ARTICLE IN PRESS

Journal of Purchasing & Supply Management ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Purchasing & Supply Management

journal homepage: www.elsevier.com/locate/pursup

Measuring overconfidence in inventory management decisions

A. Ancarani [a,*], Carmela Di Mauro [a], Diego D'Urso [b]

[a] Dipartimento di Ingegneria Civile e Architettura, Università di Catania, Viale A. Doria, 6, Catania, Italy
[b] Dipartimento di Ingegneria Industriale, Università di Catania, Viale A. Doria, 6, Catania, Italy

ARTICLE INFO

Article history:
Received 2 February 2016
Received in revised form
3 May 2016
Accepted 3 May 2016

Keywords:
Supply chain
Beer game
Inventory management
Risk management
Overconfidence

ABSTRACT

Overconfidence has emerged as a significant explanation of behaviour in diverse managerial settings. In this paper, we explore the relevance of overconfidence for supply chain management by running a series of human experiments within the framework of the classic Beer Game. Unlike previous experimental studies, participants were knowledgeable about supply chain management, either being graduate students in Operations Management or purchasing professionals. Results of the study support the view that overconfidence may lead supply chain professionals to be less careful in the management of inventories and thus incur more costs. A first implication for organizations is that purchasing professionals should be trained to discount their expectations of success by removing this optimistic bias. A second is the importance of providing managers and employees with benchmarks that allow them to assess correctly their performance in relative terms. The study also underlines the effect of environmental uncertainty as an important contextual factor influencing overconfident behaviour.

1. Introduction

Today's purchasing professionals have to handle complex environments and turbulent markets and often are asked to take decisions under conditions of increasing uncertainty (Harland et al., 2003; Wagner and Neshat, 2010). Recent literature has shown that – under these conditions, individual cognition and personality attributes of the decision maker may become crucial in determining outcomes (Ancarani and Di Mauro, 2011; Bendoly et al., 2010, 2006; Gino and Pisano, 2008; Loch and Wu, 2008; Lu et al., 2015).

Findings gathered from diverse disciplines, such as economics, finance and management have emphasised the relevance of one particular individual bias, namely overconfidence, as a determinant of individual decisions in complex and uncertain environments (Camerer and Lovallo, 1999; Hayward et al., 2006; Li and Tang, 2010; Malmendier and Tate, 2005; Shipman and Mumford, 2011). Overconfident individuals tend to believe that their information or their estimates are more accurate than they actually are, or that they hold superior skills and abilities than average (Moore and Healy, 2008). Uncertainty may encourage overconfidence because decision makers misunderstand the hazards they face (Kahneman and Lovallo, 1993; Park and Santos-Pinto, 2010), or because it provides more room for discretion (Li and Tang, 2010).

Overconfidence has been shown to result in poor performance in different decision contexts. In particular, empirical evidence suggests that overconfidence negatively affects judgment and decision making of managers (Aspinwall et al., 2005; Åstebro et al., 2007; Shipman and Mumford, 2011), leading to over-trading behaviour in the stock market (Odean, 1998), use of more long-term, as opposed to short-term, debt (Ben-David et al., 2007), imprecision of forecast (Hribar and Yang, 2011), and excessive risk taking (Li and Tang, 2010; Simon and Houghton, 2003),

In supply management, overconfidence may bring about negative consequences for risk management, by leading to risk underestimation, to build a limited supply-base, or to forego the use of appropriate procedures in the selection, evaluation and monitoring of external sources. Overconfidence may lead purchasing managers to under-estimate the variance of demand or of lead times, thus inducing them to hold too little safety stock in inventory (Ren and Croson, 2013).

Notwithstanding the potential relevance of investigating overconfidence in supply management, there is a surprising paucity of empirical analysis. Further, we are not aware of any empirical study investigating the interplay between uncertainty and overconfidence in affecting supply chain performance.

In this paper, we address this literature gap by focusing on inventory decisions within a serial supply chain. Specifically, we address the following research questions:

1. Do buyers along a supply chain exhibit overconfidence?
2. Is overconfidence enhanced under conditions of greater environmental uncertainty?
3. What is the impact of overconfidence on inventory

* Corresponding author.

http://dx.doi.org/10.1016/j.pursup.2016.05.001
1478-4092/© 2016 Elsevier Ltd. All rights reserved.

management?

