The Effect of Payment Schemes on Inventory Decisions: The Role of Mental Accounting

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In the newsvendor problem, a decision maker chooses an inventory order quantity prior to the realization of a random demand. The decision maker faces a trade-off between ordering too many and having leftover inventory versus ordering too few and missing out on potential sales. Keeping the net profit structure constant, we study how the payment scheme affects inventory decisions. Specifically, we examine three payment schemes which can be interpreted as the inventory order being financed 1) by the newsvendor herself, 2) by the supplier, and 3) by the customer. We find in laboratory experiments that the order quantities may be higher or lower than the expected profit-maximizing solution depending on the payment scheme. Specifically, the order quantity under newsvendor own financing is greater than that under supplier financing, which is, in turn, greater than the order quantity under customer financing. This observed behavior biases orders in the opposite direction as what a regular or hyperbolic time-discounted utility model would predict, and cannot be explained by loss aversion models. Instead, the findings are consistent with a model that underweights the order-time payments, which is consistent with the “prospective accounting” assumption in the mental accounting literature. A second study shows the results hold even if all actual payments are conducted at the same time, suggesting that the framing of the payment scheme is sufficient to induce mental accounting of payments at different times. We further validate the robustness of our model under different profit-margin conditions. Our findings contribute to the understanding of the psychological processes involved in newsvendor decisions and have implications for supply chain financing practices and supply chain contract design.

Key words: Behavioral operations, newsvendor, mental accounting, decision under uncertainty
1 Introduction

In the newsvendor problem, a decision maker chooses an inventory order quantity to meet a random future demand. The goal is to choose an order quantity that optimally balances the expected cost of overordering (i.e., having leftover inventory) with the expected cost of underordering (i.e., missing out on potential sales). The newsvendor framework is commonly used in practice for managing products with a short selling season and limited replenishment opportunities, such as fashion apparels and high-tech products. It also serves as a building block for models of stochastic inventory management. In practice, many newsvendor ordering decisions are made by humans based on subjective judgments due to lack of historical data and/or difficulty in determining the problem parameters in advance (e.g., the fashion buying problem studied by Fisher and Raman, 1996). Furthermore, even if the demand distribution and cost parameters are fully specified, human subjects are often observed deviating significantly from the optimal solution in experiments (e.g., Schweitzer and Cachon 2000). Therefore, it is important to understand the psychological processes that may cause human biases in newsvendor decision-making. In this paper, we study how seemingly innocuous differences in the payment scheme can lead to significantly different ordering decisions in repeated newsvendor experiments.

We define the payment scheme as the mapping of inventory events to financial payments. In the newsvendor problem, the payment scheme describes how the inventory order, sales, and salvage determine payment transactions. There are many payment schemes used in practice, designed for reasons including risk-sharing, cash constraints, financial health transparency, and price discrimination. Clearly, a change in payment scheme may affect the inventory decision for perfectly rational reasons (if the net profit structure is altered), but there may also be a behavioral effect of payment scheme on the decision maker. Thus, understanding this potential behavioral effect is not only of academic interest but also useful for practitioners as it can help inform the design of payment schemes in supply chain financing and contracting.

In order to isolate the behavioral effect of payment schemes, we study inventory decisions under different payment schemes whose net profit structures are identical (i.e., the net profits are equal for any order quantity and demand realization). Thus, the expected profit-maximizing order quantities under these payment schemes should also be equal. In fact, the order quantities are the
same for any decision model based on the net profit, including the utility models of risk aversion, risk seeking, loss aversion, and other utility preferences as they are formulated in Schweitzer and Cachon (2000). However, we propose and provide evidence that payment schemes have a behavioral effect on ordering decisions because individuals are influenced not only by the net profit that results from the payments, but also by how the payments unfold. The literature on mental accounting in consumer behavior (Thaler 1985) describes how consumers perceive and aggregate multiple gains and/or losses by placing them into different mental accounts before evaluating them. The implication for the newsvendor setting is that payment schemes may affect ordering behavior by inducing different mental accounting of payments.

In order to examine the newsvendor’s mental accounting of payments, we consider three payment schemes in our paper. These payment schemes also have practical interpretations. Our first payment scheme is similar to a standard wholesale price contract: the newsvendor pays for the order quantity at the time of order and receives revenue according to the number of units sold. We call this payment scheme “own-financing,” because while the inventory is on location the newsvendor has paid for its cost but not yet received the revenue from sales. Secondly, we consider the case where newsvendor’s order payment is delayed until after the demand is realized because an external party covers the order payment. We call this payment scheme “supplier-financing” because suppliers frequently offer this kind of delayed order payments (Peterson and Rajan 1997). However, any entity (e.g., a bank) could offer the newsvendor this kind of service. Finally, we consider the payment scheme where the newsvendor receives advanced revenues, so that they receive revenue for the inventory ordered even though it has not yet been sold. We call this payment scheme “customer-financing” because large buyers occasionally provide this kind of service (O’Sullivan 2007). However, again, any entity (e.g., a bank) could offer this financial service to the newsvendor using the inventory as collateral. Finally, we eliminate differences in the interest rates and risk-premiums associated with these types of arrangements by setting them to zero. This allows us to keep the net profit structure constant, isolating the behavioral effect of these payment schemes.

We present four models that represent different possible ways that individuals account for the multiple payments in the newsvendor problem, and derive their predictions on newsvendor ordering behavior. As a normative benchmark, we first show that the expected-profit-maximizing model, which correctly aggregates and evaluates all payments, predicts orders to be identical across
the three payment schemes. A second descriptive model assumes that the inventory manager is loss averse with respect to the order-time payments and the demand-time payments separately, because they occur at different times. A third descriptive model assumes that when inventory managers account for all of the payments, they discount the demand-time payments because of time-discounting. Finally, the fourth descriptive model assumes that when inventory managers account for all the payments they underweight the order-time payments due to a mental accounting phenomenon called “prospective accounting,” in which individuals fully account for utilities looking forward in time, but largely discount utilities looking backwards in time (Prelec and Loewenstein, 1998).

Three newsvendor experimental studies with human decision-makers allow us to empirically compare the predictions of the above models. Recall, within each study, the net profit structures are identical across the three payment schemes. In Study 1, the cost of overordering is equal to the cost of underordering, so that the expected profit-maximizing solution is to order the median demand under all three payment schemes. Setting the optimal solution at the center (median) of the demand distribution allows us to isolate the effect of payment schemes from the pull-to-center effect—a bias towards ordering the median demand (Schweitzer and Cachon 2000; Bostian et al. 2008; Bolton and Katok 2008). Our results show that payment scheme has a significant effect on inventory decisions such that orders may be higher, lower, or equal to the expected profit-maximizing solution.

We find that orders under the own-financing payment scheme are higher than orders under the supplier-financing payment scheme, which in turn are higher than orders under the customer-financing payment scheme. This ordering behavior is inconsistent with the loss aversion model. It is also inconsistent with a model of time discounting (or hyperbolic discounting, Laibson 1997). In fact, a time discounted model would predict the opposite ordering behavior: orders under own-financing should be lower than orders under supplier-financing and customer-financing because the own-financing scheme requires the greatest up-front cost. Rather, the observed ordering behavior is consistent with the prospective accounting model of underweighting the payments associated with the order quantity. Prospective accounting predicts that under own-financing the decision-maker orders more than the expected profit maximizing order quantity because she discounts the up-front cost. This is because from the vantage point of the order, the pain of the order cost is buffered
by the thought of future revenue from sales. However, from the vantage point of the demand realization, the pleasure derived from the revenue is relatively unhindered by the thought of the order cost because it occurred in the past. On the other hand, prospective accounting predicts that under customer-financing the decision-maker orders less than the expected profit maximizing order because she discounts the up-front gain of payment receipts (i.e., advanced revenues). Under supplier-financing, however, all payments are equally weighted because they are all calculated at the same time; as a result, the newsvendor correctly orders the expected profit maximizing quantity.

In Study 2, we isolate the mental accounting of payments over time from the actual accounting of payments over time by eliminating the differences in the actual timing of payments. We demonstrate that the same ordering pattern in Study 1 can be achieved by simply framing the payment schemes to induce different mental payment times, even if all actual payments are conducted at the same time. In other words, even if all payments are conducted at the same time, order quantities may be different because the framing of the payment scheme causes the decision-maker to associate different mental payments to the order, sale, and salvage events, which occur at different times. Finally, in Study 3, we demonstrate that the effect of payment schemes on the relative sizes of order quantities is robust under high- and low-profit conditions, though the magnitude of the difference between two payment schemes may interact with the profit margin.

