(B) The reference payoff is low, that is, $2/3 < \beta < 1$, and the agent's loss aversion parameter satisfies $\frac{2\beta-1}{1-\beta} < \lambda < \frac{2\beta}{1-\beta}$.

These statements are summarized in the main text as Assumption 1.

Part D: Expectation-Based, Loss-Averse Newsvendor

Here, we provide a proof of Proposition 2 which states that a loss-averse newsvendor—whose reference point is shaped by her rational expectations as in Kőszegi and Rabin (2007)—orders weakly less than optimal, irrespective of the cost price ratio. The general proof we present extends to any discrete subset of the continuous action space, but requires some additional notation.

Let $X, Y : \Omega \to \mathbb{R}_+$ be independent and identically distributed random variables which determine the demand for newspapers. We assume that X follows a cumulative distribution function F which is differentiable with probability density function f.[1] The

[1] As we will refer to two independent realizations of the same distribution later in the proof, we will use two i.i.d. random variables for notational convenience.

newsvendor chooses an order quantity q from her strategy space $Q \subset \mathbb{R}_+$. Furthermore, denote $R(q) : \Omega \to \mathbb{R}$ a reference lottery, that is, a random variable which assigns a reference payoff $r(q, y) = p \min\{q, y\} - wq$ to each feasible demand realization $y \in \mathbb{R}_+$. Let $R(q)$ be distributed according to a cumulative distribution function G with density g. Then, for a given demand realization x, the reference-dependent utility derived from order quantity q equals

$$u(x, q|R(q)) = \int_{-\infty}^{\infty} u(x, q|r(q, y))g(r(q, y))dr(q, y),$$

where $u(x, q|r(q, y))$ is defined in Equation (3).

Thus, an agent chooses q in order to maximize

$$U(X, q|R(q)) = \int_{0}^{\infty} u(x, q|R(q))f(x)dx.$$

Proof of Proposition 2. Denote q^* the optimal order of a rational decision maker (who is captured in the present model by $\eta = 0$). Now suppose an agent with $\eta > 0$ chooses q^*. For a given demand realization x, she perceives a gain if and only if $u(x, q^*) - r(q^*, y) > 0$, that is, $u(x, q^*) - u(y, q^*) > 0$ for some $y \in \mathbb{R}_+$ with $f(y) > 0$. Rewriting this inequality yields $\min\{q^*, x\} > \min\{q^*, y\}$. Therefore, the agent experiences a gain with probability $Pr(q^*)$ where $Pr(q) := Pr(\min\{q, X\} > \min\{q, Y\})$. Note that

$$\mathrm{d}Pr(q)/\,\mathrm{d}q > 0. \tag{4}$$

As X and Y are independent and identically distributed, the probability of a loss also equals $Pr(q^*)$. Hence, the expected gain-loss utility

$$U(X, q|R(q)) - U(X, q) = \int_{0}^{\infty} \int_{-\infty}^{\infty} \mu(u(x, q) - r(q, y))g(r(q, y))f(x)\,\mathrm{d}r(q, y)\ \mathrm{d}x$$

is zero if $Pr(q) = 0$, and decreases in $Pr(q)$ as losses are overweighted relative to gains (remember that $\eta > 0$ and $\lambda > 1$). Thus, the agent can increase her gain-loss utility by choosing some $q < q^*$. Choosing a larger quantity (i.e., $q > q^*$), however, decreases both her expected payoff and her gain-loss utility. Hence, we have $q \leq q^*$. $\square$

As a consequence, the model by Kőszegi and Rabin (2007) cannot account for the newsvendor problem if the agent's choice set is continuous. Applying this proof to our simplified newsvendor game is straightforward.

