Title

Entrepreneurs and Newsvendors: Do Small Businesses Follow the Newsvendor Logic When Making Inventory Decisions?

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Entrepreneurs and newsvendors: do small businesses follow the newsvendor logic when making inventory decisions?

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Abstract

This work empirically assesses the degree to which inventory decisions made by entrepreneurs and small businesses are informed by the logic underlying the newsvendor or base stock model and are influenced by the decision-maker's risk profile. We used a web- and email-based survey, combined with a telephone follow-up to elicit risk profiles, obtaining 51 usable responses. Our findings suggest that entrepreneurs do follow the newsvendor logic, but more so for high-margin than for best-selling products. We find that entrepreneurs' risk profiles are consistent with a key prediction from prospect theory, displaying risk aversion for profits and risk-seeking behavior for losses. Furthermore, we find that risk aversion for profits is associated with higher safety stocks, in contradiction to existing theory, and discuss several possible explanations for this finding.

Keywords: entrepreneurs, inventory, newsvendor, empirical, risk, prospect theory.

1. Introduction

The newsvendor model and the base stock policy are key components of the theory of inventory control. Despite that, it is not well-known how individuals make inventory-related decisions in real life. Often, the information needed to apply the newsvendor model or base stock policy is not available: the costs of over- and understock are often not well-defined, and the demand distribution is not known. How do individuals make inventory decisions under such circumstances? This challenge is even more acute for entrepreneurs and small businesses, who are less likely to have the historical data, information systems, and managerial sophistication the newsvendor model or base stock policy require.

In this paper we report on a survey of how entrepreneurs and small businesses make inventory decisions. Entrepreneurs and small businesses are a particularly interesting population for an empirical study like this, as there is usually only one single person who makes all inventory-related decisions, and quite often that same person also makes decisions related to sales, marketing, finance, etc. In small businesses, the incentive distortions that arise in large companies due to decentralization of decision-making occur less or not at all. Moreover, inventory is one of several common causes of problems in small businesses, especially in retailing (Wu and Young 2002).

Even less well-understood is the effect of risk preferences on inventory decisions. Existing theory shows that more risk-averse newsvendors should order less, but we are not aware of empirical work on this link, beyond a small number of experimental studies. Entrepreneurs and small businesses are again a good context to study this effect, as the consequences of incorrect inventory decisions are felt more immediately by the decision-makers themselves than is the case in large firms.

In this paper, we report on a survey of 51 entrepreneurs and small businesses, in which we ask them about their (perceived) costs of over- and understock, about their inventory policy, and about their risk profile. We find that the respondents do follow the logic of the newsvendor model, at least for their highest-margin product: their perceptions of the consequences of over- or understock have the predicted effects on their inventory decisions. Profit margins and markdowns have no effect on their inventory decisions. The respondents' risk preferences display the asymmetry around current wealth predicted by prospect theory. However, more risk averse respondents hold higher safety stocks, contrary to existing theory. Our findings provide an intriguing starting-point for further research. We use the term "newsvendor model" as shorthand to include the base stock policy, and we use the terms entrepreneur and small business interchangeably, rather than attempt an arbitrary distinction between them.

In Section 2, we review related literature on empirical studies on inventory control and on entrepreneurial decision-making and risk preferences. In Section 3 we formulate our hypotheses, and describe the data in more detail in Section 4. We present our results in Section 5, and discuss our findings, some alternative explanations and limitations in Section 6. Section 7 offers our final conclusions and suggestions for future research.

2. Literature

We first review experimental and empirical work on inventory control, then that on entrepreneurial decision-making and risk preferences. Schweitzer and Cachon (2000) construct theoretical models for newsvendor decision-making under a range of utility functions, and then conduct two sets of experiments with 34 and 44 MBA students respectively. The first set finds a "too-low/too-high" pattern: when the optimal order quantity would be above the mean forecast demand, participants order less than optimal, and vice versa. This is consistent with several theoretical perspectives, including prospect theory. The second set of experiments shifts the range of possible demand outcomes upwards, and the results are no longer consistent with prospect theory. The authors conclude that respondents systematically deviate from profit-maximizing behavior but that no single theoretical adjustment can account for these deviations. Barlas and Özevin (2004) also find that no existing inventory model can explain the behavior in their experiments. The newsvendor experiments by Kremer et al. (2007) find that regret theory also does not explain the participants' ordering behavior. Using experiments and interviews, Brown and Tang (2006) find that decision makers can order less than the newsvendor solution due to the performance metrics in place to evaluate them. Croson and Donohue's (2002, 2003) experiments on the "beer game" focus on whether exchanging point-of-sale information or other mechanisms can reduce the bullwhip effect. Wu and Katok (2006) find that training alone, without communication between the supply chain partners, does not improve system performance.

Empirical studies of inventory at the aggregate level have focused mostly on the theory on production smoothing; see Cachon et al. (2006) and the references therein. More recently, using Compustat data, Roumiantsev and Netessine (2005) find that aggregate inventories at publicly traded firms vary in ways that mostly conform to predictions from the EOQ and newsvendor models. We are not aware of studies that have directly asked individual decision-makers about how they make their inventory decisions.

Several studies establish theoretical predictions for how risk preferences should affect inventory behavior. Eeckhoudt et al. (1995) show that a more risk-averse newsvendor should order less. Dionne and Mounsif (1996) and Ibarra-Salazar (2005) examine types of change in risk under which risk-neutral and risk-averse newsvendors will order less. Parlar and Weng (2003) propose modeling risk by letting the decision-maker specify the probability with which he will exceed a moving target profit level.