Perhaps the most surprising result from our study is that it documents an effect that works in the opposite direction as time discounting. Therefore, industry practices such as trade credit (similar to supplier financing) and advanced payment programs (similar to customer financing), which are designed to incentivize an increased newsvendor order, may have reduced effectiveness because they inadvertently influence the newsvendor in the opposite way due to this additional behavioral effect.

Furthermore, Study 3 also provides us with a plausible explanation for a result previously reported in the literature. Schweitzer and Cachon (2000) and Bolton and Katok (2008) find that the pull-to-center effect (i.e., the deviation from the optimal order quantity towards the center of the demand distribution) is larger in the low-profit case compared to the high-profit case. They leave this as an open question and suggest stockout aversion or context-specific anchoring and adjustment as possible explanations. We note that the framing of the newsvendor problem in their studies is similar to a wholesale price contract (i.e., own-financing scheme). As a result, such an
asymmetry of the pull-to-center effect can be explained by our prospective accounting model (see the discussion in Study 3). We further show that the pull-to-center deviations for high- and low-profit cases are symmetric under supplier-financing and that the asymmetry of the pull-to-center effect is reversed under customer-financing. This implies that the direction of the asymmetry of the pull-to-center effect is actually dependent on the framing of the newsvendor payment schemes.

The rest of the paper is organized as follows. We provide a literature review in Section 2. We present the three stylized payment schemes and four decision models in Section 3. We present our experimental results in Section 4. We conclude with a discussion of the results and their managerial implications in Section 5.

2 Literature Review

There is a growing literature on behavioral operations management (see Bendoly et al. 2006 for a review), in which researchers study how humans make operational decisions and how these decisions may differ from the expected profit-maximizing decision. For example, the pull-to-center effect in the newsvendor problem, first studied by Schweitzer and Cachon (2000), documents how order quantities are biased towards the median demand. Others have shed further light on newsvendor decisions by examining decision heuristics (Bostian et al. 2008), the role of learning and feedback (Bolton and Katok 2008; Lurie and Swaminathan 2009), demand estimation biases (Feiler et al. 2011), psychological costs (Ho et al. 2010), and bounded rationality (Su 2008; Kremer et al. 2010). Researchers have also examined behavior in a serial supply chain setting, finding that human subjects do not sufficiently account for the pipeline inventory and subsequently overreact to their inventory levels, contributing to the bullwhip effect (Sterman 1989, Croson and Donohue 2005, 2006). Others examine behavioral issues in supply chain contracts, such as social preferences (Loch and Wu 2008) and the effectiveness of risk-sharing contracts (Ho and Zhang 2008; Katok and Wu 2009). The latter two papers are perhaps the most closely related to our paper. Ho and Zhang compare the two-part tariff and the quantity discount contracts, while Katok and Wu study the buyback and revenue sharing contracts.

Mental accounting (see Thaler 1999 for a review) has long been used to help understand the psychology behind choice behavior (Kahneman and Tversky 1979; Tversky and Kahneman 1981;
Thaler 1980, 1985). Mental accounting describes how individuals aggregate, segregate and evaluate multiple gains and/or losses. It provides an explanation for many phenomena in human behavior that seem irrational—most notably in consumer behavior (e.g., Thaler 1985; Heath and Soll 1996), but also in other functional areas, such as finance (Shefrin and Statman 1985) and accounting (Burgstahler and Dichev 1997). Our experimental findings provide an example of mental accounting in operations management. The consumer behavior mental accounting literature is especially related to our paper because, like newsvendors, consumers evaluate the transaction of a payment in return for a good. A consumer’s payment is mentally coupled with the consumption. Similarly, the newsvendor’s order payment is mentally coupled with the payments at the time of demand. Shafir and Thaler (2006) find that the typical wine connoisseur thinks of her initial purchase of a case of wine as an investment, later thinks of the wine as free when she drinks it, and so goes through the entire process never experiencing the pain of payment. Similarly, Prelec and Loewenstein (1998) find that people prefer to prepay for a vacation because they think that a prepaid vacation is more pleasurable than one that must be financed after returning. This is because at the vantage point of the vacation, the payment has occurred in the past and so feels less relevant. Gourville and Soman (1997) call the gradual reduction in relevance of past payments “payment depreciation.” More generally, Prelec and Loewenstein (1998) call the mental accounting rule that fully recognizes future payments but largely writes off past payments “prospective accounting.” We contribute to the mental accounting literature by applying these concepts to the newsvendor problem.

Our paper is also related to the literature on the interface of operations and finance. The payment contracts schemes we consider are actually stylized versions of real practices. For example, retailers often delay their payments to their supplier by seeking financing from the supplier (trade credit) or from a bank. The practice of trade credit is widespread (Peterson and Rajan 1997; Ng et al. 1999) and the trade credit terms can certainly affect a firm’s optimal ordering policy (e.g., Haley and Higgins 1973 and Gupta and Wang 2009). Similarly, small suppliers often seek advanced payments from another party by leveraging their inventory. This is commonly executed with a bank or customer, and has been increasing in popularity due to an increase in buyer-based supply chain financing solutions which leverage the buyer’s credit (for example, see O’Sullivan 2007). Other financial considerations can also affect inventory decisions, such as asset-based financing (Buzacott and Zhang 2004) and capital constraints (Xu and Birge 2004; Babich and Sobel 2004;
Xu and Zhang 2010). Our paper contributes to this literature by demonstrating that the choice of financial payment scheme also has a behavioral effect on inventory decisions.

3 Models of Newsvendor Decision Making

In the newsvendor problem, a decision-maker chooses an order quantity \( q \) of a product to meet a future random demand \( D \). Let \( F(\cdot) \) denote the cumulative distribution function for the random demand. We assume that backlogs are not allowed (i.e., unmet customer demand is lost) and leftover inventory cannot be carried over to the subsequent period and has zero salvage value. The unit cost of the product is \( c \) and it is sold at price \( p \) (with \( p > c \)).

In this paper, we consider the following payment schemes. (1) Own financing (payment scheme O): The newsvendor pays the cost \( c \) per unit herself at the time of ordering and receives a revenue \( p \) per unit sold when demand is realized. (2) Supplier financing (payment scheme S): Another firm (e.g., the supplier) finances the newsvendor’s order and permits the newsvendor to delay her payment for units ordered until the time of demand realization. Thus, under this scheme, the newsvendor pays nothing at the time of ordering; at the time of demand realization, she receives \( p - c \) per unit sold and pays the external financing party \( c \) per unit leftover. (3) Customer financing (payment scheme C): Another firm (e.g., the customer) advances payment \( p \) per unit that the newsvendor orders, but requires that the newsvendor refund the payment for the units that are not demanded. Thus, under this scheme, the newsvendor receives \( p - c \) per unit ordered at the time of ordering, but must refund \( p \) per unit leftover at the time of demand realization. The payment schemes are summarized in Table 1.

<table>
<thead>
<tr>
<th>Payment Scheme</th>
<th>Payments at time of order per unit ordered</th>
<th>Payments after demand realization per unit sold</th>
<th>Payments after demand realization per unit leftover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Financing (O)</td>
<td>(-c)</td>
<td>(+p)</td>
<td>0</td>
</tr>
<tr>
<td>Supplier Financing (S)</td>
<td>0</td>
<td>(+ (p - c))</td>
<td>(-c)</td>
</tr>
<tr>
<td>Customer Financing (C)</td>
<td>(+ (p - c))</td>
<td>0</td>
<td>(-p)</td>
</tr>
</tbody>
</table>

Table 1: Net payments and transaction timing under different payment schemes.

Payment scheme O corresponds to the standard wholesale price contract. Payment scheme S is similar in terms of the timing of the payments to trade-credit arrangements that are commonly
observed in practice between suppliers and retailers (e.g. Peterson and Rajan 1997). However, it is a stylized scheme as it does not reflect the lower interest rate benefits that such arrangements typically offer. Payment scheme C is similar to receiving revenues in advance from the customer (O’Sullivan 2007) or financing inventory from an external party using inventory as a collateral. This scheme is also stylized as the amount financed (or the revenue advanced) in practice may only be part of the total selling value.

Next, we describe four models that differ in how the decision maker takes the payment scheme into account. We use the first normative model, which predicts the same order decision across payment schemes, as a benchmark. Three other models, inspired by behavioral decision-making and consumer behavior literature, predict different ordering behaviors across payment schemes. We use the term “reward function” to denote how the individual aggregates payments, possibly dependent on payment scheme.