In order to address the three research questions, we run a series of controlled human experiments using the framework of the "Beer Game" (Forrester, 1958), a business game that is a paradigmatic representation of a serial supply chain (Croson and Donohue, 2002; Nienhaus et al., 2006; Sterman, 1989). Controlled human experiments have recently been acknowledged as a useful methodology to study the impact of behavioural characteristics (including heuristics and biases such as overconfidence) in operations management (Boyer and Swink, 2008; Tokar, 2010), due to the high internal validity of findings and their replicability. Human experiments can supplement supply management research by providing insight into how the human factor influences supply decisions and by exploring how human characteristics interact with operational and organizational aspects (Boyer and Swink, 2008; Croson and Donohue, 2002; Knemeyer and Naylor, 2011).

Our experiments compare buyers' behaviour and performance under two different supply chain scenarios: the first characterised by demand uncertainty, the second featuring both demand and supply uncertainty. Results suggest that – contrary to intuitive reasoning, when uncertainty increases buyers overrate their ability to control for uncertainty, thus holding insufficient inventory and incurring costs of stock outs. This makes it important for organizations to design appropriate monitoring systems and risk plans that apply in cases of higher turbulence and disruption risk, in order to counterbalance any potential optimistic bias of the decision maker. Our experiments also provide evidence that overconfident buyers exhibit a worse performance in terms of costs, size of backlogs, and variance of orders.

The rest of the paper is organised as follows: Sections 2 and 3 review the relevant literature and present the hypotheses tested, Section 4 describes the experimental design and the measures of overconfidence used in this paper, while Section 5 reports the results of the experiments. Section 6 discusses implications for research and for management. Section 7 concludes with limitations and an agenda for future research.

2. Facets of overconfidence

The concept of overconfidence is an umbrella under which three main psychological effects have been gathered, namely overprecision (or miscalibration), overplacement, and overestimation (Moore and Healy, 2008).

Overconfidence as overprecision refers to the systematic underestimation of the variance of a relevant measure affecting performance (demand, costs, etc.) (Soll and Klayman, 2004; Glaser and Weber, 2007). Conversely, the term overplacement, or better-than-average effect, applies when the decision maker considers herself to be better than others (Alicke and Govorun, 2005; Larrick et al., 2007; Moore and Healy, 2008). Overestimation holds when the decision maker expresses unreasonable optimism about her performance or chances of success (Griffin and Tversky, 1992), and ability to control (Presson and Benassi, 1996; Thompson et al., 1998).

Over-precise managers underrate the volatility of future cash flows (Shefrin, 2001), exhibit higher trading volumes (Odean, 1998), overweight private signals (Gervais and Goldstein, 2007), and choose a longer-term debt structure (Ben-David et al., 2007). These results entail that mis-calibrated managers estimate future unknowns with probability distributions that are too narrow, either because they overrate their ability to predict the future or because they underrate the volatility of random events (Ben-David et al., 2010). Overconfidence as overplacement of one's capabilities has been investigated by Malmendier and Tate (2008), who find that overconfident CEOs engage more frequently in unsuccessful mergers and acquisitions. Hribar and Yang (2011) show that overconfident CEOs tend to issue earnings forecasts in the form of point estimates rather than in intervals. Glaser and Weber (2007) find that financial analysts who consider themselves better than average place more orders. Overestimation of one's chances of success influences entry into competitive markets (Camerer and Lovallo, 1999). With reference to entrepreneurial venture performance, Lowe and Ziedonis (2006) find that, consistently with the overestimation bias, start-ups continue unsuccessful development efforts for longer periods than do established firms.

While overprecision has been the focus of many studies, including one in the supply and purchasing management discipline (Ren and Croson, 2013), there is a relative paucity of research addressing overestimation and overplacement in business studies, and no study in the area of supply and purchasing. Therefore, this study focuses on the overestimation and overplacement of buyers within a supply chain. In competitive environments, where decision makers need to assess their performance not only in absolute terms but also in relation to other competitors, these two dimensions are of particular interest.