Bouakiz and Sobel (1992) show that a base-stock policy is still optimal under an exponential (risk-averse) utility function. Chen et al. (2006) study various multiperiod inventory models with exogenous and endogenous prices, and find that the structure of the optimal policy under an exponential utility function is closely related to that for the risk-neutral inventory and pricing policies. In a small numerical experiment, they find that the optimal policy is not very sensitive to the degree of risk aversion. Archibald et al. (2002) assume that the objective of a start-up firm is to maximize the probability of long-term survival, and show, using Markov decision processes, that with finite cash reserves, start-ups should be more cautious than profit-maximizing firms. Su (2007) proposes an interesting framework to model bounded rationality and applies it to (among others) the newsvendor model, and provides experimental evidence that supports the presence of bounded rationality. The optimal production, sales and financing policy in Babich and Sobel (2004) describes when a risk-neutral or risk-averse start-up should conduct an initial public offering. We contribute to this literature by empirically assessing whether entrepreneurs follow the newsvendor logic and how their risk preferences affect their inventory decisions.

It is not unambiguous whether entrepreneurs and small business owners differ, with respect to risk-taking behavior, from other managers. Kihlstrom and Laffont (1979) show in an economic model that less risk-averse individuals become entrepreneurs, and other studies empirically confirm that. Cramer et al. (2002) and Hartog et al. (2002) find that entrepreneurs are more risk-seeking, and Brown et al. (2006) find that more risk-seeking individuals tend to have more risky employment contracts, where self-employment is the most risky. Stewart et al. (1998) find that entrepreneurs and small business owners are more risk-seeking than other managers, but also that overall small business owners are more like managers than like entrepreneurs. By contrast, Halek and Eisenhauer (2001) and Miner and Raju (2004) find that entrepreneurs are more risk-averse than others.

Recognizing that risk-taking behavior has multiple aspects, Busenitz and Barney (1997) and Busenitz (1999) find that entrepreneurs tend to be more overconfident and more likely to generalize from smaller samples. Keh et al. (2002) document how entrepreneurs' risk perception is affected by similar cognitive biases. Norton and Moore (2006) also find that entrepreneurs perceive risk differently, but that they are not different from others in risk propensity. Mullins and Forlani (2005) suggest that one needs to decouple the magnitude of losses and gains from the likelihoods, in studying how risk perceptions and risk propensities affect decision-making. Wu and Knott (2006) find empirical evidence, based on an equilibrium model, that, in making entry decisions, entrepreneurs are risk-averse with respect to demand uncertainty but overconfident about their abilities. We contribute to this literature by measuring risk preferences for profits and losses separately, and linking those risk preferences to inventory decision-making behavior; we find that most of our respondents are risk-averse for profits and risk-seeking for losses, as prospect theory predicts (Kahneman and Tversky 1979), and that they view investments in inventory as potential profits rather than losses, consistent with being (over)confident about their ability to sell excess inventory.

3. Hypotheses

We are interested in three interrelated issues: how do entrepreneurs perceive risk, how do they make inventory decisions, and how does their risk profile affect the way they make inventory decisions? Our hypothesis related to risk profile draws on prospect theory, a key element of which (Kahneman and Tversky 1979, p. 279) is that "the value function is (i) defined on deviations from the reference point; (ii) generally concave for gains and convex for losses; (iii) steeper for losses than for gains." To determine whether entrepreneurs perceive inventories as potential losses or potential profits, we focus on the second element. To assess the validity of our risk preference data, we first test whether the entrepreneurs conform to that prediction:

> Hypothesis 1: entrepreneurs are risk-averse for profits and risk-seeking for losses.

The newsvendor model relies on two cost parameters: the costs of overstock and understock. These are generally understood to be broadly defined; for instance, the costs of overstock can include markdowns, capital tied up in inventory, storage space, insurance, etc, while the costs of understock can include opportunity costs or backorder costs as well as loss of future business. Markdowns and opportunity costs are often the main focus, as in for instance the Sport Obermeyer case (Hammond and Raman 1994). Recognizing that the full costs of over- and understock are more inclusive than this, one can nevertheless hypothesize that entrepreneurs consider markdowns and profit margins in inventory decisions:

> Hypothesis 2a: higher profit margins are associated with higher safety stocks.
>
> Hypothesis 2b: higher costs of markdowns are associated with lower safety stocks.

The full "costs of overstock" and "costs of understock" are very difficult to quantify, let alone for small firms without sophisticated information systems. However, they presumably have some beliefs about how serious it would be to have excess inventory or to face stockouts. With these broader but more subjective measures, we hypothesize:

> Hypothesis 3a: the more serious a decision-maker perceives the consequences of understock to be, the higher the safety stock s/he will hold.

Hypothesis 3b: the more serious a decision-maker perceives the consequences of overstock to be, the lower the safety stock s/he will hold.

The classical treatment of risk aversion in inventory decisions is Eeckhoudt et al. (1995), though they cite several earlier sources that examine special cases of the newsvendor model under risk aversion. Eeckhoudt et al. (1995, p. 788) show that a more risk-averse newsvendor will hold lower safety stocks, as this is a concave transformation of the utility function (Pratt 1964). This leads to our final hypothesis:

Hypothesis 4: higher degrees of risk-aversion are positively associated with lower safety stocks.