Part E: Experimental Implementation

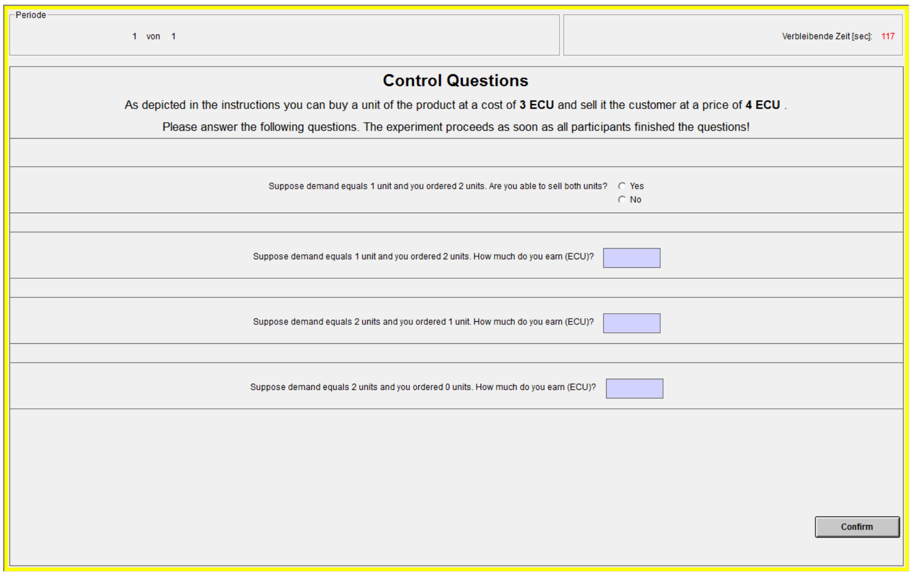

Figure 1: *Control questions in treatments LS and LL (English translation).*

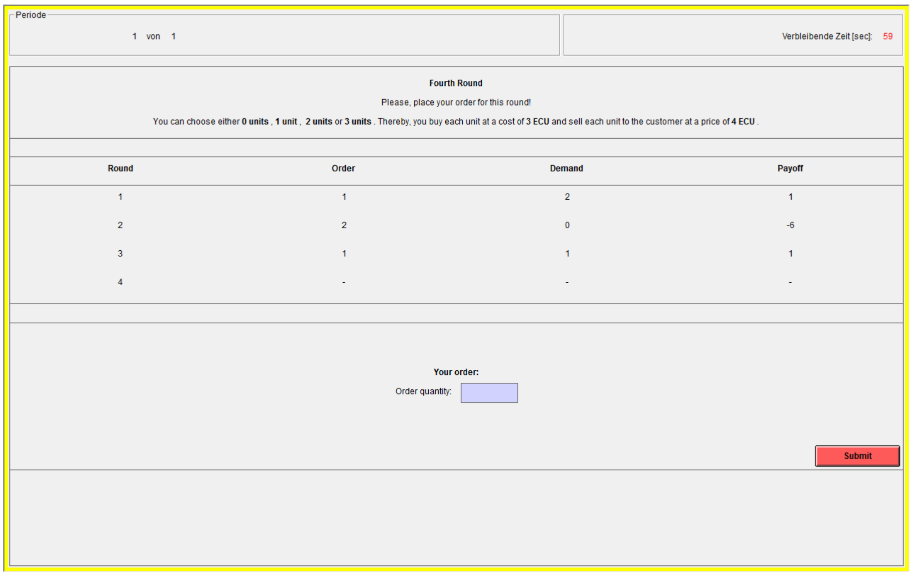

Figure 2: *Decision screen in treatment LL (English translation).*

Information on the experiment

Welcome to this experimental study. Please note that you are not allowed to talk to other participants or use your mobile phone during the course of the experiment. Please read through the following instructions carefully. For a succesful implementation it is important that you really understand the following information. If you have any questions during the experiment, please raise your hand. We will answer your question privately.
First of all, you will receive an endowment of 7 Euros independent of potential earnings during the experiment. Thereby, gains from the following task will be added to this sum while losses will be deducted from the endowment.