There is no agreement among scientists on the factors that activate the three facets of overconfidence described above. The presence of overconfidence and its strength has been associated with psychological, social and contextual factors. Hayward et al. (2006) argue that antecedents of entrepreneurs' overestimation of the wealth they can generate from their ventures can be found in overconfidence in their knowledge, in their ability to predict, and in their personal skills. Radzevick and Moore (2011) show that the drivers of overconfidence are not only psychological but also social, by showing that competitive pressures in a market exacerbate overprecision.

Among contextual factors, building on upper echelon theory (Hambrick, 2007; Hambrick and Mason, 1984), Li and Tang (2010) argue that managerial discretion is the channel through which overconfidence may be transmitted to organizational performance. In addition, there is evidence that an uncertain environment leads decision makers to believe they hold more information than they actually have (Kahneman and Lovallo, 1993; Lichtenstein and Fischhoff, 1977; March and Shapira, 1987; Park and Santos-Pinto, 2010), thus resulting in overconfidence. In the same vein, Hayward et al. (2006) suggest that overconfidence in own ability to predict is strongest in uncertain environments, while Kumar (2009) finds that investors make larger investment mistakes and systematically overestimate their investment ability when stocks are more difficult to evaluate.

3. Overconfidence in supply management decisions

3.1. Environmental uncertainty and overconfidence

Research has emphasised that more and more often purchasing professionals are called to manage unforeseen adverse events (Kleindorfer and Saad, 2005), or they have to take decisions in the face of complex environments and uncertainty (Harland et al., 2003; Wagner and Neshat, 2010). At the same time, there is evidence that often even large corporations disregard uncertainties, and therefore fail to devise appropriate plans against disruptions or accurately build their supply network. Hence, there are grounds for positing that increased uncertainty in governing supply may exacerbate the detrimental effects of managerial overconfidence.

In the supply management field, Carter et al. (2007) posit that overconfidence (interpreted as overestimation) will lead a buyer to place too much confidence in the process of supplier evaluation adopted, for instance by mistakenly assuming that a random sample of events is representative of the essential characteristics of a process. Kaufmann et al. (2009), looking at the use of debiasing strategies to enhance the rationality of sourcing in uncertain environments, find evidence that the use of experts in supply management may result in wrong suggestions. In fact, experts themselves can be a source of decision biases when they come to an unwarranted feeling of control, leading to possibly over-optimistic evaluations (Kaufmann et al., 2012).

One pre-requisite for overconfident attitudes to turn into overconfident behaviour and to affect organizational performance is that the decision maker enjoys sufficient discretionary power. This contention is one of the tenets of upper echelon theory (Hambrick, 2007), which posits that in settings where managers enjoy discretion, their overconfidence matters for organizational success (Li and Tang, 2010). Even if upper echelon theory refers to top executives, it is plausible that this argument may extend to lower level managers, provided they enjoy some degree of discretion, as is the case with professional buyers. Management research provides evidence that discretion is amplified by environmental uncertainty, such as when a market does not provide reliable information, or when ambiguity concerning means-ends is high (Hambrick and Finkelstein, 1987).

Duncan (1972) identifies two dimensions of environmental uncertainty: the simple-complex effect, referring to the number of factors that have to be taken into account in decision-making, and the static-dynamic dimension, pertaining to the variability of the factors relevant for decision making over time. Supply chain can be characterised both by varying degrees of complexity (stemming from numbers of echelons of the chain, number of products exchanged, demand variability, unreliable or long lead times, etc.) (Bozarth et al., 2009) and by different degrees of variability, due to the fact that the factors involved in decision making may change due to several contextual, contractual, and relational conditions (turbulent demand or supply unreliability or disruption).