### 3.1 Expected Profit-Maximizing Solution

Let $R^i(q, D)$ denote the reward function given the quantity $q$ and demand realization $D$ under the payment scheme $i \in \{O, S, C\}$. If the decision-maker is an expected profit-maximizer, then $R^i(q, D)$ is simply the net profit given by

$$R^i(q, D) = \begin{cases} 
-cq + p \min(q, D) & \text{if } i = O, \\
(p - c) \min(q, D) - c \max(q - D, 0) & \text{if } i = S, \\
(p - c)q - p \max(q - D, 0) & \text{if } i = C.
\end{cases}$$

This formulation does not take the time dimension into account. The optimal order quantity that maximizes the expected profit is $q^i = \arg \max_q \mathbb{E}_{D}[R^i(q, D)]$.

**Proposition 1** The expected profit-maximizing quantities under the three payment schemes are $q^O = q^S = q^C = q^*$, where $q^* = F^{-1}((p - c)/p)$.

It is easy to verify Proposition 1 by noting that $R^O(q, D) = R^S(q, D) = R^C(q, D)$ for any $q$ and $D$. The term $(p - c)/p$ is known as the critical fractile.

In fact, any utility function (e.g., the models of loss aversion and risk aversion as formulated by Schweitzer and Cachon 2000) predicts the same expected utility maximizing order quantities under the three payment schemes if they are evaluated based on the net profit (see Appendix A).
3.2 Loss Aversion at the Times of Order and Demand

The most prominent feature of Prospect Theory (Kahneman and Tversky 1979) is that individuals are loss averse with respect to a reference wealth, which is usually assumed to be an individual’s current wealth. The decision maker may be loss averse with respect to the order-time payments and the demand-time payments separately because she updates her reference wealth between the time of order and the time of demand. Let \( \pi_1^i(q) \) denote the net payment at the time of the order and \( \pi_2^i(q) \) denote the net payment at the time of the demand realization under payment scheme \( i \in \{O, S, C\} \). As in Schweitzer and Cachon (2000), we capture loss aversion using the utility function \( U^i(x) = \begin{cases} x & \text{if } x \geq 0; \lambda x & \text{if } x < 0 \end{cases} \) for \( \lambda > 1 \). Then the newsvendor’s total reward is:

\[
R^i(q) = U^i(\pi_1^i(q)) + U^i(\pi_2^i(q, D)) = \begin{cases} -\lambda c q + p \min(q, D) & \text{if } i = O, \\ 0 + U^i[(p - c) \min(q, D) - c \max(q - D, 0)] & \text{if } i = S, \\ (p - c) q - \lambda p \max(q - D, 0) & \text{if } i = C. \end{cases}
\]

The following proposition compares the subsequent expected rewards-maximizing order quantities to the expected profit maximizing order quantity.

**Proposition 2** If the decision maker is loss averse and updates her reference wealth between the time of order and the time of demand, then the expected-utility-maximizing quantities under the three payment schemes are all less than the expected profit maximizing order quantity, i.e., \( q^O < q^*, q^S < q^*, \) and \( q^C < q^*. \)

**Proof:** The critical fractiles for payment schemes O and C are \( (p - \lambda c)/p \) and \( (p - c)/\lambda p \), respectively, which are both less than the expected-profit-maximizing critical fractile. For payment scheme S, because all payments are made at the same time we refer to Schweitzer and Cachon’s (2000) loss aversion model. They show that the optimal solution is also less than the expected profit maximizing solution.

3.3 Time-Discounted Rewards

The decision-maker may prefer to receive benefits earlier and delay costs until later, which effectively means that future payments are discounted (see Frederick et al. 2002 for a discussion on time discounting). This is also known as the time-discounted utility model. The discounting may be
due to behavioral reasons or due to the time value of money (i.e., interest rate). Under this model, the decision maker aggregates payments made at different times by discounting the payments at the time of the demand realization. Let $\delta$ ($0 < \delta < 1$) denote this discount factor. The time-discounted reward function $R^i(q, D)$ can then be expressed as follows.

$$R^i(q, D) = \begin{cases} 
-cq + \delta p \min(q, D) & \text{if } i = O, \\
\delta(p - c) \min(q, D) - \delta c \max(q - D, 0) & \text{if } i = S, \\
(p - c)q - \delta p \max(q - D, 0) & \text{if } i = C.
\end{cases}$$

As the following proposition shows, this preference model yields different expected reward-maximizing quantities under the three payment schemes.

**Proposition 3** With time-discounted rewards, the expected-rewards-maximizing quantities under the three payment schemes have the following relationships: $q^O < q^S = q^* < q^C$.

**Proof:** The critical fractiles for payment schemes O, S, and C are $(\delta p - c)/\delta p$, $(p - c)/p$, and $(p - c)/\delta p$, respectively. Because $(\delta p - c)/\delta p < (p - c)/p < (p - c)/\delta p$, we have $q^O < q^S = q^* < q^C$ for the expected-reward maximizing quantities.$\square$

More generally, the inequalities hold for any continuous and increasing utility function based on the rewards (see Appendix A). Note that since there are only two time points in the model set-up, there is no difference between standard time discounting and hyperbolic time discounting (Laibson 1997).

### 3.4 Prospective Accounting: Underweighting Order-Time Payments

Thaler (1985) suggests that for a consumer, the payment and consumption in a transaction are not necessarily seen as separate gains and losses. Rather, the payment brings to mind or is “coupled” (Prelec and Loewenstein 1998) with the thought of the associated consumption, and the consumption is coupled with the thought of the associated payment. Prelec and Loewenstein suggest that the strength of these two couplings are strongly dependent on timing. Specifically, individuals use a mental accounting rule called “prospective accounting,” in which coupling is stronger when looking forwards in time, but weaker when looking backwards in time. The result is consistent with underweighting the utility from whichever event occurs first: the payment or the
consumption. For example, consider how the prospective accounting rule applies to the case when payment precedes consumption, as in a prepaid vacation. From the vantage point of the payment, the pain of payment is buffered because it is strongly coupled with the anticipated pleasure of the future vacation. However, from the vantage point of the vacation, the pleasure of the vacation is decoupled from the pain of the payment because it occurred in the past. Thus, in this case, the result of the prospective accounting is an overall underweighting of the pain of payment.

Instead of payment and consumption, the newsvendor simply has outgoing payments and incoming payments, which we will term costs and revenues. Similar to the consumer, we propose that, for the newsvendor, the order-time payments are coupled with the demand-time payments. Thus, assuming cost is analogous to payment (both are negative utilities) and revenue is analogous to consumption (both are positive utilities), we can implement the predictions of prospective accounting for our three payment schemes. Under payment scheme O, the cost precedes the revenue.\(^1\) Thus, we capture the “prospective accounting” rule by assigning an underweighting factor \(\beta (0 < \beta < 1)\) to the order cost. Under payment scheme C, the revenue precedes the cost. Thus, we capture the “prospective accounting” rule by assigning the underweighting factor \(\alpha (0 < \alpha < 1)\) to the order revenue. Under payment scheme S, all incoming and outgoing payments are made at the same time, and are thus equally weighted. The reward function \(R_i(q, D)\) under the prospective accounting model is given below.

\[
R_i(q, D) = \begin{cases} 
-\beta cq + p \min(q, D) & \text{if } i = O, \\
(p - c) \min(q, D) - c \max(q - D, 0) & \text{if } i = S, \\
\alpha(p - c)q - p \max(q - D, 0) & \text{if } i = C.
\end{cases}
\]

This model also predicts different expected reward-maximizing quantities under the three payment schemes.

**Proposition 4** With prospective accounting, the expected reward-maximizing quantities under the three payment schemes have the following relationships: \(q^O > q^S = q^* > q^C\).

**Proof:** The critical fractiles for payment schemes O, S, and C are \((p - \beta c)/p, (p - c)/p, and\)

\(^1\)In the newsvendor problem, both time and an uncertain event (the demand realization) separate the order-time payments from the demand-time payments. We refer the reader to Prelec and Loewenstein (1991) for how individuals perceive temporal separation and uncertainty similarly.
\( \alpha(p - c)/p \), respectively. Because \((p - \beta c)/p > (p - c)/p > \alpha(p - c)/p \), we have \( q^O > q^S > q^C \) for the expected-reward maximizing quantities (i.e., for a linear utility function of the reward). □

Again, the inequalities hold for any continuous and increasing utility function based on the rewards (see Appendix A). We also refer the reader to Appendix B for a comparison of this model and the Prelec and Loewenstein (1998) model of consumer utility.

