The (non)Effect of Power on Biased Newsvendor Order Behavior

Sebastián Villa
E-mail: villabes@usi.ch
University of Lugano, Switzerland

Jaime Andrés Castañeda
MIT Center for Transportation and Logistics

Paulo Gonçalves
University of Lugano, Switzerland

ABSTRACT
We extend behavioral research in newsvendor settings by experimentally exploring the effect of power on newsvendor order decisions under two profit conditions. We also analyze people's risk profiles and explore if the expo-power utility function, which relaxes the assumption of constant absolute risk aversion, explains observed behavior.

Keywords: Experiments, Expo-Power Utility Function, Loss Aversion, Newsvendor, Risk Attitude.

INTRODUCTION

The Newsvendor problem characterizes situations where a procurement order, production order, or an inventory plan must be made by a manager before a realization of unknown demand occurs (Käki et al., 2013). Both leftovers and shortages are costly: if the manager orders too much, she will have to salvage leftovers or dispose them at a loss, whereas if she orders too little, she will forgo additional profits (Eeckhoudt et al., 1995). This classic single-period inventory problem dates back to Edgeworth's (1888) bank reserve problem and Arrow et al.'s (1951) inventory control policies under demand uncertainty and has been extended to more complex inventory systems (Choi, 2012) and other operations contexts such as advance booking of orders in service industries (Weatherford and Pfeifer, 1994), operating room management (Olivares et al., 2008), and resource allocation and scope decisions in new product development (Gonçalves et al., 2013), among others.

A behavioral approach studying how people place Newsvendor orders is more recent, dating back to Schweitzer and Cachon's (2000) seminal Newsvendor laboratory (lab) experiment. Despite the simple structure of the Newsvendor problem, experimental studies have frequently shown that people systematically deviate from the expected profit-maximizing quantity (e.g., Bolton and Katok, 2008; Bostian et al., 2008; Schweitzer and Cachon, 2000). In particular, these studies have shown that people's inventory orders are lower than the optimum in high-profit or low-cost Newsvendor systems and higher than the optimum in low-profit or high-cost Newsvendor systems. This biased order behavior is known as the pull-to-center effect (Bostian et al., 2008). Despite the pervasiveness of the bias, there is no clarity on what actually drives pull-to-center effect behavior as suggested by the different modeling approaches proposed to explain it such as ex post inventory error minimization (Schweitzer and Cachon, 2000), overconfidence (Croson et al., 2011, cited in Ren and Croson, 2013), random errors (Su, 2008), and reference dependence (Ho et al., 2010), among others.

Choice theory may provide insights into what drives typical Newsvendor order behavior. According to this theory, decisions and biases are also result of how people assign value to decision outcomes (Bernoulli, 1738/1954). Building on this idea, there is research studying how power could change the anticipated value of gains and losses, claiming that power holders might become less loss averse and/or more risk seeking, even when power can do nothing to affect the experience of future gains and losses (see Inesi (2010) and references therein). Assuming a link between loss aversion and risk preferences and the pull-to-center effect (Schweitzer and Cachon, 2000), we first manipulate power through episodic priming (Galinsky et al., 2003) to arguably reduce loss aversion and/or increase risk-seeking behavior in order to influence typical Newsvendor order behavior. In an additional contribution of our work, we then use the expo-power utility function (Saha, 1993) to explain observed behavior. This utility function is able to capture decreasing, neutral, and increasing risk attitudes, leveraging the potential to explain biased Newsvendor order behavior (Eeckhoudt et al., 1995).

LITERATURE REVIEW

A behavioral approach to the Newsvendor problem is fairly recent, dating back to Schweitzer and Cachon's (2000) seminal Newsvendor experiment. They run a lab experiment with both high and low profit margin products, observing that *"Subjects consistently ordered amounts lower than the expected profit-maximizing quantity for high-profit products and higher than the expected profit-maximizing quantity for low-profit products"* (p. 418). This systematic Newsvendor result is known as the *pull-to-center effect* (Bostian et al., 2008). Schweitzer and Cachon (2000) also showed that this biased order behavior cannot be completely explained by risk aversion, risk-seeking preferences, loss aversion, waste aversion, stockout aversion, and underestimation of opportunity costs. They also considered prospect theory (Kahneman and Tversky, 1979), observing that it was inadequate since in a gains-only domain, where pull-to-center effect behavior is rule out by design, subjects' order behavior was again consistent with this bias.

Given the pervasiveness of the pull-to-center effect (e.g., Bolton and Katok, 2008; de Véricourt et al., 2013; Kremer et al., 2010) and its adverse effects in terms of economic performance, subsequent lab experiments have explored alternative explanations. For instance, Bostian et al. (2008) explored a model of adaptive learning behavior, Ho et al. (2010) explored a reference dependence model that includes asymmetric psychological costs of leftovers and shortages, and Chen et al. (2013) explored a prospective accounting model that includes underweighting of either outgoing or incoming payments, among others. Although incremental improvements have been made, "*A full explanation for the Newsvendor behavior is proving to be elusive" and "It is likely that there is no single explanation*" (Katok, 2010, p. 39).