To the best of our knowledge, there is no ad hoc theory that can fully account for the relation between overestimation and overplacement on the one hand and the two dimensions of environmental uncertainty on the other. In order to derive a testable prediction concerning the impact of environmental uncertainty on overplacement and overestimation, this study elaborates on an acknowledged result in experimental psychology, namely the easy-hard effect (Moore and Healy, 2008). Moore and Healy (2008) show that people overestimate their performance for hard tasks and underestimate it for easy tasks. This is matched by an opposite pattern whereby overplacement is observed in easy tasks and underplacement in hard ones (Brenner, 2003; Larrick et al., 2007; Lichtenstein and Fischhoff, 1977). When formulating a prospective evaluation of performance, individuals have imperfect knowledge about their own performance but even less knowledge about the performance of others. The lack of information about own performance entails that part of the evaluation reflects skills or competence and part reflects errors. The error will make those estimates regressive, i.e. respondents underestimate performance when it is high (which is most likely in easy tasks) and will overestimate it when performance is low (which is most likely in hard tasks) (Erev et al., 1994). The same pattern of overestimation/placement has been reported also in the case when the prospective evaluation refers to ability to control rather than to performance (Thompson et al., 1998).

We conjecture that the same relationship between overestimation and underplacement that has been observed in the easy-hard task comparison will carry over to the case of low-high uncertainty. In fact, hard tasks are not only characterised by complexity in terms of information processing requirements (Moore and Healy, 2008) but also task difficulty increases if probabilistic linkages exist between decisions and outcomes (Campbell, 1988).

H1. In supply management decisions characterised by low environmental uncertainty the buyer exhibits on average overplacement of his/her performance relative to others, whereas with high environmental uncertainty the buyer exhibits on average underplacement.

H2. In supply management decisions characterised by low environmental uncertainty the buyer exhibits on average underestimation of his/her performance, whereas with high environmental uncertainty the buyer exhibits on average overestimation.

3.2. *Overconfidence and experience*

The managerial and economics literature on overconfidence conclude that overconfidence affects also highly experienced and skilled individuals such as managers (Glaser and Weber, 2007; Li and Tang, 2010; Malmendier and Tate, 2005). In the supply management field, Kaufmann et al. (2009) suggest that although purchasing managers are trained to carry out risk assessment and to apply formal models that aid decision-making, they are not immune from overconfidence. Hada et al. (2013) argue that purchasing managers' experience reduces the bias they perceive in supplier-selected referrals.

However, these findings contrast with other results reported by the psychological literature on overestimation and overplacement. In fact, several psychological studies report a reduction in overestimation of performance (Griffin and Tversky, 1992; Koriat et al., 2002; Krueger and Mueller, 2002) and in overplacement (Burson et al., 2006) once the decision maker has acquired skills in the task. Because people may find it difficult to assess their relative performance, skilled individuals who exhibit a better performance do not guess how well they have done, whereas less skilled individuals do not accurately assess how badly they have done (Burson et al., 2006). In psychological experiments, skill is often acquired through repetition of the task, and it is therefore tied to previous experience. A caveat to equating experience with skill acquisition comes from Russo and Schoemaker (1992) who show that a reduction in overconfidence is determined by a timely feedback from previous decisions and accountability of decisions. Therefore, building on the psychological literature, we formulate the following hypothesis:

H3. Experienced individuals exhibit on average less overplacement and less overestimation, provided they receive feedback on past decisions.

3.3. *Impact of overconfidence on supply chain performance*

An important question arising from the findings that purchasing professionals are affected by overconfidence and that the degree of overconfidence differs when acting in different environments is the following: how does overconfidence relate to the outcomes of their decisions?

One of the areas in which overconfidence may bring about negative consequences for supply management is risk management, which can be affected both in the valuation phase and in the choice of risk mitigation strategies. In the valuation phase, overconfidence leads to risk underestimation, whereby the decision maker may believe that severe disruptions are less likely they actually are and that they can be managed ex post, and that she will do this better than competitors will. Overconfidence as overestimation of one's own abilities and skills may lead buyers to design their supplier network with a limited supply-base, or to forego the use of appropriate procedures in the selection, evaluation and monitoring of external sources.

In terms of risk mitigation strategies, inventory management may also be affected. Croson et al. (2008), in developing a theoretical model of the newsvendor, show that overconfidence leads the newsvendor to place suboptimal orders and to earn lower profits than well-calibrated newsvendors. In particular, in high-profit (low-profit) industries, overconfident agents are likely to order fewer (higher) inventories than optimal. Overconfidence may lead purchasing managers to under-estimate the variance of demand or of lead-time, thus inducing them to hold too little safety stock (Bendoly et al., 2010). Thus, the following hypothesis with respect to inventory management within a supply chain can be formulated:

H4. Overconfidence leads to worse performance in inventory management by leading to higher costs.