During the experiment you can earn an experimental currency (ECU). At the end of the experiment, earnings will be converted at an exchange rate of

1 Euro = 2 ECU.

In this experiment you take the role of a retailer who sells a single product. In each round of the game, you have to decide how many units of the product you wish to order in **this** period at a cost of

3 ECU per unit.

You can sell the product to the customer at a price of

4 ECU per unit.

You will play the game for exactly **five rounds**, one of which will be randomly selected to determine your payoff at the end of the experiment. Thereby, each round becomes payoff-relevant with exactly the same probability. You therefore have an incentive to carefully decide on your order quantity in each round since it might determine your payoff. Each round proceeds as follows:

1. First, you decide on your order quantity. You can choose either **0** units, **1** unit, **2** units or **3** units. At the moment, you do not know what quantity the customers will demand. Therefore, you cannot assess whether you will sell all the units you are about to buy.

2. Once you place your order, the computer will randomly select the demand quantity for this period. Demand equals either **0**, **1** or **2** units. Each demand realization occurs with **equal probability**. The demand drawn for any one round is independent of the demand from earlier rounds. Moreover, demand in the actual round will not affect demand in later rounds.

3. Finally, demand is satisfied if possible and your payoff for this period will be determined. Thereby, we have to distinguish between two cases:

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Figure 3: *Instructions for treatment LL (English translation, Page 1).*

a. Actual demand is **smaller or equal to** the ordered quantity. The whole demand can be satisfied and you will earn

payoff= selling price · demand - unit cost · order quantity

1. Example: Suppose demand equals 1 unit and you ordered 2 units. You will earn:
payoff=4 ECU· 1 unit-3 ECU · 2 units=-2 ECU.

2. Example: Suppose demand equals 1 unit and you ordered 1 unit. You will earn:
payoff=4 ECU · 1 unit-3 ECU · 1 unit=1 ECU.

b. Actual demand is **larger** than the ordered quantity. Demand cannot be satisfied completely and you will earn

payoff= selling price · order quantity - unit cost · order quantity

3. Example: Suppose demand equals 2 units and you ordered 1 unit. You will earn:
payoff=4 ECU · 1 unit-3 ECU · 1 unit=1 ECU.

Now another round will begin. All unsold units go stale after a round, and **cannot be carried as inventory** into future rounds. Again, you will choose an order quantity before the demand is realized randomly and your payoff is determined.
Your total earnings correspond to your **gain/loss in a randomly drawn round of the game** plus your endowment of 7 Euros. Potential losses will be deducted from the endowment.

At the end of the experiment, please wait until you are called to collect your payment.

Good luck!

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Figure 4: *Instructions for treatment LL (English translation, Page 2).*

Informationen zum Experiment

Willkommen zu dieser experimentellen Studie. Bitte beachten Sie, dass Sie ab jetzt und während des gesamten Experiments weder Ihr Handy benutzen noch mit anderen Teilnehmern sprechen dürfen. Bitte lesen Sie sich die folgenden Instruktionen aufmerksam durch. Für eine erfolgreiche Durchführung des Experiments ist es wichtig, dass Sie diese wirklich verstanden haben. Sollten Sie zu irgendeinem Zeitpunkt eine Frage haben, melden Sie sich bitte kurz. Ein Experimentator wird Ihre Frage daraufhin individuell an Ihrem Platz beantworten.
Zunächst einmal erhalten Sie unabhängig von Ihren zusätzlichen Auszahlungen während des Experiments ein Einkommen in Höhe von 7 Euro. Dieses wird zu Ihren im Experiment erzielten Auszahlungen hinzuaddiert, d.h. eventuelle Verluste werden mit diesem Einkommen verrechnet.