4. Data

The trade-offs between the precision and control obtainable with experimental data and the presumed closeness to actual practice of field data are well-known. As there are already several experimental studies in this area, we opted to collect data on inventory decisions from actual entrepreneurs, despite several inevitable limitations. First, the sample is limited, though with 51 usable responses for a single product and 35 for two products, it is similar to the 34 and 44 subjects in Schweitzer and Cachon's (2000) experiments. Second, the measures are in the form of self-reported answers to 7-point Likert scales, rather than directly observed inventory levels, costs, demand distributions, etc., as there is no known way to collect quantitative information on such variables that can be compared across different contexts.

We collected data in two rounds: first a survey, via the internet and on paper, which was followed by a telephone call to elicit risk profiles. The survey was tested in a small pilot among local entrepreneurs, which led us to modify some questions.

The survey consisted of a few demographic questions about the company, then a series of questions about inventory policy and related factors, first for the company's highest-margin product, then for its best-selling product. If the company only had one product, or if the highest-margin and best-selling product were the same, the second series of questions was left blank. The key questions used in this analysis are shown in the Appendix. To encourage participants to consider each response carefully, the endpoints of the scales are determined using a short quote, and the direction of the scales varies, so the right-hand endpoint does not always correspond to the "highest" value. All variables were later rescaled where needed prior to the analysis, to facilitate interpretation and reporting.

The questions on risk preferences, shown in the Appendix, are based on the discussion in Clemen (1991, pp. 375-381) and on conversations with experts in decision analysis. The feedback from the pilot led us to conduct the risk profile elicitation by telephone, as the questions were fairly easy to explain interactively but difficult to write in a way that was both concise and general, while preserving the desired respondent-specific framing.

We were not able to identify a database of potential participants that fit our profile, so we followed an incremental approach instead. Several research assistants recruited subjects for the survey, which we estimated took about 15-20 minutes to complete, in addition to the 5-minute telephone follow-up. We did not offer any compensation to the respondents. Lack of time was the main reason individuals cited for not participating, and any compensation we could offer was unlikely to change that.

To invite respondents, we sent an email to various alumni mailing lists. The research assistants also visited some local small businesses in Los Angeles, and used their personal networks of entrepreneurs. The text we used to let potential respondents decide if they fit our profile was: “We are looking for entrepreneurs or individuals who manage small businesses with less than 30 employees, where inventory is an important part of day-to-day business. This could include retailers, distributors, import/export firms, traders, or light manufacturing and assembly operations.” After the initial emails to alumni lists, we targeted individual respondents using the mechanisms above, with the aim of reaching 50 usable responses. The data-gathering took place between May 2003 and February 2006, by which time we had received 62 responses, of which 51 provided sufficient information about one product, and 35 about two different products, both in addition to providing information about risk preferences. The 11 observations we dropped either did not respond to some of the key questions of our analysis, or were suspect, for instance answering “1” to every question. The remaining respondents cover a wide range of types of business, including food products, books, fashion accessories, sportswear, apparel, building supplies, electronics, household items, industrial supplies, and others. The response rate is not well-defined with this approach, as we did not have a predefined population from which to draw.

Descriptive statistics for the final sample are shown in Table 1, with correlations in Tables 2a and 2b. Statistics are provided first for the full sample (with answers for at least one product), and then for those respondents that gave answers for both their high-margin and best-selling product separately. The descriptive statistics are almost identical for the two sets, so there is no apparent bias associated with whether respondents have one or more products.

TABLES 1, 2a AND 2b ABOUT HERE

5. Methods and results

Our first hypothesis is that, in line with prospect theory, entrepreneurs are risk-averse for profits and risk-seeking for losses (H1). Table 3 shows frequency distributions for the full sample and for the subset of two-product responses. (The variables in Table 3 have been rescaled so that higher values mean higher risk aversion.) Although one could perform nonparametric tests to assess H1, simply looking at the data shows that the overwhelming majority of respondents are risk-averse with respect to profits (category 5 through 8), with 92% and 97% respectively for the two datasets. Similarly, 70% and 83% respectively are risk-seeking (category 1 through 4) with respect to losses. The degree to which the respondents' risk preferences correspond to those predicted by prospect theory and subsequently found elsewhere provides some reassurance about our risk preference data.

The remaining hypotheses all concern respondents' inventory decision-making. In its most general form, the model to be estimated is:

$$\text{inventory}_{ip} = \alpha_{ip} + \boldsymbol{\beta}_p \mathbf{X}_i + \boldsymbol{\eta}_p \mathbf{Y}_{ip} + \varepsilon_{ip}$$

where i is the index for the respondent, $p \in \{\text{HM}, \text{BS}\}$ is the index for the two types of product, $\mathbf{X}_i$ the matrix of company-specific factors that do not depend on the product (risk preferences for profits and for losses), $\mathbf{Y}_{ip}$ the matrix of company- and product-specific factors (such as perceived consequences of over- and understock), ε_{ip} the error term, and α_{ip}, $\boldsymbol{\beta}_p$, and $\boldsymbol{\eta}_p$ the parameters to be estimated. Depending on what assumptions we make about ε_{ip}, α_{ip}, $\boldsymbol{\beta}_p$, and $\boldsymbol{\eta}_p$, different estimation methods are appropriate. We include the degree to which demand is perceived to be predictable as an explanatory variable, both separately and its interaction with a variable that proxies for the critical ratio (more on which below). All estimates reported here are directional rather than accurate given that our dependent variable is measured on a 7-point scale.