3.5 Summary

In this section, we have derived the predictions of four behavioral models that predict various ordering patterns under payment schemes O, S, and C. We provide a summary of the model predictions in Table 2. We note that the effects in each model need not be mutually exclusive. For example, in reality, time-discounting and prospective accounting may exist simultaneously. Because they bias orders in opposite directions, the resulting order would depend on which effect dominates (see Section 5 for further discussion).

<table>
<thead>
<tr>
<th>Newsvendor Model</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected-Profit Maximization</td>
<td>( q^O = q^S = q^C = q^* )</td>
</tr>
<tr>
<td>Loss Aversion at the Times of Order and Demand</td>
<td>( q^O &lt; q^* ), ( q^S &lt; q^* ), ( q^C &lt; q^* )</td>
</tr>
<tr>
<td>Time Discounted Rewards</td>
<td>( q^O &lt; q^S = q^* &lt; q^C )</td>
</tr>
<tr>
<td>Prospective Accounting</td>
<td>( q^O &gt; q^S = q^* &gt; q^C )</td>
</tr>
</tbody>
</table>

Table 2: Summary of model predictions for orders under payment schemes O, S, and C.

4 Newsvendor Experiments

In this section, we present three repeated newsvendor experiments to examine the behavioral effect of payment scheme on inventory decisions. To isolate the behavioral effect of the payment scheme, we eliminate factors such as capital constraints and interest rates in our experimental designs (see Section 5 for a discussion of the impact of these factors). In the first study, we test whether ordering behavior can be described by the models presented in the previous section. We find that ordering behavior is consistent with the model of prospective accounting and is inconsistent with the other models. In the second study, we test whether the framing of the problem is sufficient to induce differences in the mental accounting even if all actual payments are made at the same
time. In the third study, we test the robustness of the model predictions under high- and low-profit conditions.

### 4.1 Study 1: A Simple Payment Scheme Experiment

#### 4.1.1 Experimental Design

In Study 1, we test the three payment schemes O, S, and C (refer to Table 1) under parameters $c = $1, $p = $2 in a repeated newsvendor setting.

In each round, subjects roll three fair six-sided dice, the sum of which determines the demand for that round. Thus, demand is independent, identically distributed, and symmetric with a minimum value of 3, maximum value of 18, and mean value of 10.5. We choose to generate random numbers using three dice instead of a computer in order to facilitate participant understanding of the payment schemes through active demand generation and counting. The distribution of the sum of three dice is also well approximated by a normal distribution.

Recall that all payment schemes are equivalent in the sense that they produce identical total net profits or losses for any given ordering decision and demand realization. Furthermore, the actual overage cost and underage costs are equal at $1 each and the expected-profit-maximizing solution under all payment schemes is to order either 10 or 11 units every period. The newsvendor pull-to-center effect suggests that participants are biased towards the mean of the demand distribution, or 10.5.

Next, we describe our experimental methods, present our results, and provide a discussion of the results for Study 1.

#### 4.1.2 Methods

We recruited 99 undergraduate and graduate students from a major American university. Bolton et al. (2010) find that qualitatively students and managers perform similarly in the newsvendor problem. Croson and Donohue (2006) also find managers' and students' inventory decisions are similar in a serial supply chain setting. Thus, we believe it is justifiable to use students as proxies for studying managerial behavior. The experimental conditions were assigned sequentially to the
participants. In exchange for their participation, participants received a minimum of $5 plus a $1 bonus for every 50 play dollars they had at the end of the game (each participant began with 100 play dollars). Participants earned anywhere from 7-13 dollars and took approximately 15 minutes to complete the experiment.

Participants were given an instruction sheet explaining the details of the game for the payment scheme to which they were assigned (see Appendix C). Instructions were also read out loud by a research assistant before beginning play. Participants were told that they would be selling “widgets” (represented by poker chips) and that customer demand for the widgets in a given round was represented by the sum of the rolling of three standard dice. Each participant interacted one-on-one with a research assistant, who facilitated payment transfers and recorded ordering decisions and dice rolls. A participant decided an order quantity vocally, placed that many poker chips into the “store” (represented by a square drawn on an index card), and made appropriate payment transfers. Then, the participant rolled the three dice, determined how many units were sold and/or leftover, and again made appropriate payment transfers. Finally, the participant removed all chips from the store to begin the next round.

Payment transfers were conducted in the form of play paper currency in denominations of 1, 5, and 10. All payments to the participant were conducted by the research assistant, while all payments from the participant were conducted by the participant. Appropriate payment transactions occurred immediately following the ordering decision and immediately following demand realization. The participant also moved the poker chips and rolled the dice themselves, which facilitated their understanding of the process. Game play was for 25 rounds, after which a follow-up question was administered: “If you could play the game again choosing only one order quantity, what number would you choose?” Finally, two written comprehension questions were administered at this time: “What is the minimum demand possible you can roll with three dice?” and “What is the maximum demand possible you can roll with three dice?”

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2 We conducted this study in two parts. In the first part, we randomly assigned one payment scheme O or S to each subject (57 subjects). In the second part, we randomly assigned one payment scheme S or C to each subject (42 subjects). Thus, each subject completed the experiment under only one payment scheme. We found no significant differences between the two repetitions of condition S, and therefore aggregated the data for analysis, yielding 29 subjects for condition O, 49 for condition S, and 21 for condition C.
4.1.3 Results

All 99 participants completed the study. One participant in the S condition incorrectly answered both comprehension questions and also made multiple orders of more than 18, and was therefore removed from the analysis (though all results hold when included). The resulting average ordering decisions in each round are shown in Figure 1, and a summary of our main results can be found in Table 3.

<table>
<thead>
<tr>
<th>Payment Scheme</th>
<th>Mean order quantity (standard deviation in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average over 25 rounds</td>
</tr>
<tr>
<td>Own Financing (O)</td>
<td>11.728 (1.392)</td>
</tr>
<tr>
<td>Supplier Financing (S)</td>
<td>10.573 (1.031)</td>
</tr>
<tr>
<td>Customer Financing (C)</td>
<td>9.749 (1.058)</td>
</tr>
</tbody>
</table>

Contrast tests

- $q^O - q^S$: 1.155***
- $q^S - q^C$: 0.824**
- $q^O - q^C$: 1.979***

Table 3: Mean and standard deviations of ordering quantities, and significance tests for differences between payment schemes in Study 1. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

We conducted a repeated measures generalized linear model to analyze the 25 inventory order decisions under each payment scheme. We found that payment scheme significantly affected ordering behavior ($F(2, 95) = 18.88, p < 0.0001$). Specifically, we found that orders were highest
under payment scheme O and lowest under payment scheme C. In order to test these differences, we conducted planned contrast tests. These tests showed that all three differences were significant: orders under O were significantly greater than orders under S \((F(1, 95) = 18.10, p < 0.0001)\), orders under S were significantly greater than orders under C \((F(1, 95) = 7.46, p = 0.0075)\), and orders under O were significantly greater than orders under C \((F(1, 95) = 35.83, p < 0.0001)\). As Table 3 shows, these same trends are present in the first ordering decision (which is unconfounded by experience or feedback), the average order quantity, and the follow-up question. However, not all differences were significant. Specifically, the differences appear to be more significant for the average orders and the follow-up question than for the first ordering decision (see a discussion on this in the summary below).

We also compared the average orders with the mean of the demand distribution, 10.5, because both the expected profit-maximizing criterion and the pull-to-center effect predicted orders near mean demand. We found that average orders under O were significantly greater than mean demand \((t(28) = 4.751, p < 0.001)\), average orders under C were significantly less than mean demand \((t(20) = -3.256, p = 0.004)\), while average orders under S were not significantly different from mean demand \((t(47) = 0.493, p = 0.624)\).

The actual demands generated by rolling the three dice were relatively consistent with the theoretical predictions. The means were 10.739, 10.557, and 10.764, under O, S, and C, respectively. Also, all participants (except the one eliminated participant in condition S) correctly answered 3 and 18 for the minimum and maximum possible demand that could be generated by rolling the three dice.

There was no significant difference in the overall ordering levels over time (Wilks’ Lambda = 0.701, \(F(24, 72) = 1.28, p = 0.212\)). In other words, there was no main effect for round. We also found no significant interaction between payment scheme and experience gained as more rounds were played (Wilks’ Lambda = 0.614, \(F(48, 144) = 0.83, p = 0.774\)).