4. The experiment

4.1. The design

In order to investigate overconfidence in ordering decisions within a supply chain, the "beer game" framework was adopted (Forrester, 1958, 1961). In the classic beer distribution game the supply chain consists of four echelons (retailer-wholesaler-distributor-factory). During the game each i-participant, i [1,…,4], at each t-period, t [1,..,T], places orders, O_{it}, to the immediate upstream supplier and fills downstream customer's orders, D_{it}. Typically, at each echelon, when a buyer places an order a delay (information lead time LTI) occurs before this latter is known to the upstream supplier, $D_{it}= O_{i-1,t-1}$. Further, a distribution lead time (LTD) is requested to ship orders to the downstream echelon. The same happens to the factory when beer is produced (production lead time LTP). Assuming LTI =1 and LTD = LTP =2, at each echelon, goods received at time t, R_{it}, correspond to those shipped by the upstream supplier two periods before, $_{Si+1,t-2}$. During the game, the inventory balance is such that: $I_{it}= I_{i,\ t-1}+ R_{it}-S_{it}$, where I_{it} is the on hand quantity ($I_{it} \geq 0$); customer orders are filled completely if $I_{it} \geq D_{it}$ otherwise $S_{it} < D_{it}$ and backorders occur, $B_{it}= B_{i,t-1}+ D_{it}-S_{it}$. An order placed with the supplier can be partially fulfilled with a continuous distribution, depending on the supplier's inventory availability. Each role incurs unit inventory costs of €0.50 and unit backlog costs of €1.00 per period (Sterman, 1989).

Most of the extant literature on the Beer Game has focused on ordering behaviour in the face of external demand uncertainty, exploring for instance the effect of varying the demand distribution or inventory information (Sterman, 1989; Croson and Donohue, 2006; Wu and Katok, 2006, among others). Generally, demand uncertainty is considered the baseline form of the beer game, on the ground that uncertainty stemming from the demand side is difficult to diversify away for firms. More and more often, however, firms face uncertainty originating from the supply side (Tang and Tomlin, 2008), either because of lean supply chains (Harland et al., 2003), or because of globalised chains in which the logistics may present some form of failure (because of transport times, political issues, etc.). As a consequence, the literature has also paid attention to beer game scenarios where supply-side uncertainty is also present, alongside demand uncertainty, through the hypothesis of variable distribution lead times (Ancarani et al., 2013; Chatfield et al., 2004; Truong et al., 2008).

In order to explore whether overconfidence in supply chain inventory decisions depends on the degree of environmental uncertainty, two experimental treatments were built. The first treatment (hereafter called the control) reproduces a beer game with four echelons (i =1,…,4), i.i.d. normally distributed external demand with parameters known to all echelons ($\mu=100$, $\sigma=20$), known and constant lead times equal to one period for information lead times (LTI=1) and to two periods for distribution lead times and production lead times (LTD=2; LTP=2). This design differs from the original framework by Sterman (1989) only because in Sterman's experiments the retail demand was completely unknown and non-stationary and was represented by a simple step-function whereby demand started at 4 units and jumped to 8 units after the eighth game period.

The second treatment (hereafter called S_U for supply uncertainty) consists of a game with variable external demand, as in the control, known and constant LTI =1, and stochastic LTD and LTP. The stochastic nature of the distribution and production lead times is made operational through a random variable uniformly distributed in the interval (1, 2, 3) periods. The comparison between the control and the S_U treatment allows assessing the differences in players' overconfidence and cost performance brought about by a more uncertain environment, (S_U), where both demand and supply are stochastic.

In both settings, the information available to each player includes their own histories of incoming demands, past shipments, and past purchases. From this information, outstanding orders can be worked out both in the control and in S_U treatment. No information sharing about actual demand, inventories, backlogs, and own lead times is allowed among supply chain participants. Communication among participants during the game was strictly forbidden. Thus, both games can be assumed to mimic a non-integrated serial supply chain in which each buyer has a single supplier.