Our first approach assumes that the ε_{ip} are independent for all *i* and *p*, and that $\alpha_{ip} = \alpha_p$. This corresponds to assuming there is a single law describing how all respondents set their inventory policy for their HM product, and a possibly different law for their BS product, and that each respondent's inventory policy for their HM and BS product are independent. For this case, we can use OLS for the HM and BS responses separately. We report three sets of results: one for all HM responses, one for all BS responses, and one for the subset of responses with two different products. The all-HM sample refers to the 35 complete responses that include answers for both HM and BS products plus the 16 who only gave responses for one product. Similarly, the all-BS sample refers to the 35 complete responses that include answers for both products, plus the 16 who only gave responses for one product; we are assuming that for those 16 respondents, the HM and BS product are indeed the same. The results reported in Table 4 use OLS output from PROC SYSLIN in SAS 9.1.

TABLE 4 ABOUT HERE

Table 4 leads to several observations, most of which recur with the other estimation methods. First, the perceptions of the seriousness of understock and overstock are highly significant, in the direction expected, in explaining inventory policy for HM products. The magnitude of the parameter estimates (0.64 vs. -0.67 for the all-HM sample, or 0.67 vs. -0.73 for the two-product firms) are almost symmetric, meaning that a 1-point increase in the seriousness of understock has the same effect on inventory policy (on a 7-point scale) as a 1-point decrease in the seriousness of overstock. This is consistent with Schweitzer and Cachon's (2000) finding that participants appeared to minimize ex-post inventory error, as that would mean attaching equal weight to units of overstock and understock[1]; note again though that our parameter estimates are directional rather than precise. The overall model fit is far lower for the BS product and no variables are significant at the 10% level.

Second, profit margin and costs of markdown are virtually never significant. Together with the previous observation, this implies that, at least for HM products, the respondents do trade off the consequences of under- and overstock in the way prescribed by the newsvendor model, but that these consequences are far more complex than just lost profit margin and costs of markdown. This is not a consequence of multicollinearity: when only the profit margin and cost of markdowns are included, they are still not significant.

Third, more predictable demand is associated with significantly higher safety stock for HM products. This would be consistent with the newsvendor model if, for instance, demand were normally distributed and the critical ratio were less than 0.5. However, in our data, the consequences of understock are on average more severe than those of overstock. To further investigate this interaction effect, we defined a "critical fractile" based on the seriousness of understock and overstock respectively, i.e., $\alpha = \frac{\text{seriousness of understock}}{\text{seriousness of understock} + \text{seriousness of overstock}}$. This measure should display directionally similar behavior to the actual (but unobservable) critical fractile. The interaction between α and predictability is highly significant and negative, meaning that the positive association between predictability and safety stock becomes lower as the critical fractile increases. This is as expected.

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[1] Thanks to Reynold Byers of UC Irvine for pointing this out.

Finally, the effect of risk aversion is surprising. For the BS product, both types of risk preferences are insignificant, but for the HM product, we find that higher risk aversion for profits is associated with higher safety stocks, contrary to Eeckhoudt et al. (1995). This effect is significant at the 5% level, and robust to different model specifications. Before interpreting these findings in more detail, we report on the results obtained with the other estimation procedures.

In the second approach, we still assume the ε_{ip} are independent for all *i* but we now allow $\varepsilon_{i,\mathrm{HM}}$ and $\varepsilon_{i,\mathrm{B}S}$ to be correlated. As before, $\alpha_{ip} = \alpha_p$. This corresponds to assuming that a single law describes how all respondents set their inventory policy for their HM product, with a possibly different law for the BS product, and that the error a respondent makes in setting his or her inventory policy is correlated across the HM and the BS products. In this case, seemingly unrelated regression (SUR) is appropriate. Table 5 reports estimates for the 35 responses for which the two products are different. We see that the effects of perceptions, uncertainty, risk aversion, and the interaction between alpha and uncertainty, remain largely the same.

TABLE 5 ABOUT HERE

The third approach uses the panel structure in the data, where the cross sections are the respondents and the longitudinal dimension is the two observations per respondent. Because we are not interested in the behavior of specific respondents, but in that of the sample at large, and because the sample is a random subset of a much larger population, a random effects formulation is appropriate (Hsiao 1993). Therefore, we let $\alpha_{ip} = \alpha_p + \nu_i$ where ν_i is a respondent-specific random error term. We do allow different slopes for the HM and BS products, i.e., we do not require $\boldsymbol{\beta}_p = \boldsymbol{\beta}$ or $\boldsymbol{\eta}_p = \boldsymbol{\eta}$. The findings, in Table 6, are largely consistent with those from before. We conclude that the main results are robust across these different specifications.

TABLE 6 ABOUT HERE

6. Discussion, alternative explanations, and limitations of the study

Here we return to our original hypotheses, discuss our three main findings, and point to several possible alternative explanations. With respect to our first hypothesis, we find that the respondents are risk-averse for profits and risk-seeking for losses, consistent with prospect theory and supporting H1.

With respect to our second and third hypotheses, we observe that the narrow definition of costs of under- and overstock (profit margins and markdowns respectively) have no effect on inventory policy, so H2a and H2b are rejected. On the other hand, the respondents' perceptions of how serious understock and overstock are do have strong effects on inventory policies for their high-margin products, but not for their best-selling products, meaning that H3a and H3b are partially supported. One could speculate that a more instinctive decision-making mode is used for the frequent decisions needed for a best-selling product while a more analytical mode is used for the less frequent decisions needed for a highest-margin product. Schultz et al. (2007) found, in an experimental setting, that respondents behaved precisely in accordance with predictions from prospect theory for simple questions, but when confronted with a more complex (make-or-buy) decision, that was no longer the case. Schultz et al. speculate that the respondents, unable to use rational analysis for their decision, fell back on a more instinctive approach, which led to different behavior. Dijksterhuis et al. (2006) also suggest that unconscious thought processes are more common and more desirable for complex decisions. However, we can also not rule out the possibility that the quality of our BS product data is poorer than that of the HM data, as the corresponding questions came last in the survey instrument.