**Summary** Study 1 establishes that payment schemes have a significant effect on ordering behavior in the newsvendor problem. Refer to Table 2. We found that order decisions can be higher or lower than the expected-profit-maximizing decision depending on the payment scheme, which is inconsistent with the expected profit-maximizing model. Furthermore, none of the utility-maximizing decision models proposed by Schweitzer and Cachon (2000) can explain differences in
orders under payment schemes O, S, and C, because they are all based on the net profit. Consistent with the prospective accounting model, we found that orders were generally largest under payment scheme O and smallest under payment scheme C. This is inconsistent with the time discounted-rewards model, which would predict the reverse order. It is also inconsistent with the loss aversion at the times of order and demand model, since orders under O are significantly greater than the expected-profit-maximizing order. Finally, the differences appear to not only be robust over 25 rounds, but actually more significant over time. This suggests that the feedback individuals use to inform their future ordering quantity is also subject to the prospective accounting effect, making the order deviation robust over 25 rounds of experience (see Section 5 for a brief discussion of recency and anchoring and adjustment).

**Structural Parameter Estimates** In order to provide further validation of the prospective accounting model, and to obtain estimates for its parameters, we estimated \( \beta \) and \( \alpha \) using a structural estimation technique. Note that the prospective accounting model reduces to the expected profit maximizing model when \( \beta = \alpha = 1 \). Therefore, we can test the model fit of the prospective accounting model against the expected profit maximizing model by testing if \( \beta \) and \( \alpha \) are less than 1.

The structural model assumes that the decision maker’s average order quantities over the 25 periods under payment scheme O were normally distributed with mean \( F^{-1}((2 - \beta)/2) \) under payment scheme O and \( F^{-1}(\alpha/2) \) under payment scheme C. Furthermore, we approximate the demand distribution with a normal distribution with mean 10.5 and standard deviation 2.958, matching the mean and standard deviation of the discrete demand distribution of the sum of three dice. The resulting maximum likelihood estimates for \( \beta \) and \( \alpha \) (denoted with \( \hat{\beta} \) and \( \hat{\alpha} \)) and 95% confidence intervals (given in parentheses) are as follows: \( \hat{\beta} = 0.678 (0.552, 0.804) \) and \( \hat{\alpha} = 0.800 (0.681, 0.919) \). (See Casella & Berger 2002, Chapter 10 for computation of the standard error of the MLE estimator).

In other words, in this experiment we found that on average individual’s orders are consistent with only taking into account 67.8% of payments that occur at the order time when costs precede revenues (payment scheme O), and only 80% of payments that occur at the order time when revenues precede costs (payment scheme C). For example, under payment scheme O, this suggests that an individual who orders 10 units at $1 each perceives the $10 cost as if it were only $6.78.
**Expected Profits** We also calculated the expected profits given each ordering decision of each participant. Rather than using actual profits (which is an outcome-based measure), the expected profits represent a measure of the participants’ decision efficiency. Expected profits were significantly affected by payment scheme \( F(2, 95) = 5.65, p = 0.005 \). Average expected per-round profits (standard deviations in parentheses) by condition were 7.461(0.696), 7.805(0.240), and 7.746(0.348) for O, S, and C respectively. It is not surprising that the expected profits were highest under payment scheme S, since the average order quantity under S was closest to the expected-profit maximizing quantity. Contrast tests show that all differences between conditions are significant differences at the \( p < 0.05 \) level except the difference between S and C.

One might suggest that these differences in profit are not extremely large (the expected per-round profits are 4.61% greater under S than under O). This is due to the fact that the expected profit function is relatively flat near the optimal solution. However, other important metrics are not as flat around the optimal solution. For example, the supplier’s revenue is the wholesale price times the newsvendor’s order. Thus, the supplier’s average per-round revenue is 20.29% greater under O than under C (on average she sells 11.728 units to the newsvendor versus 9.749). The differences between payment schemes also impact customer service. We calculated the customer’s expected in-stock rate for each ordering quantity. This analysis shows that the average expected per-round in-stock rates are .675(0.122), 0.564(0.116), and 0.462(0.120) for O, S, and C, respectively.

### 4.2 Study 2: A Payment Scheme Experiment with Constant Payment Timing

#### 4.2.1 Experimental Design

The purpose of Study 2 is to test whether we can achieve similar results as Study 1 by manipulating only the framing of the payment scheme (i.e., when and how payments are determined), while keeping constant the actual timing of payments. Study 2 implements the same study design as Study 1 with the following exception: all payments are postponed to the end of each round (i.e., conducted after the demand realization), even if some payments are determined at the time of the ordering decision. In other words, in Study 2 we test whether associating payments with different times (i.e., the order decision or the demand realization) in only the framing of the newsvendor problem is sufficient to induce differences in ordering decisions. For this reason, we will refer to these three payment schemes as payment frames, and denote our conditions with an overbar: Ō,
S, and C. Refer to Appendix C for the description of each payment frame in the instructions to the participants.

In the present study, since all payments are delayed until after the demand realization, there are no real differences between payment schemes in the actual financial position over time. However, the framing of the payment scheme may induce different timing of the mental accounting of payments over time. That is, participants may mentally impute order payments at the time of order even if the payments are not conducted until after the demand realization. If so, we would expect results in Study 2 to be similar to the results of Study 1.

In the subsequent sections, we describe our experimental methods, present our results, and provide a discussion of the results for Study 2.

4.2.2 Methods and Results

We recruited 57 undergraduate and graduate students from a major American university. The methods were the same as Study 1 except for the following differences. First, as described above, all payments were conducted at end of each round, after the demand realization. Secondly, in addition to the comprehension questions asked in Study 1, at the end of the experiment we also asked each participant the question: “What do you think is the long-run average demand generated by rolling three dice?”

All 57 participants completed the study and were included in the following analyses. A summary of our findings can be found in Table 4. As in Study 1, the repeated measures generalized linear model showed that payment frame significantly affected ordering behavior (F(2, 54) = 10.94, p < 0.0001). Orders under O were significantly greater than orders under S (F(1, 54) = 5.17, p = 0.0270). Orders under S were significantly greater than orders under C (F(1, 54) = 5.34, p = 0.0246), and orders under O were significantly greater than orders under C (F(1, 54) = 21.89, p < 0.0001). Comparing average orders to the mean demand of 10.5, we again found that average orders under O were significantly greater than mean demand (t(19) = 2.98, p = 0.007), average orders under C were significantly less than mean demand (t(18) = −3.14, p = 0.006), while average orders under S were not significantly different from mean demand (t(17) = 0.80, p = 0.436). Overall, Table 4 demonstrates ordering behavior remarkably similar to the results in Study 1, as seen in Table 3. A comparison of the contrast test results in the two tables does reveal a few differences.
Table 4: Mean and standard deviations of ordering quantities, and significance tests for differences between payment frames in Study 2. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

For instance, in Study 2 there are no significant differences in the order quantities in Round 1. Also, the overall significance of contrasts seem to be slightly less in Study 2 than in Study 1 for the average ordering quantities (two less contrasts are significant at the $p < 0.01$ level) and for the follow-up question (one less contrast is significant at the $p < 0.01$ level). As in Study 1, orders did not significantly change over time (Wilks’ Lambda = 0.472, $F(24, 31) = 1.44, p = 0.1672$).

We also found no significant interaction between payment frame and round (Wilks’ Lambda = 0.309, $F(48, 62) = 0.46, p = 0.4520$).

All participants correctly answered 3 and 18 for the minimum and maximum possible demand that could be generated by rolling three dice. Participant estimates of the long-run average demand with three dice revealed some variation, but were not significantly affected by condition ($F(2, 54) = 0.34, p = 0.714$). Their average estimates by condition were 10.35(0.96), 10.25(0.65), and 10.45(0.47) for $\bar{O}$, $\bar{S}$, and $\bar{C}$, respectively (standard deviations in parentheses). T-tests show that these estimates are not significantly different from 10.5 (For $\bar{O}$: $t(19) = -0.7, p = 0.494$; for $\bar{S}$: $t(17) = -1.64, p = 0.1197$; for $\bar{C}$: $t(18) = -0.49, p = 0.630$). The actual mean demands were 10.787, 10.679, and 10.670, under $\bar{O}$, $\bar{S}$, and $\bar{C}$, respectively.

For Study 2, we followed the same procedure to estimate the $\beta$ and $\alpha$ parameters as we did in Study 1. The maximum likelihood estimates and 95% confidence intervals are $\hat{\beta} = 0.698 (0.509, 0.887)$ and $\hat{\alpha} = 0.778 (0.643, 0.913)$.

The expected per-round profits in Study 2 also closely resembled the results from Study 1. Expected profits were significantly affected by payment frame ($F(2, 54) = 4.50, p = 0.016$). Average
expected profits by condition were $7.402(0.657), 7.824(0.262), and 7.735(0.341)$ for $\bar{O}$, $\bar{S}$, and $\bar{C}$ respectively. Contrast tests show that all differences between conditions are significant differences at the $p < 0.05$ level except between $\bar{S}$ and $\bar{C}$.