Während des Experiments können Sie eine experimentelle Währung (ECU) verdienen, die am Ende des Experiments in Euro umgerechnet wird. Der Wechselkurs beträgt

1 Euro = 2 ECU.

Sie werden in diesem Experiment die Rolle eines Verkäufers übernehmen, der ein einzelnes Produkt anbietet. Vor jeder Runde des Spiels, müssen Sie aufs Neue entscheiden, wie viele Einheiten des Produkts Sie für **diese** Spielrunde zu einem festen Einkaufspreis von

3 ECU pro Einheit

bestellen möchten. Der Preis, zu dem Sie eine Einheit weiter verkaufen können, beträgt

4 ECU pro Einheit.

Sie werden insgesamt **fünf Runden** spielen. Nach Abschluss dieser fünf Runden wird **eine** zufällig ausgewählt und ausgezahlt. Die Wahrscheinlichkeit, dass eine bestimmte Runde ausgewählt wird, ist für alle Runden gleich hoch. Daher haben Sie einen Anreiz jede Ihrer Entscheidungen mit der gleichen Sorgfalt zu treffen, da jede Runde Ihre Auszahlungsrunde sein könnte. Jede Runde ist wie folgt aufgebaut:

1. Zunächst entscheiden Sie Ihre Bestellmenge. Hierbei können Sie **0** Einheiten, **1** Einheit, **2** Einheiten oder **3** Einheiten des Produkts auswählen. Zu diesem Zeitpunkt wissen Sie allerdings noch nicht, wie hoch die Nachfrage nach dem Produkt sein wird. Sie wissen folglich nicht, ob Sie die gesamte Bestellung auch verkaufen können.

2. Nachdem Sie eine Bestellmenge gewählt haben, wählt der Computer zufällig wie hoch die Nachfrage nach Ihrem Produkt in dieser Runde ist. Die Nachfrage kann entweder **0** Einheiten, **1** Einheit oder **2** Einheiten betragen. Alle drei Mengen treten **mit gleicher Wahrscheinlichkeit** auf. Weiterhin wird die Nachfrage in der aktuellen Runde weder durch die Nachfrage in früheren Runden beeinflusst, noch wirkt sich diese auf die Nachfrage in den folgenden Runden aus.

1

Figure 5: *Instructions for treatment LL (Page 1).*

3. Abschließend wird die Nachfrage, soweit dies möglich ist, von Ihnen bedient und Ihre Rundenauszahlung berechnet. Hierbei müssen zwei Fälle unterschieden werden:

   a. Die tatsächliche Nachfrage ist **kleiner oder gleich** der bestellten Menge. Die gesamte Nachfrage wird bedient und Ihre Auszahlung in dieser Runde beträgt

   $$\text{Auszahlung= Verkaufspreis} \cdot \text{Nachfrage - Einkaufspreis} \cdot \text{Bestellmenge}$$

   1. Beispiel: Nehmen Sie an, dass die Nachfrage 1 Einheit beträgt und Sie 2 Einheiten bestellt haben. Sie erhalten:
   Auszahlung=4 ECU· 1 Einheit-3 ECU · 2 Einheiten=-2 ECU.

   2. Beispiel: Nehmen Sie an, dass die Nachfrage 1 Einheit beträgt und Sie 1 Einheit bestellt haben. Sie erhalten:
   Auszahlung=4 ECU · 1 Einheit-3 ECU · 1 Einheit=1 ECU.

   b. Die tatsächliche Nachfrage ist **größer** als die bestellte Menge. Nicht die gesamte Nachfrage kann bedient werden und Ihre Auszahlung in dieser Runde beträgt

   $$\text{Auszahlung= Verkaufspreis} \cdot \text{Bestellmenge - Einkaufspreis} \cdot \text{Bestellmenge}$$

   3. Beispiel: Nehmen Sie an, dass die Nachfrage 2 Einheiten beträgt und Sie 1 Einheit bestellt haben. Sie erhalten:
   Auszahlung=4 ECU · 1 Einheit-3 ECU · 1 Einheit=1 ECU.