With respect to our fourth hypothesis, for high-margin products, more risk aversion for profits is associated with higher safety stocks, contrary to the theoretical prediction in Eeckhoudt et al. (1995). We offer several speculative explanations for this contradiction. First, the Eeckhoudt et al. result is for a one-period model, whereas our respondents typically face multi-period horizons. The effect of risk aversion on a base stock policy is not known. The presence of future gambles can induce risk-seeking behavior in risk-averse individuals (Gollier 1996, McCardle and Winkler 1992). We cannot rule out the possibility that it is sometimes optimal in a multi-period context for safety stocks to increase with risk aversion.

Another explanation could be that entrepreneurs have a limited amount of cash, which they can invest in inventory or in other ways, for instance in new product development, marketing campaigns, etc. If those other types of investment have more uncertain payoffs than inventory, a more risk-averse entrepreneur would invest more in inventory. This would be particularly true if entrepreneurs are optimistic about their ability to sell the goods, in line with the evidence cited earlier (Busenitz and Barney 1997 and Busenitz 1999) about entrepreneurs tending to be overconfident, and with Paul Hawken's (1987) justification for over-ordering on the basis that excess inventory can always be sold at cost.

A third explanation might be that more risk-averse entrepreneurs start companies in high-margin industries that need higher safety stock, in which case the correlation would be spurious. To fully investigate this one would need to use structural equation modeling, which requires a substantially larger sample than we have here (Shah and Goldstein 2006). Formulating a structural equation model and using PROC CALIS in SAS does give largely similar results as reported here, except that the parameter estimates for the BS product are now also significant (though still less so than for the HM product) and in the direction expected; the perceived consequences depend weakly or not at all on risk preferences. Our sample is far too small for SEQ modeling to provide good estimates, but at least this preliminary analysis does not point to endogeneity as an obvious factor driving our results.

A fourth possibility is that respondents' inventory decisions are influenced by risk preferences over small gains and losses, and that these differ from the risk preferences over the large gains and losses that we elicited. Rabin (2000) shows how individuals must be approximately risk neutral over modest stakes in order to have non-extreme risk preferences over large stakes. However, even if the scale of our risk measures is not appropriate for inventory decisions, we would not expect the reverse result we find here.

An interesting and robust observation is that only risk aversion for profits is linked to inventory policy, and not risk aversion for losses. This would suggest that the respondents treat investments in inventory as potential profits, not as potential losses; that is consistent with their documented tendency to be overconfident, in this case about their ability to sell whatever inventory they have. Based on this, inventory models for small businesses should perhaps always be formulated as profit maximization models.

Finally, we need to emphasize some inherent limitations of this study. Our data are collected on 7-point scales, so the error terms cannot follow a normal distribution, as required for the estimation methods we use. Therefore, our results are approximate and directional, not precise estimates of the magnitudes of the effects or significance levels. Another limitation is the opportunistic composition and small size of our sample. While we believe this is justified for an initial study like ours, a follow-up study, designed specifically to confirm or reject our observations, should be based on a larger sample, perhaps stratified into a limited number of industries to allow examining and controlling for industry effects.

7. Conclusions

We find initial evidence that entrepreneurs and small businesses make inventory decisions that are partly consistent with the newsvendor model. For their highest-margin products, their safety stocks do vary in line with their perceived consequences of over- and understock, but not for their best-selling products. The profit margin and costs of markdowns are not associated with safety stocks. The respondents' risk profiles are largely consistent with a basic prediction from prospect theory: they are risk-averse for profits and risk-seeking for losses. However, the interaction between risk aversion and safety stock is the opposite of that predicted by theory: more risk averse respondents hold higher safety stocks. We have discussed various possible alternative explanations and pointed out several limitations of this study, which we hope will stimulate further work aimed at refuting or validating these findings.

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complete responses (N)	HM and BS are same or different products 51				HM and BS are different products 35			
	mean	st.dev.	min.	max.	mean	st.dev.	min.	max.
number of employees	16.07	12.91	1.00	57.00	16.44	13.14	1.00	57.00
risk aversion for profits	7.04	1.18	4.00	8.00	7.20	0.93	4.00	8.00
risk aversion for losses	3.12	1.96	1.00	8.00	2.77	1.63	1.00	7.00
HM:								
inventory policy	4.98	1.74	1.00	7.00	4.71	1.79	1.00	7.00
understock serious	3.94	1.96	1.00	7.00	3.63	2.04	1.00	7.00
overstock serious	2.78	1.93	1.00	7.00	2.77	1.93	1.00	7.00
profit margin	4.63	1.96	1.00	7.00	4.69	1.98	1.00	7.00
cost of overstock	3.47	2.18	1.00	7.00	3.57	2.30	1.00	7.00
predictability	4.14	1.65	1.00	7.00	3.89	1.55	1.00	7.00
alpha	0.59	0.20	0.13	0.88	0.57	0.21	0.13	0.88
BS:								
inventory policy	5.22	1.74	1.00	7.00	5.06	1.83	1.00	7.00
understock serious	4.47	1.80	1.00	7.00	4.40	1.90	1.00	7.00
overstock serious	2.76	1.67	1.00	7.00	2.74	1.52	1.00	5.00
profit margin	3.92	1.98	1.00	7.00	3.66	1.95	1.00	7.00
cost of overstock	3.37	2.10	1.00	7.00	3.43	2.20	1.00	7.00
predictability	4.33	1.51	1.00	7.00	4.17	1.38	1.00	7.00
alpha	0.62	0.17	0.17	0.88	0.61	0.17	0.17	0.86

Table 1: Descriptive statistics

Note: all variables have been rescaled from the original questions shown in the Appendix, where needed, to ensure that higher scores correspond to higher values.