**Summary** Study 2 establishes that the payment scheme can have a significant effect on inventory decisions even if the schemes have no differences in the actual timing of payments, but only in the framing. This suggests that the framing of the payments is sufficient to induce differences in the mental accounting of individuals, even if the actual accounting of payments over time are identical across conditions. In other words, individuals mentally impute the order payment at the time of the order, even though it is not conducted until after the demand realization. In fact, we actually observed several participants who at the time of order physically set aside or held in-hand the order payment, even though the order payment was not to be conducted until after the demand realization.

### 4.3 Study 3: Payment Scheme Experiments with High and Low-Profit Products

#### 4.3.1 Experimental Design and Hypotheses

In Study 3, we implement two repeated newsvendor experiments to test the effect of payment schemes for products with two different profit margins. The high-profit condition is conducted for a product with parameters $c = \$1$, $p = \$4$, which implies an actual overage cost of $\$1$ and an actual underage cost of $\$3$. Under the expected-profit-maximizing model, this yields a critical fractile of $75\%$. The low-profit condition is conducted for a product with parameters $c = \$3$, $p = \$4$, which implies an actual overage cost of $\$3$ and actual underage cost of $\$1$. Under the expected-profit-maximizing model, this yields a critical fractile of $25\%$. Within each high- and low-profit condition, we again test payment schemes O, S and C. Since in practice payments are usually made when they are determined, we use the payment schemes in Study 1. One can substitute the appropriate values of $c$ and $p$ into Table 1 to obtain a description of the payment schemes for the high- and low-profit conditions. As in the previous studies, demand is determined by the sum of three standard dice rolled by the subject in each round.

For each payment scheme O, S, and C, the expected profit-maximizing solution is $13$ for the high-profit condition and $8$ for the low-profit condition. The pull-to-center effect predicts that individuals are biased towards the center of the distribution, $10.5$, causing actual orders to be
somewhere between 13 and 10.5 for the high-profit condition, and somewhere between 8 and 10.5 for the low-profit condition. Nevertheless, the pull-to-center effect still predicts no difference between the payment schemes. Thus, though Study 3 does not allow us to determine whether deviations from the expected-profit-maximizing solution are due to the pull-to-center effect or payment schemes, it provides a test of robustness of the inequality predictions in Table 2 across high- and low-profit products.

In the subsequent sections, we describe our experimental methods, present our results, and provide a discussion of the results for Study 3.

### 4.3.2 Methods

We recruited 130 undergraduate and graduate students from a major American university—70 for the high-profit experiment and 60 for the low-profit experiment. The payment scheme conditions were assigned sequentially to the participants within each experiment. In exchange for their participation, participants received a minimum of $5, with a bonus based on how much play cash they earned in the game. In the high-profit condition, participants earned a $1 bonus for every 100 play dollars they had at the end of the game (each participant began with 100 play dollars). In the low-profit condition, participants earned a $1 bonus for every 50 play dollars they had at the end of the game (each participant began with 150 play dollars). For Study 3, each participant played the game for 20 rounds. In all respects except for the payment scheme parameter changes and the reduced number of rounds, the experimental design and methods were the same as in Study 1.

### 4.3.3 Results

All 130 participants completed the study and were included in the analyses. The resulting average ordering decisions for each round are shown in Figure 2, and a summary of our findings can be found in Table 5.

**High-Profit Experiment** For the high-profit experiment, the repeated measures generalized linear model showed that payment scheme significantly affected ordering behavior ($F(2, 67) = 18.61, p < 0.0001$). We again found that average orders were highest under payment scheme O, and lowest under payment scheme C. Follow-up planned contrasts showed that some of the differences between conditions were significant, while others were not. Orders under O were not
Figure 2: Average order quantities of subjects in each round of play in Study 3 for (a) high-profit and (b) low-profit conditions under own financing (O), supplier financing (S), and customer financing (C).

significantly greater than orders under S ($F(1,67) = 3.34, p = 0.0719$). However, orders under S were significantly greater than orders under C ($F(1,67) = 16.80, p = 0.0001$), and orders under O were significantly greater than orders under C ($F(1,67) = 35.75, p < 0.0001$). Table 5 shows that this same pattern of significant differences appears to be present in the average order, round 1 order, and the follow-up question.

Though orders appear to be increasing over time in the high-profit condition, the effect was not significant (Wilks’ Lambda = 0.641, $F(19,49) = 1.44, p = 0.1502$). We also found no significant interaction between payment scheme and round (Wilks’ Lambda = 0.719, $F(38,98) = 0.46, p = 0.9957$). The actual mean demands were 10.787, 10.679, and 10.670, under O, S, and C, respectively.

**Low-Profit Experiment** For the low-profit experiment, the repeated measures generalized linear model showed that payment scheme significantly affected ordering behavior ($F(2,57) = 7.15, p = 0.0017$). We again found that average orders were highest under payment scheme O, and lowest under payment scheme C. However, the differences that were significant were not the same as in the high-profit experiment. Order quantities under O were significantly greater than orders under S ($F(1,57) = 9.22, p = 0.0036$) but orders under S were not significantly greater than orders under C ($F(1,57) = 0.19, p = 0.666$). Orders under O were significantly greater than orders
Table 5: Mean and standard deviations of ordering quantities, and significance tests for differences between payment schemes in Study 3. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

under C ($F(1, 57) = 12.04, p = 0.001$). Again, Table 5 shows that these significance patterns appear in average order, round 1 order, and the follow-up question. Though from Figure 2 it appears that orders were decreasing over time, the effect was not significant (Wilks’ Lambda $= 0.728, F(19, 39) = 0.77, p = 0.73$). We also found no significant interaction between payment scheme and round (Wilks’ Lambda $= 0.440, F(38, 78) = 1.04, p = 0.428$). The actual mean demands were 10.523, 10.570, and 10.690, under O, S, and C, respectively.

Summary Study 3 examines the effect of payment schemes for high- and low-profit products. We find that for both types of products, payment schemes significantly affects ordering decisions. Study 3 also provides a robustness check of the prospective accounting model. In support of the prospective accounting model, we find that in both high and low-profit experiments, orders trend from highest to lowest $q^O > q^S > q^C$. Nevertheless, not all of these differences are significant. Specifically, for the high-profit condition, we find significant support for $q^S > q^C$ and $q^O > q^C$ but not for $q^O > q^S$. On the other hand, for the low-profit condition, we find significant support for
$q^O > q^S$ and $q^O > q^C$ but not for $q^S > q^C$.

We offer the following explanation for this distortion. Because of the high/low profit margin parameters, the amount of order payment subject to underweighting under prospective accounting is different under schemes O, S, and C. Under the high-profit condition, the magnitudes of the order payments per unit under schemes O, S, and C are $1$, $0$, and $3$, respectively. Thus, prospective accounting has a much greater impact on payment scheme C compared to schemes O and S. This is consistent with our observations that differences between O and C and between S and C are significant, but the difference between O and S is not. Similarly, for the low-profit case, the order payments per unit are $3$, $0$, and $1$, under O, S, and C, respectively. Thus, prospective accounting has a much greater impact on payment scheme O compared to schemes S and C, leading to significant differences between O and C and between O and S, but not between S and C.

To further understand this phenomenon, we calculate the expected reward-maximizing order quantities based on the prospective accounting model using the estimated factors $\beta$ and $\alpha$ obtained from Study 1, and derived the predictions for the relationships between orders under different payment schemes. The results are shown in Table 6, along with the observed differences in order quantities in Study 3. From this table, we see that the prospective accounting model is consistent with the findings of Study 3 in terms of the relative differences between order sizes under O, S, and C.

<table>
<thead>
<tr>
<th>Payment Scheme Contrast</th>
<th>Predicted differences under Prospective Accounting model with $\beta = 0.678$, $\alpha = 0.8$</th>
<th>Average differences observed in Study 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Profit</td>
<td>Low Profit</td>
</tr>
<tr>
<td>$q^O - q^S$</td>
<td>0.833</td>
<td>1.932</td>
</tr>
<tr>
<td>$q^S - q^C$</td>
<td>1.246</td>
<td>0.494</td>
</tr>
</tbody>
</table>

Table 6: Contrasts between payment schemes in the average observed order quantities in Study 3 and the theoretical order quantities according to the prospective accounting model.