Nun beginnt die nächste Runde. Alle nicht verkauften Einheiten gehen verloren, d.h. Sie können bestellte Einheiten **nicht lagern**, um diese in späteren Runden zu verkaufen. Sie wählen zunächst wieder eine Bestellmenge, bevor die Nachfrage zufällig gewählt wird und Ihr Auszahlungsbetrag für diese Runde berechnet wird.
Ihre Gesamtauszahlung entspricht Ihrem **Gewinn/Verlust in der zufällig ausgewählten Auszahlungsrunde** plus Ihrem Einkommen von 7 Euro. Mögliche Verluste werden mit diesem Einkommen verrechnet.

Nach Beendigung des Experiments bleiben Sie bitte solange auf Ihrem Platz sitzen bis Sie aufgerufen werden.

Viel Erfolg!

2

Figure 6: *Instructions for treatment LL (Page 2).*

Part F: Time Trends and Learning

Time trends. Our main results refer to the average order quantities in the first period. As a robustness check, we analyze how the average order quantities in the different treatments change over periods. For each treatment, we run a Tobit panel regression of order quantities on a constant and period dummies where the first period serves as the reference period. This gives estimates of the average order quantities in the different periods. Table 1 illustrates the regression results.

	LS	**LL**	**HS**	**HL**
Dependent variable	$q_{i,t}$	$q_{i,t}$	$q_{i,t}$	$q_{i,t}$
constant	0.766***	1.196***	1.215***	1.427***
	(0.176)	(0.160)	(0.101)	(0.094)
period				
2	-0.094	0.010	-0.066	-0.211**
	(0.161)	(0.151)	(0.089)	(0.104)
3	0.216	-0.279*	0.096	-0.155
	(0.160)	(0.153)	(0.089)	(0.104)
4	-0.045	-0.163	0.102	-0.081
	(0.162)	(0.153)	(0.090)	(0.104)
5	-0.113	-0.451***	0.030	-0.085
	(0.161)	(0.155)	(0.089)	(0.104)
# of observations	205	200	195	190
# of participants	41	40	39	38

Standard errors in parantheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 1: *Tobit panel regression per treatment.*

First, we observe that the average order quantities in treatments LS and HS do not significantly change over periods. Hence, the newsvendor problem persists even though subjects should be able to learn the optimal order quantity in our simple setup. Second, we observe a significant reduction in the average order quantity for treatment LL (HL) in both the third and the fifth period (in the second period) relative to the first period. This supports the intuition that choice set effects decline over time. In treatment LL, for instance, the average order quantity in the fifth period is reduced (compared to the first period) by roughly the initial choice set effect.

Learning. Next, we classify subjects according to their choices over the five periods in order to analyze learning on an individual level. Thereby, we distinguish seven groups (see Table 2). *Optimal* refers to subjects who chose the optimal order quantity in each period. Subjects in *Optimal/NotOptimal* chose the optimal order quantity in the first period, but then switched to a suboptimal order quantity in some later period(s). *Newsvendor* indicates that the subject ordered the middle option (1 unit) in each period. *Newsvendor/Optimal* refers to subjects who chose the middle option in the first period, but then switched to the optimal order quantity in some later period and stuck to it. Subjects in *Newsvendor/NotOptimal* chose the middle option in the first period, but then switched to another suboptimal order quantity in some later period(s). *Opposite/Anything* refers to subjects who chose the worst among the not-dominated options in the first period and switched to another option in some later period(s). *Dominated/Anything* indicates that the subject chose the dominated option in the first period and then switched to another option in some later period(s).

	LS		**LL**		**HS**		**HL**	
	Choice		Choice		Choice		Choice	
Optimal	5	12.20%	3	7.50%	4	10.26%	1	2.63%
Optimal/NotOptimal	3	7.32%	1	2.50%	3	7.69%	13	34.21%
Newsvendor	7	17.07%	5	12.50%	21	53.85%	15	39.47%
Newsvendor/Optimal	4	9.75%	5	12.50%	4	10.26%	2	5.27%
Newsvendor/NotOptimal	19	46.34%	13	32.50%	6	15.38%	6	15.79%
Opposite/Anything	3	7.32%	12	30.00%	1	2.56%	0	0.00%
Dominated/Anything	-	-	1	2.50%	-	-	1	2.63%
# of participants	41		40		39		38	