N=51				HM							BS						
		risk aversion for profits	risk aversion for losses	inventory policy	understock serious	overstock serious	profit margin	cost of overstock	predictability	alpha	inventory policy	understock serious	overstock serious	profit margin	cost of overstock	predictability	alpha
	risk aversion for profits	1.00	-0.28	0.35	-0.03	-0.31	0.39	0.04	0.07	0.27	0.39	0.10	-0.20	0.21	-0.02	0.20	0.28
	risk aversion for losses	-0.28	1.00	-0.05	-0.01	0.08	-0.07	0.18	0.16	0.00	0.04	-0.09	-0.11	0.04	0.10	0.27	0.14
HM	inventory policy	0.35	-0.05	1.00	0.27	-0.54	0.36	0.08	0.49	0.56	0.57	0.09	-0.30	0.55	0.00	0.35	0.33
	understock serious	-0.03	-0.01	0.27	1.00	0.04	-0.03	0.29	0.04	0.60	0.11	0.79	0.19	0.19	0.12	-0.10	0.43
	overstock serious	-0.31	0.08	-0.54	0.04	1.00	-0.42	0.24	-0.46	-0.73	-0.22	0.09	0.54	-0.57	0.19	-0.40	-0.34
	profit margin	0.39	-0.07	0.36	-0.03	-0.42	1.00	-0.04	0.22	0.30	0.34	-0.05	-0.48	0.77	-0.09	0.26	0.35
	cost of overstock	0.04	0.18	0.08	0.29	0.24	-0.04	1.00	-0.27	0.06	0.13	0.25	0.13	-0.05	0.58	-0.11	0.15
	predictability	0.07	0.16	0.49	0.04	-0.46	0.22	-0.27	1.00	0.37	0.21	-0.12	-0.29	0.36	-0.04	0.74	0.15
	alpha	0.27	0.00	0.56	0.60	-0.73	0.30	0.06	0.37	1.00	0.23	0.41	-0.28	0.55	0.00	0.27	0.56
BS	inventory policy	0.39	0.04	0.57	0.11	-0.22	0.34	0.13	0.21	0.23	1.00	0.22	-0.40	0.24	0.16	0.33	0.55
	understock serious	0.10	-0.09	0.09	0.79	0.09	-0.05	0.25	-0.12	0.41	0.22	1.00	0.19	0.03	0.11	-0.07	0.57
	overstock serious	-0.20	-0.11	-0.30	0.19	0.54	-0.48	0.13	-0.29	-0.28	-0.40	0.19	1.00	-0.44	0.05	-0.29	-0.62
	profit margin	0.21	0.04	0.55	0.19	-0.57	0.77	-0.05	0.36	0.55	0.24	0.03	-0.44	1.00	-0.05	0.27	0.35
	cost of overstock	-0.02	0.10	0.00	0.12	0.19	-0.09	0.58	-0.04	0.00	0.16	0.11	0.05	-0.05	1.00	-0.10	0.11
	predictability	0.20	0.27	0.35	-0.10	-0.40	0.26	-0.11	0.74	0.27	0.33	-0.07	-0.29	0.27	-0.10	1.00	0.23
	alpha	0.28	0.14	0.33	0.43	-0.34	0.35	0.15	0.15	0.56	0.55	0.57	-0.62	0.35	0.11	0.23	1.00