**Structural Parameter Estimates** In order to obtain an estimate for the parameters $\beta$ and $\alpha$ in the high- and low-profit experiments, we follow the same procedure as in Studies 1 and 2, but control for the pull-to-center effect by estimating our parameters from the differences between payment schemes. That is, by assuming the pull-to-center effect is independent with $\alpha$ and
\( \beta \), we can estimate \( \beta \) from \( q^O - q^S \) and \( \alpha \) from \( q^S - q^C \). The resulting maximum likelihood estimates and the 95% confidence intervals\(^3\) are as follows. High-profit condition: \( \hat{\beta} = 0.765 \) \( (0.673, 0.857) \) and \( \hat{\alpha} = 0.785 \) \( (0.748, 0.822) \). Low-profit condition: \( \hat{\beta} = 0.813 \) \( (0.766, 0.860) \) and \( \hat{\alpha} = 0.930 \) \( (0.824, 1.036) \).

**Expected Profits** For the high-profit experiment, expected profits were significantly affected by payment scheme \( (F(2, 67) = 11.98, p < 0.001) \). The expected profits were highest under payment scheme O. Average expected per-round profits by condition were 26.690(0.500), 26.552(0.679), and 25.567(1.222) for O, S, and C respectively. Contrast tests show that all differences between conditions are significant differences at the \( p < 0.05 \) level except between O and S. In other words, participants under O and S performed significantly better than those under C. For the low-profit experiment, expected profits were significantly affected by payment scheme \( (F(2, 57) = 6.30, p = 0.003) \). The average expected per-round profits were lowest under payment scheme O. Average expected profits by condition were 4.858(1.555), 5.881(0.743), and 5.847(0.496) for O, S, and C respectively. Contrast tests show that all differences between conditions are significant differences at the \( p < 0.05 \) level except between S and C. In other words, participants under C and S performed significantly better than those under O. The expected profit analysis above also demonstrates how the effect of payment scheme interacts with the pull-to-center effect and the resulting effectiveness of ordering behavior. For the high profit product, the pull-to-center effect is mitigated by the effect of payment scheme O, but exacerbated by the effect of payment scheme C. Conversely, for the low profit product, the pull-to-center effect is mitigated by the effect of payment scheme C, but exacerbated by the effect of payment scheme O.

**On the Asymmetry of the Pull-to-Center Effect** Schweitzer and Cachon (2000) and Bolton and Katok (2008) find that the pull-to-center effect is stronger, i.e., the deviation from the optimal order quantity towards the center of the demand distribution is larger, in the low-profit case. They suggest stockout aversion, or that the high profit case is more “intuitive” as possible explanations, but do not provide substantive evidence. The framing of the newsvendor problem in those papers is similar to the wholesale price contract (i.e., own-financing scheme). Thus, to examine this issue, we compare the level of deviation from the optimal order quantity under high- and low-profit

\(^3\)We employed the “standard bootstrapping method” (Chernick 1999) to estimate the standard errors of the estimators by the standard deviation of the MLE estimates from 2000 random samples (with replacement).
conditions for the three payment schemes.

As previous laboratory results have shown, we found that under payment scheme O, participants deviated farther from the optimal solution (toward the median demand) under the low-profit experiment compared to the high-profit experiment ($F(5, 124) = 13.70, p = .0003$). Average orders under the low-profit experiment were 2.478 above the optimal order 8, but average orders under the high-profit experiment were only 1.179 below the optimal 13. However, under payment scheme S, participants deviated approximately the same distance from the optimal solution in both the high- and low-profit experiments, and the deviations were not significantly different ($F(5, 124) = 1.70, p = .194$). Average orders under the low-profit experiment were 1.305 above the optimal order 8, and average orders under the high-profit experiment were 1.767 below the optimal 13. Finally, under payment scheme C, participants deviated farther from the optimal solution (toward the median demand) under the high-profit experiment compared to the low-profit experiment ($F(5, 124) = 30.70, p < .0001$). Average orders under the high-profit experiment were 3.100 below the optimal 13, but average orders under the low-profit experiment were only 1.138 above the optimal order 8.

Hence, how the wholesale price contract (own-financing) is perceived by subjects using prospective accounting provides an explanation for the asymmetry of the pull-to-center effect between high- and low-profit conditions. The effect is not present with supplier-financing and is reversed with customer-financing, as our prospective accounting model predicts.

5 Discussion

Summary In this paper, we find that payment schemes have a significant behavioral effect on ordering decisions in the newsvendor problem. Our findings help us gain insights into how human subjects account for payments in the newsvendor problem. We provide evidence that order-time payments receive less weight than demand payments, which is consistent with prospective accounting. Study 1 shows that ordering behavior is well modeled by a prospective accounting model and that orders may be higher, lower, or equal to the expected profit maximizing solution depending on the payment scheme. Interestingly, we find that orders under own-financing, which is the same as a typical wholesale price contract, induces an order above the expected profit maximizing solution.
(which was set at mean demand). Study 2 demonstrates the framing of the payments is sufficient to induce differences in ordering behavior, even if the actual timing of payments are the same across payment schemes. Finally, Study 3 shows the effect of payment schemes is robust for high- and low-profit products. Study 3 also shows that the differences between the payment schemes can explain the pull-to-center effect’s asymmetry across profit conditions which has been reported by Schweitzer and Cachon (2000) and Bolton and Katok (2008).

**Alternative Interpretations:** In this paper, we propose a prospective accounting interpretation of our results because there are similarities between the newsvendor’s experience of procuring and selling inventory and a consumer’s experience of payment and consumption. However, our results are not entirely inconsistent (and are related to) other behavioral interpretations. Schweitzer and Cachon (2000) apply the idea of “recency” to obtain a “chasing demand” heuristic, in which individuals use their previous order quantity as an anchor and adjusts towards the previous demand realization. Instead, one can apply the same idea of recency to obtain a heuristic in which individuals also anchor on their previous order quantity and adjust by putting a greater weight on the most recent payment feedback (the payments after demand realization). This would also yield behavior similar to if the decision maker underweights the order payments, and is similar to what Gourville and Soman (1998) call “payment depreciation.” (Payment depreciation is essentially the second half of the prospective accounting rule that states that events are weakly coupled looking backwards in time.) However, such an adjustment heuristic does not explain why we find differences in ordering behavior between payment schemes in the first round of order decisions in our experiments. Another behavioral effect that is relevant to our setting is “debt aversion.” Because the newsvendor is in debt to the supplier in the supplier-financing case, debt aversion would predict larger orders under own-financing than supplier-financing. However, it does not explain why own-financing leads to orders larger than the expected-profit maximizing solution in Study 1. Furthermore, Prelec and Loewenstein (1998) suggest that “prospective accounting induces strong debt aversion,” which implies that debt aversion is a result of mental accounting rather than a behavioral effect on its own. Study 2 demonstrates that indeed our effect is not solely driven by the actual financial position of the individual over time, but how the individual mentally processes the payments over time. Lastly, our results are not entirely inconsistent with being selectively loss averse only for the demand-time payments, but not for the order-time payments. Individuals
may be loss averse only for the demand-time payments because these payments are partially determined by the uncertain realization of demand. However, such selective loss aversion alone does not explain why individuals tend to order more than the expected profit-maximizing quantity under own-financing in Study 1.

Managerial Implications: The behavioral effect of payment schemes on newsvendor orders has direct implications on the newsvendor’s expected profit, the supplier’s revenue, and the customer’s service level. Therefore, from the newsvendor’s standpoint, one should select the appropriate payment scheme strategically to encourage a weighting of payments that achieves an optimal order. In our experiments, payment scheme S, which conducts all payments at the time of demand, encourages equal weighting of all payments and achieves the optimal order when the overage and underage costs are equal. However, payment schemes can also be used to mitigate other behavioral biases. For example, for the pull-to-center effect, the payment scheme that would lead to order quantities closest to the optimal solution is the own-financing payment scheme under high-profit conditions and the customer-financing scheme under low-profit conditions. Furthermore, Study 2 demonstrates that even if the actual payment contract does not have a timing of the payments that induces an optimal ordering decision, one can simply rewrite the payment scheme in the framing of the problem for the decision maker in such a way that encourages optimal behavior. On the other hand, the supplier and the customer would like to choose a payment scheme which induces the highest order, which interestingly for our experiments is the wholesale price scheme (payment scheme O). In addition to practitioners, our results may inform future newsvendor experiments, as individuals weigh the payments correctly only under the supplier-financing payment scheme or payment frame.