Although the inventory control literature is extensive, no much work has been done to determine what psychological factors are likely to influence typical biased Newsvendor behavior. By exploring learning, reference dependence, and mental accounting, the above lab experiments provide some exceptions. We take a similar approach and explore an arguably more ubiquitous psychological factor, namely, power. More specifically, we examine how a sense of power affects pull-to-center effect behavior.

Different scholars have revealed how power often operates non-consciously and identified different methods and paradigms used to activate or create a psychological sense of power outside of conscious awareness (Smith and Galinsky, 2010). In addition, recent findings suggest that power may affect decision making. For instance, power has been linked to increased action-orientation (Galinsky et al., 2003), more variable and less normative behavior (Galinsky et al., 2008), risk-seeking behavior (Anderson and Galinsky, 2006), and reduced loss aversion (Inesi, 2010).

In the Newsvendor framework, a loss-averse decision maker order less than the profit-maximizing quantity (Schweitzer and Cachon, 2000). Thus, loss aversion could explain pull-to-center effect behavior in high-profit settings. According to Inesi (2010), power reduces loss aversion. Taken together, we would expect a high sense of power to reduce pull-to-center effect behavior in high-profit settings via a reduction in loss aversion. Hence:

H1: *In a high-profit Newsvendor setting, the higher the power felt by a subject, the larger the order quantity placed by her compared to low and no power feelings.*

Loss aversion cannot account for pull-to-center effect behavior in low-profit settings since such biased behavior corresponds to orders above the profit-maximizing quantity. However, risk-seeking preferences can. In the Newsvendor framework, a risk-seeking decision maker orders more than the profit-maximizing quantity (Schweitzer and Cachon, 2000). According to Anderson and Galinsky (2006), power induces more risk-seeking behavior. Taken together, we would expect a high sense of power to increase pull-to-center effect behavior in low-profit settings via an increase in risk-seeking behavior. Hence:

H2: *In a low-profit Newsvendor setting, the higher the power felt by a subject, the larger the order quantity placed by her compared to low and no power feelings.*

We propose how power may affect typical Newsvendor order behavior via influences in loss aversion and/or risk attitudes. There is some research that already analyzes analytically how loss aversion and/or risk attitudes affect Newsvendor behavior. For instance, Schweitzer and Cachon (2000) show that both loss and risk aversion should lead to smaller order quantities than Newsvendor optima, whereas risk seeking attitudes should lead to larger order quantities. In addition, they also show that optima may change contingent on loss aversion and/or risk aversion and risk seeking attitudes.
Also, Keren and Pliskin (2006) show that risk aversion attitudes in a setting with high demand variability can both increase and decrease the optimal order quantity.
In order to avoid making assumptions about risk preferences, Holt and Laury (2002), motivated by Saha (1993), highlighted the expo-power utility function as an alternative to explain subjects' risk preferences. This utility function permits the type of increasing (or decreasing) relative risk aversion and avoids the arguably absurd prediction of constant absolute risk aversion characteristic of other utility functions such as the exponential (Holt and Laury, 2002). To the best of our knowledge, this expo-power utility function has not been tested yet as an alternative explanation of the previously described newsvendor biases. Given the flexibility offered by the expo-power utility function.

H3. *The expo-power utility function is able to explain newsvendor biases.*

EXPERIMENT

We run a Newsvendor lab experiment in which individuals first complete a power mindset task and then make a one-shot inventory order decision for a general item. More specifically, we create a 2x3 full factorial between-subjects design. The factors are Profit condition and Power condition. Individuals thus make inventory order decisions under three power conditions: high (HP), low (LP) and no-power (NP), each in two profit conditions: high (HN) and low-profit (LN).

Power conditions

When individuals are activated with the construct of power, whether via actual experience in a powerful or powerless role or by mere exposure to past experiences related to power or powerlessness, the feelings and behavioral tendencies associated with power will also be activated (Bargh and Álvarez, 2001; Smith and Galinsky, 2010) and these individuals will behave similarly to individuals who actually possess power (Carney et al., 2010; Smith et al., 2008).
We manipulate power following a mindset or episodic priming task, which has been established as an effective means of activating the desired power mindset (Fast et al., 2009; Gruenfeld et al., 2008; Inesi, 2010). For example, individuals in the high-power condition were assigned to:

"Please recall a particular incident in which you had power over another individual or individuals. By power, we mean a situation in which you controlled the ability of another person or persons to get something they wanted, or were in a position to evaluate those individuals. Please describe the situation in which you had power: events, feelings, thoughts, etc"

Profit conditions

Individuals have to choose an order quantity **q** of a general item, which arrives before the start of a single selling period. They know in advance that demand **D** follows an uniform distribution D ~ U[1, 100] with

integer values. They are told that they can buy each unit from a supplier at a cost **c** (40 or 80 $/item) and can sell each unit at a price **p** (100 $/item) > c. They are also told that any leftovers are salvaged at a price **s** (20 $/item) < c each unit. Finally, they are also reminded that they will forgo p – c profits for each unit short of demand. This parameterization is consistent with related Newsvendor lab experiments (e.g., Bolton and Katok, 2008; Schweitzer and Cachon, 2000).
It is well-known that the optimal inventory order quantity is a base-stock policy characterized by the critical fractile:

$$F(q^*) = \frac{p - c}{p - s} \tag{1}$$

where **F** is D's cdf and $\mathbf{q^*}$ the optimal inventory order quantity. The above parameterization implies optimal inventory order quantities q^*_{HN} = *75* and q^*_{LN} = *25* items for high and low-profit conditions, respectively.