Table 2a: Spearman correlations where HM and BS are same or different products

N=35				HM							BS						
		risk aversion for profits	risk aversion for losses	inventory policy	understock serious	overstock serious	profit margin	cost of overstock	predictability	alpha	inventory policy	understock serious	overstock serious	profit margin	cost of overstock	predictability	alpha
	risk aversion for profits	1.00	-0.16	0.33	0.02	-0.23	0.37	0.10	0.18	0.24	0.34	0.10	-0.05	0.13	0.02	0.38	0.24
	risk aversion for losses	-0.16	1.00	0.02	-0.10	0.06	-0.07	0.20	0.15	-0.06	0.24	-0.11	-0.33	0.00	0.05	0.35	0.29
HM	inventory policy	0.33	0.02	1.00	0.37	-0.57	0.42	0.14	0.54	0.62	0.38	0.18	-0.15	0.65	0.02	0.31	0.29
	understock serious	0.02	-0.10	0.37	1.00	-0.03	-0.16	0.40	0.09	0.65	0.17	0.77	0.23	0.08	0.15	-0.10	0.41
	overstock serious	-0.23	0.06	-0.57	-0.03	1.00	-0.38	0.23	-0.47	-0.75	-0.08	0.07	0.30	-0.62	0.16	-0.33	-0.12
	profit margin	0.37	-0.07	0.42	-0.16	-0.38	1.00	-0.02	0.20	0.16	0.39	-0.21	-0.46	0.69	-0.08	0.27	0.22
	cost of overstock	0.10	0.20	0.14	0.40	0.23	-0.02	1.00	-0.24	0.12	0.20	0.31	0.06	0.02	0.44	-0.02	0.27
	predictability	0.18	0.15	0.54	0.09	-0.47	0.20	-0.24	1.00	0.38	0.13	-0.03	-0.15	0.38	0.10	0.56	0.08
	alpha	0.24	-0.06	0.62	0.65	-0.75	0.16	0.12	0.38	1.00	0.16	0.41	-0.06	0.50	0.05	0.22	0.34
BS	inventory policy	0.34	0.24	0.38	0.17	-0.08	0.39	0.20	0.13	0.16	1.00	0.37	-0.32	0.22	0.24	0.30	0.63
	understock serious	0.10	-0.11	0.18	0.77	0.07	-0.21	0.31	-0.03	0.41	0.37	1.00	0.21	-0.10	0.15	0.02	0.60
	overstock serious	-0.05	-0.33	-0.15	0.23	0.30	-0.46	0.06	-0.15	-0.06	-0.32	0.21	1.00	-0.36	-0.04	-0.13	-0.56
	profit margin	0.13	0.00	0.65	0.08	-0.62	0.69	0.02	0.38	0.50	0.22	-0.10	-0.36	1.00	0.03	0.24	0.18
	cost of overstock	0.02	0.05	0.02	0.15	0.16	-0.08	0.44	0.10	0.05	0.24	0.15	-0.04	0.03	1.00	-0.01	0.24
	predictability	0.38	0.35	0.31	-0.10	-0.33	0.27	-0.02	0.56	0.22	0.30	0.02	-0.13	0.24	-0.01	1.00	0.19
	alpha	0.24	0.29	0.29	0.41	-0.12	0.22	0.27	0.08	0.34	0.63	0.60	-0.56	0.18	0.24	0.19	1.00

Table 2b: Spearman correlations where HM and BS are different products

Note: all variables have been rescaled from the original questions shown in the Appendix, where needed, to ensure that higher scores correspond to higher values.

	HM and BS are same or different products		HM and BS are different products	
complete responses (N)	51		35	
risk category for profits	number of responses	% of total	number of responses	% of total
1 (most risk-seeking)	0	0%	0	0%
2	0	0%	0	0%
3	0	0%	0	0%
4	4	8%	1	3%
5	1	2%	0	0%
6	7	14%	6	17%
7	16	31%	12	34%
8 (most risk-averse)	23	45%	16	46%
total:	**51**	100%	**35**	100%
risk category for losses	number of responses	% of total	number of responses	% of total
1 (most risk-seeking)	15	29%	10	29%
2	8	16%	7	20%
3	8	16%	8	23%
4	5	10%	4	11%
5	11	22%	4	11%
6	1	2%	1	3%
7	1	2%	1	3%
8 (most risk-averse)	2	4%	0	0%
total:	**51**	100%	**35**	100%

Table 3: frequency distributions for risk categories

Note: these variables have been rescaled from the original question shown in the Appendix to ensure that higher values correspond to higher degrees of risk aversion.

	full sample						two-product subsample					
	all HM			all BS			HM, different from BS			BS, different from HM		
	parameter estimate	t-value	p-value	parameter estimate	t-value	p-value	parameter estimate	t-value	p-value	parameter estimate	t-value	p-value
intercept	-0.33	-0.21	0.83	0.75	0.41	0.68	-1.87	-1.04	0.31	-0.78	-0.32	0.75
risk aversion for profits	0.40	2.52	0.02	0.27	1.40	0.17	0.55	2.48	0.02	0.42	1.24	0.23
risk aversion for losses	0.02	0.21	0.83	0.02	0.21	0.84	0.12	0.89	0.38	0.25	1.29	0.21
understock serious	0.64	3.92	0.00	0.44	1.66	0.10	0.67	3.68	0.00	0.34	1.10	0.28
overstock serious	-0.67	-4.06	0.00	-0.36	-1.17	0.25	-0.73	-4.31	0.00	-0.10	-0.24	0.81
profit margin	0.09	0.94	0.35	0.02	0.13	0.90	0.21	1.91	0.07	0.11	0.71	0.48
cost of overstock	0.05	0.57	0.57	0.11	1.13	0.27	0.02	0.23	0.82	0.12	0.97	0.34
predictability	1.11	3.64	0.00	0.37	0.74	0.47	1.05	3.37	0.00	-0.24	-0.36	0.72
alpha * predictability	-1.34	-2.72	0.01	-0.20	-0.25	0.80	-1.39	-2.70	0.01	0.43	0.43	0.67
	N	51		N	51		N	35		N	35	
	R-sq.	0.63		R-sq.	0.39		R-sq.	0.74		R-sq.	0.49	
	adj. R-sq.	0.56		adj. R-sq.	0.28		adj. R-sq.	0.66		adj. R-sq.	0.34	

Table 4: OLS regression estimates for various subsets of the data

	HM			BS		
	parameter estimate	t-value	p-value	parameter estimate	t-value	p-value
intercept	-1.60	-0.89	0.38	-0.64	-0.26	0.80
risk aversion for profits	0.53	2.41	0.02	0.40	1.19	0.24
risk aversion for losses	0.10	0.75	0.46	0.23	1.19	0.24
understock serious	0.63	3.47	0.00	0.42	1.39	0.18
overstock serious	-0.70	-4.19	0.00	-0.23	-0.58	0.57
profit margin	0.18	1.64	0.11	0.08	0.54	0.59
cost of overstock	0.04	0.43	0.67	0.12	1.00	0.33
predictability	0.98	3.18	0.00	-0.06	-0.09	0.93
alpha * predictability	-1.25	-2.45	0.02	0.18	0.18	0.86