Table 2: *Individual choices over the five periods.*

Only very few subjects made the optimal decision throughout the whole experiment. For the small choice set also very few subjects chose optimally in the first period. In line with salience theory, this number is much higher for the high margin treatment if the choice set is enlarged (14 subjects in HL vs. only 7 subjects in HS). Enlarging the choice set should raise the order quantitiy of a local thinker, thereby increasing the number of subjects choosing two units, which is optimal if the margin is high. Most subjects, however, do not stick to the optimal choice for the subsequent rounds (13 out of 14 subjects). This is in line with salience theory as long as at some point in time subjects realize that the excessive quantity is dominated and therefore discard it from their consideration set. Also in line with salience theory, for the low margin more subjects chose two units in the first period if the excessive option is available than when it is not (12 subjects in LL compared to 3 subjects in LS). Half of these subjects revealed the newsvendor problem from some later period on, which is in line with the salience prediction as long as the dominated option is discarded from the subject's consideration set at some point in time. In line with the literature on the newsvendor game and in line with our salience-based explanation, the newsvendor problem is persistent: only a few subjects learned to choose optimally. Also in line with salience theory, there are more subjects revealing the newsvendor problem in every period if the choice set is small than if it is large.

Part G: Salience Predictions for an Insufficient Dominated Option

Suppose demand is $x_2 = 2$, $x_3 = 3$, or $x_4 = 4$, with $Pr(x_i) = 1/3$ for $2 \leq i \leq 4$. Let $p \in \{4, 10\}$ and $w = 3$ such that $z \in \{3/4, 3/10\}$. We derive a local thinker's choices from the sets $Q^S := \{2, 3, 4\}$ and $Q^L := \{1, 2, 3, 4\}$, respectively. Given these parameter values, Table 3 summarizes the payoffs associated with the respective order quantities for each state of the world.

	$x_2 = 2$		$x_3 = 3$		$x_4 = 4$	
	$p = 4$	$p = 10$	$p = 4$	$p = 10$	$p = 4$	$p = 10$
$q_1 = 1$	1	7	1	7	1	7
$q_2 = 2$	2	14	2	14	2	14
$q_3 = 3$	-1	11	3	21	3	21
$q_4 = 4$	-4	8	0	18	4	28
Average payoff in Q^S	-1	11	$\frac{5}{3}$	$\frac{53}{3}$	3	21
Average payoff in Q^L	$-\frac{1}{2}$	10	$\frac{3}{2}$	15	$\frac{5}{2}$	$\frac{35}{2}$

Table 3: *Payoffs derived from order quantity q_j in state i for $i, j = 0, 1, 2$.*

As a benchmark case consider a rational decision maker. The rational agent maximizes her expected payoff by choosing the small order quantity q_2 if the cost price ratio is high (i.e., $z = 3/4$) and the large order quantity q_4 if the cost price ratio is low (i.e., $z = 3/10$).

First, consider a local thinker who faces the small choice set $Q^S = \{2, 3, 4\}$. Since the small option q_2 yields the same payoff in each state of the world a local thinker's valuation for this option coincides with its expected payoff. Applying Definition 2 shows that a local thinker's focus lies on state 3 for the middle option q_3. Irrespective of the cost price ratio z, we obtain

$$
\begin{aligned}
\sigma\left(u\left(x_3, q_3\right), \overline{u}_3\right) &> 0 \\
&= \sigma\left(u\left(x_2, q_3\right), \overline{u}_2\right) \\
&= \sigma\left(u\left(x_4, q_3\right), \overline{u}_4\right).
\end{aligned}
$$