PRELIMINARY RESULTS

Power manipulation check

We first check the effectiveness of the power manipulation by performing a content analysis on the episodic tasks done by participants. We used two coders with no relation with the project. Coders were highly coherent in their ratings and had a high level of agreement about the effectiveness of the power manipulation.

Newsvendor results

In Table 1, results in the high-profit condition (HN) are consistent with typical biased Newsvendor order behavior in all power manipulations. In particular, only one of the confidence intervals around average inventory order quantities contains the optimal inventory order quantity (NP). In addition, none of the confidence intervals includes the average demand. Although the high-power condition seems to lead to larger order quantities, the effect is not significant, providing no support for **H1**.

Table 1. Optimal and average participants' Newsvendor decisions.[*]

			Power condition		
		$\mathbf{q^*}$	**HP**	**LP**	**NP**
Profit condition	**HN**	75	68.24 (3.38) [61.6 74.8]	65.81 (3.31) [59.3 72.2]	67.67 (4.36) [59.1 76.2]
	LN	25	57.96 (4.23) [49.6 66.2]	65.65 (3.98) [57.8 73.4]	64.33 (5.24) [54.0 74.6]

[*] Standard errors in parentheses; confidence intervals in brackets.

On the other hand, results in the low-profit condition (LN) show a more pronounced underperformance in all power manipulations. In particular, besides the confidence intervals not containing the optimal inventory order quantity, two of them are above the average demand (LP and NP). This is consistent with an asymmetry in the pull-to-center effect observed in other Newsvendor experiments (e.g., Bolton and Katok, 2008; Schweitzer and Cachon, 2000). Contrary to our expectations, the high-power condition seems to lead to smaller (and better) order quantities. However, the effect is not significant, providing no support neither for a reverse effect nor for **H2**.

Expo-power utility function analyses

To estimate risk attitudes and assess the importance of risk preferences, we followed the approach used by Holt and Laury (2002) and Harrison et al. (2007) characterizing an hybrid expo-power utility function (Saha, 1993), which permits the type of increasing/decreasing relative risk aversion, but avoids the predictions of constant absolute risk aversion. Motivated by the prospect theory (Kahneman and Tversky 1979) and the previous work done by (Xie, 2000), the expo-power utility function can be re-defined as:

$$U(w_{ij}) = \begin{cases} \frac{1-\exp(-\alpha * w_{ij}^{1-r})}{\alpha} & ,if\ w_{ij} \geq 0 \\ -\lambda \frac{1-\exp(-\alpha * (-w_{ij})^{1-r})}{\alpha} & ,if\ w_{ij} < 0 \end{cases} \quad \forall i,j \in [1,100] \qquad (2)$$

Where r, λ, and α are parameters to be estimated and w_{ij} is the possible outcome when a subject place an order of i units and the realized demand is j.

If we assume that expected utility theory holds for these choices over risky alternatives, the likelihood function for the choices that subjects make can be written for each possible order decision *i* as:

$$E[U_i] = \sum_{j=1}^{100} \left(p(w_{ij}) * U(w_{ij})\right), \ \forall i \in [1,100] \qquad (3)$$

To determine conditional likelihoods on the model, the Luce stochastic specification could be implemented. The expected utility ($E[U_i(w)]$) for each possible order decision is calculated by:

$$\nabla EU_i = \frac{E[U_i]^{1/\mu}}{\sum_{k=1}^{100} E[U_i]^{1/\mu}} \ ,\forall i \in [1,100] \qquad (4)$$

Where μ is the noise that reflects actual decision-making errors or unknown heterogeneity. The conditional log-likelihood can then be written as:

$$L(\propto, r, \mu, \lambda; i, w) = \ln \sum (ln(\nabla EU_i) | decision = i) \qquad (5)$$

Where decision = i represents the order decision in the newsvendor problem. This conditional log-likelihood function could be estimated for each treatment using maximum likelihood. Once the parameters $\propto, r$ and μ are determined, the expo-power utility function is completely characterized and we would be able to compute the optimal inventory prepositioning behavior based on their risk preferences, as follows:

$$q_U^* = \min_q \sum_{D=0}^{q-1} U\left((c-s)f(D)(q-D)\right) + \sum_{D=q}^{Dmax} U\left((p-c)f(D)(D-q)\right) \qquad (6)$$

We obtained q_U^* of 68 units for the high profit condition and 38 units for the low profit condition. These values reflect the well know pull-to-center effect and the higher perceived underperformance in low-profit conditions. We have shown that the common underperformance (pull-to-center) in a Newsvendor problem can be explained by subjects' specific believes and risk preferences that were accounted for an expo-power utility function, providing thus support for **H3**.

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