Our results also help us gain insight on the behavioral effect of financial contracts in practice. For instance, suppliers often offer retailers trade credit, allowing retailers to delay payment for goods until they make the sale, hoping that this will encourage higher orders. This intended effect of trade credit is captured by the time-discounted rewards model in Section 3.3. When capital constraint is not an issue and the interest rate is negligible, the practice of trade credit (corresponding to the supplier financing scheme) might inadvertently lower the retailer’s order quantity relative to that without trade credit (corresponding to the own-financing scheme) as shown by our experiments. When the interest rate is significant or the capital constraint is binding, however, the prospective
accounting effect may be dominated. Similarly, though we show that providing the newsvendor advanced revenues may decrease the inventory order, such a behavioral effect may be dominated by the discount factor due to the risk-premium and/or time value of money. Therefore, in general, one should carefully evaluate these effects before proposing financing terms to their supply chain partners.

Another application is in supply chain contract design and coordination (see Cachon and Lariviere 2005 for a review). A wholesale-price contract typically has payment transactions resembling the own-financing scheme in this paper. Our results suggest that the retailer may place larger-than-optimal orders due to prospective accounting, reducing some of the supply chain inefficiency due to wholesale-price contracts (Lariviere and Porteus 2001). If the supplier can estimate the retailer’s underweighting factor $\beta$ as we did in Section 4, then she may coordinate the supply chain by setting the wholesale price equal to the unit production cost divided by the underweighting factor. Under a buy-back contract, the retailer receives a refund for leftover inventory upon demand realization. To the retailer, the refund payment is likely to be weighted more than the purchase cost incurred earlier at the order time. Thus, the supplier may exploit this effect to achieve supply chain coordination by offering a smaller buy-back price for leftover inventory. For a similar reason, under a revenue-sharing contract, with prospective accounting, the supplier may be able to charge a higher wholesale price to the retailer and still achieve supply chain coordination. It would be interesting to empirically investigate these potential implications. However, we acknowledge that there could be many other factors at work simultaneously in real-world contract settings, so isolating the mental accounting effect of payment schemes may present a non-trivial challenge.

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References


**Appendix A: Extensions to utility-maximizing order quantities based on the rewards**

**Proposition 5** Let \( U(\cdot) \) be a utility function based on the net profit. If the decision maker is payment-scheme neutral, then the expected utility-maximizing quantities under the three payment
schemes are identical, i.e., \( Q^O = Q^S = Q^C \).

**Proof:** Let \( \pi^i(q, D) \) denote the net profit under payment scheme \( i \). The optimal order quantity that maximizes the expected utility is \( q^i = \arg\max_\pi \mathbb{E}_D[U(\pi^i(q, D))] \). For any given utility function \( U(\cdot) \) based on the net profit, we have \( U(\pi^O(q, D)) = U(\pi^S(q, D)) = U(\pi^C(q, D)) \). Thus, the result follows. □

**Proposition 6** Let \( U(\cdot) \) be a continuous and increasing utility function based on the rewards. With time-discounted rewards, the expected-utility-maximizing quantities under the three payment schemes have the following order: \( Q^O < Q^S < Q^C \).

**Proof:** Define \( 1(q < D) \) as the binary indicator function. By rewriting \( R^S(q, D) = \delta[-c q + p \min(q, D)] \), we see that \( \partial R^S(q, D)/\partial q = -\delta c + \delta p 1(q < D) > -c - \delta p 1(q < D) = \partial R^O(q, D)/\partial q \) for any \( D \). We can also rewrite \( R^S(q, D) = \delta[(p - c)q - p \max(q - D, 0)] \), so that \( \partial R^S(q, D)/\partial q = \delta (p - c) - \delta p 1(q \geq D) < (p - c) - \delta p 1(q \geq D) = \partial R^C(q)/\partial q \). Thus, the derivatives follow the order of \( \partial R^O(q, D)/\partial q < \partial R^S(q, D)/\partial q < \partial R^C(q)/\partial q \) for any value of \( D \). To compute the optimal solution of \( q^i = \arg\max_\pi \mathbb{E}_D[U(R^i(q, D))] \), we need to derive first-order conditions. Because the reward functions have bounded derivatives, they satisfy the Lipschitz condition of order one. This means that we can exchange expectation and derivatives to get the first order conditions (see Glasserman 1994). As a result, one can show that the first derivatives of the expected utility functions under the three schemes follow the increasing order O, S, and C. Thus, we have \( Q^O < Q^S < Q^C \) for the expected-utility-maximizing quantities. □

**Proposition 7** Let \( U(\cdot) \) be a continuous and increasing utility function based on the rewards. With prospective accounting, the expected-utility-maximizing quantities under the three payment schemes have the following order: \( Q^O > Q^S > Q^C \).

**Proof:** The proof is similar to that of Proposition 6. □

**Appendix B: Comparison to Prelec and Loewenstein (1998) Prospective Accounting Model**

Prelec and Loewenstein (1998) model prospective accounting for a consumer through a “double-entry” model of mental accounting. In the context of the newsvendor problem, the “double-entry”
feature of their model suggests that the newsvendor imputes payments twice: once from the vantage point of the order and once from the vantage point of the demand realization. Their model is quite sophisticated—including loss aversion, time-discounting, and the idea of coupling. Here, we focus on the coupling feature. In the newsvendor context, “coupling” qualifies the prospective accounting rule by allowing only partial appreciation of payments looking forward. Thus, we add a coupling term \( b, 0 \leq b \leq 1 \) to denote how strongly an outgoing payment at the time of order is “buffered” by the thought of future incoming payments. Similarly, we add a coupling term \( a, 0 \leq a \leq 1 \) to denote how strongly an incoming payment at the time of order is “attenuated” by the thought of future outgoing payments. The resulting rewards are:

\[
R_i(q, D) = \begin{cases} 
-cq + bp \min(q, D) + p \min(q, D) & \text{if } i = O, \\
2[\langle p-c \rangle \min(q, D) - c \max(q - D, 0)] & \text{if } i = S, \\
(p - c)q - ap \max(q - D, 0) - p \max(q - D, 0) & \text{if } i = C.
\end{cases}
\]

The above formulation also results in the prediction \( q^O > q^S > q^C \). However, for simplicity, our prospective accounting model uses a simpler formulation that merely underweights the order-time payments. Under O, the cost is “buffered,” so we use the notation \( \beta < 1 \). Under C, the revenue is “attenuated,” so we use the notation \( \alpha < 1 \).

**Appendix C: Experiment Instructions to Participants**

We present excerpts from the instructions of Studies 1 and 2. Participants in each treatment group are provided with the description of the relevant payment scheme only. Study 3 instructions are the same as Study 1 except for the values of the price and cost parameters and the reduced number of rounds.

**Study 1 Instructions**

In this simplified game, you own a business that makes money by selling widgets for 25 simulated days. At the beginning of each simulated day you decide how many widgets to have available for sale in your store that day.

\{(O) At this time you pay $1 per unit and place the units in your store. Then roll the 3 dice to determine demand for that day. Sell as many units in your store that you can (the minimum of
demand and units in your store) and receive $2 per unit that you sell.

\{(S)\} Your supplier sends you these units and you place them in your store. Then roll the 3 dice to determine demand for that day. Sell as many units in your store that you can (the minimum of demand and units in your store). You receive $1 profit per unit that you sell, but you must pay a penalty of $1 for each leftover unit.

\{(C)\} At this time you actually receive $1 per unit that you place your store (advanced payment.) Then roll the 3 dice to determine demand for that day. Sell as many units in your store that you can (the minimum of demand and units in your store). You receive $0 for each unit that you sell, but you must pay a penalty of $2 for each extra unit you have leftover.

Then discard all leftover units from your store and start empty for the beginning of the next day. Your goal is to maximize your play cash by the end of the 25 days.

**Study 2 Instructions**

In this simplified game, you own a business that makes money by selling widgets (represented by poker chips) for 25 simulated days. At the beginning of each simulated day you need to decide how many widgets to order to have available for sale in your store that day. Place the units ordered in your store. Then roll the 3 dice to determine demand for that day. Sell as many units in your store that you can (the minimum of demand and units in your store). Then discard all leftover units from your store and start empty for the beginning of the next day.

\{(\bar{O})\} At the end of each day, you settle payments for that day. You pay $1 per unit that you ordered and you receive $2 per unit that you sold.

\{(\bar{S})\} At the end of each day, you settle payments for that day. You pay $1 per unit that is leftover and you receive $1 per unit that you sold.

\{(\bar{C})\} At the end of each day, you settle payments for that day. You receive $1 per unit that you ordered, but you pay $2 per unit that is leftover.

Your goal is to maximize your play cash by the end of the 25 days.