N (number of observations for both products): 35
system weighted R-sq: 0.66

Table 5: Seemingly Unrelated Regression estimates

	HM			BS		
	parameter estimate	t-value	p-value	parameter estimate	t-value	p-value
product (HM=0, BS=1)	-0.33	-0.16	0.87		(same)	
risk aversion for profits	0.39	2.48	0.02	0.36	1.26	0.21
risk aversion for losses	0.04	0.24	0.81	0.22	1.28	0.21
understock serious	0.50	2.54	0.01	0.46	1.76	0.08
overstock serious	-0.64	-3.19	0.00	-0.28	-0.84	0.40
profit margin	0.10	0.82	0.42	0.07	0.51	0.62
cost of overstock	0.09	0.79	0.43	0.13	1.25	0.22
predictability	0.78	2.28	0.03	0.02	0.04	0.97
alpha * predictability	-0.87	-1.54	0.13	0.08	0.09	0.93

number of cross sections N: 35
observations per cross section: 2
R-sq: 0.94

Table 6: Random Effects estimates

Appendix: survey questions

Below are those questions from the survey that were used in the analysis reported here. These questions were repeated for the company's best-selling product.

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8. *Please describe your highest margin product.*

14. *How would you characterize your inventory policy for this* **(highest-margin)** *product, on the 7-point scale below?*

"Extremely aggressive, I always make sure that I never run out of stock for this product."

↓						
1	2	3	4	5	6	7
						↑

"Extremely conservative, I never order or make a product without having received a complete cash payment from my customer covering the order."

15. *Suppose you invest the amount from question 13 in inventory of this* **(highest-margin)** *product, and you are unable to sell any of it. What percentage of your investment do you lose?*

"Nothing; I can always return the product to the manufacturer or supplier or some other party and receive a full refund."

↓						
1	2	3	4	5	6	7
0-19%	20-39%	40-59%	60-79%	80-99%	100-119%	more than 120%
						↑

"Everything I invested and more, due to the costs of storage, insurance, etc."

16. *Suppose you invest the amount from question 13 in inventory of this* **(highest-margin)** *product, and you sell it all before you would usually place your next order. How much* <u>*profit*</u> *would you earn on your investment?*

"If I invested $10,000 in this product, I would receive between $10,000 and $11,900 in sales revenues, for a profit margin of 0-19%"

↓						
1	2	3	4	5	6	7
0-19%	20-39%	40-69%	70-99%	100-149%	150-200%	more than 200%
						↑

"If I invested $10,000 in this product, I would receive at least $30,000 in sales revenues."

17. *How serious would it be if you held too much inventory of this* **(highest-margin)** *product, with the result that you still have product left in inventory by the time you can no longer sell it?*

"Extremely serious; if this happens I would be out of business immediately."

↓

1	2	3	4	5	6	7

↑

"No problem at all; I can always sell this product at a price that covers my cost or better."

18. *How serious would it be if you held too little inventory of this* **(highest-margin)** *product, i.e., if you run out of the product before your next order arrives or is completed?*

"Extremely serious; if this happens my customers will go to a competitor and I will go out of business."

↓

1	2	3	4	5	6	7

↑

"No problem at all; my customers will wait until the product becomes available, they will pay the same price, they will be just as happy, and continue to buy from me."

19. *Suppose you know that the demand for this* **(highest-margin)** *product, between now and the time when your next order arrives or is completed, lies between a minimum of 1 unit and a maximum of 10 X units (X is the amount you sold during the past period). How would you characterize the demand uncertainty for this product over this coming horizon?*

"Extremely uncertain: it could equally well be any number between 1 and 10*X*, I have absolutely no idea what the actual demand will be."

↓

1	2	3	4	5	6	7

↑

"Extremely predictable: I know exactly, down to the last unit, what my demand will be."

The risk preferences were elicited in a short telephone interview, based on the following protocol, which is based on the discussion in Clemen (1991) and which was refined after conversations with several decision analysis experts.

What is the current value of your company? (A rough estimate is sufficient; eg, is it $100K, $1M, $5M, $10M, etc.) Let this be V.

Now, we would like to present you with two business investments with uncertain payouts, and ask you how much you would be willing to pay for these opportunities.

The first opportunity will give you a payout of $V with 50% probability, and a payout of $0 with 50% probability. We would like to know how much you would be willing to pay for this opportunity.

Would you pay V/2 for this opportunity?
- If "yes": Would you pay 3V/4 for this opportunity?
  - If "Yes": Would you pay 7V/8 for this opportunity?
  - If "No": Would you pay 5V/8 for this opportunity?
- If "no": would you pay V/4 for this opportunity?
  - If "yes": would you pay 3V/8 for this opportunity?
  - If "no": would you pay V/8 for this opportunity?

Record the answers to each of these questions; we can then categorize the respondents in 8 intervals.

Now for the second scenario. Due to factors beyond your control, your company is faced with the possibility of losing $V/2 with probability 50%, or losing $0 with probability 50%. We would like to know how much you would be willing to pay to avoid this loss.

Would you pay V/4 to avoid this loss?
- If "yes": would you pay 3V/8 to avoid this loss?
  - If "yes": would you pay 7V/16 to avoid this loss?
  - If "no": would you pay 5V/16 to avoid this loss?
- If "no": would you pay V/8 to avoid this loss?
  - If "yes": would you pay 3V/16 to avoid this loss?
  - If "no": would you pay V/16 to avoid this loss?

Record the answers to each of these questions; we can then categorize the respondents in 8 intervals.