Thus, a local thinker overvalues the middle option q_3 relative to the small order quantity q_2 which maximizes the expected payoff for $z = 3/4$. As a consequence, for a high cost price ratio (i.e., a low profit margin), the local thinker orders strictly more than the rational agent if the salience bias is sufficiently strong (i.e., $\delta < 1/2$). Note that, for $z = 3/4$, the conclusion that the local thinker's order quantity exceeds the optimal quantity choice of one unit is independent of whether the local thinker values the large quantity q_4 above or below its expected payoff. If instead the cost price ratio is low (i.e., the profit margin is high), a local thinker overemphasizes the downside of the large option q_4:

$$\begin{aligned}\sigma\left(u\left(x_2,q_4\right),\overline{u}_2\right) &= 3/19 \\ &> \sigma\left(u\left(x_4,q_4\right),\overline{u}_4\right) = 1/7 \\ &> \sigma\left(u\left(x_3,q_4\right),\overline{u}_3\right) = 1/107.\end{aligned}$$

Since the upside of the middle option q_3 in state 3 is salient, the local thinker opts for q_3 at $z = 3/10$ if the salience bias is sufficiently strong (i.e., $\delta < 0.93$). Hence, the local thinker's order quantity—given the small choice set—represents the newsvendor problem.

Second, consider a local thinker who faces the broader choice set $Q^L = \{1, 2, 3, 4\}$. Remember that a local thinker will never choose a dominated option as salience theory satisfies first-order stochastic dominance. Suppose a high cost price ratio $z = 3/4$. In this case, the downside payoff of the middle option q_3 in state 2 is salient since

$$\begin{aligned}\sigma\left(u\left(x_2,q_3\right),\overline{u}_2\right) = \sigma\left(u\left(x_3,q_3\right),\overline{u}_3\right) &= 1/3 \\ &> \sigma\left(u\left(x_4,q_3\right),\overline{u}_4\right) = 1/11.\end{aligned}$$

Thus, a local thinker overvalues the small option q_2 relative to the middle option q_3. Moreover, we obtain the following salience ranking for the large order quanitity q_4:

$$\begin{aligned}\sigma\left(u\left(x_3,q_4\right),\overline{u}_3\right) &= 1 \\ &> \sigma\left(u\left(x_2,q_4\right),\overline{u}_2\right) = 7/9 \\ &> \sigma\left(u\left(x_4,q_4\right),\overline{u}_4\right) = 3/13.\end{aligned}$$

Hence, the local thinker overweights q_4's downside in state 2 relative to its upside in state 4. This implies that the salience-weighted expected payoff from ordering four units is strictly negative since $u\left(x_2,q_4\right) = -u\left(x_4,q_4\right)$ and $u\left(x_3,q_4\right) = 0$. As a consequence, for any $\delta \in (0,1)$, the local thinker orders two units if $z = 3/4$.

Suppose a low cost price ratio $z = 3/10$. In this case, the upside payoff of the large option q_4 in state 4 attracts a local thinker's attention. Formally, Definition 2 yields

$$\begin{aligned}\sigma\left(u\left(x_4,q_4\right),\overline{u}_4\right) &= 3/13 \\ &> \sigma\left(u\left(x_2,q_4\right),\overline{u}_2\right) = 1/9 \\ &> \sigma\left(u\left(x_3,q_4\right),\overline{u}_3\right) = 1/11.\end{aligned}$$

Note that also for the middle option q_3 the upside payoff (in state 3) is salient since

$$\begin{aligned}\sigma\left(u\left(x_3,q_3\right),\overline{u}_3\right) &= 1/6 \\ &> \sigma\left(u\left(x_4,q_3\right),\overline{u}_4\right) = 1/11 \\ &> \sigma\left(u\left(x_2,q_3\right),\overline{u}_2\right) = 1/21.\end{aligned}$$

Comparing the salience-weighted expected payoffs from ordering three units and four units, respectively, shows that the local thinker chooses the large option q_4 for any $\delta \in (0, 1)$ if the cost price ratio is $z = 3/10$. Altogether, for any $\delta \in (0, 1)$, the local thinker behaves in line with rational choice when facing the enlarged choice set Q^L.

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