All experiments use the same random number seed to generate demand, i.e., D_{it}, t=1, …..,T is identical across groups. This allows separating variations due to ordering behaviour from variations due to different demand streams. Finally, behaviour in both experiments is observed for a number of periods (T). During the game, players were not informed of the final period of the game in order to avoid end-of-game behaviour that might trigger over- or under-ordering.

Upon signing up for the experiment, players were randomly assigned to one of the two treatments. First, they were oriented to the rules and objectives of the game by means of a tutorial lasting about 30 min. Then, each player participated in two different beer game sessions of the same treatment, the second taking place about one month after the first. The first repetition of each experiment was considered a sort of warm-up of the game (Wu and Katok, 2006), useful for making the players aware of the rules of the game and of the impact of the interaction with the other players in the same chain. In the second repetition, each player kept the same role he/she had been assigned in the first game but was assigned to a different chain, in order to avoid members of a chain during the first session agreeing on a specific strategy for the next. This would have changed the non-integrated supply chain to a coordinated one.

Two different groups of subjects participated in the experiment: 152 graduate students (76 in the control and 76 in S_U), and 24 professional purchasing managers (all in the S_U treatment). Although the use of students in operations management experiments has been criticised, several studies have provided evidence that experimental outcomes of managers and students in beer game experiments are similar (Croson and Donohue, 2006; Machuca and Barajas, 2004). However, if a manager has a better understanding and greater experience of the principles of inventory management than a student does, he should perform better in the game and exhibit less unjustified optimism about his performance (Bolton et al., 2012). Therefore, comparison of behaviour of students and managers allows the assessment of the impact of professional purchasing experience on overconfidence and therefore a test of Hypothesis 3.

Student participants were graduates in Operations Management who had already attended Logistics classes, and had a good knowledge of inventory management problems. All of them had previous work experience through internships. Participants were divided equally between men and women, and median age was 24. Purchasing managers were all members of the same multinational organization, 25% were female, 50% of them had been with the same company for over 5 years, and 46% were younger than 35 years.

Graduate students played for a minimum of 36 periods to a maximum of 50, whereas the purchasing managers played for 20 periods due to a time limit fixed by their company. The incentive used in the student game was both monetary and in terms of coursework grades. Participants were instructed that the members of the supply chain team with the lowest total costs (inventory + backlog costs) shared a final prize of €77. In addition, the members of the winning chain received an extra course grade (out of 30 grades). Purchasing managers were instead rewarded with a wellness package.

The version of the beer game here adopted was developed in a Googledocs® software application which enables Excel® spreadsheets to be shared by the different supply chain members.

4.2. Overconfidence measures

In order to assess the presence of overplacement and overestimation, participants were asked to evaluate their performance prospectively in the “beer game”. Statements and questions used for the purpose were adapted from Glaser and Weber (2007).

Since the first repetition of the game was considered as a warm-up, overconfidence statements were elicited at the beginning of the second repetition, i.e. once participants had acquired sufficient experience of the game, and could formulate informed valuations on their prospective performance.

Overplacement was assessed through the following item based on expected prospective performance:

Please, indicate here following which is, in your opinion, the percentage of participants playing in your same role who will complete the game with lower total costs than yours (provide a number between 0% and 100%).

In Glaser and Weber (2007) overplacement was also assessed through an item based on perceived skills, in addition to the one referring to expected performance. This item was not used in our study, since we reasoned that applying a measure of skills was questionable. In fact, skills would have implied pre-experimental experience, and both students and professional buyers had no experience of the beer game before they signed up for the experiment.

The measure of overplacement was calculated for each player simply as the difference between the actual percentage of participants in the same role with lower total costs than the respondent and the percentage expected by the respondent. The measure was then normalised dividing by 100 and this resulted in a range of the measure between -1 and $+1$, with negative values indicating underplacement and positive values standing for overplacement. In order to allow for players' small estimation errors, players exhibiting under (over) placement were defined as those whose placement score was lower than -0.1 (higher than 0.1).

A measure of overestimation was derived from responses to the following statement, meant to mimic locus of control questions (Presson and Benassi, 1996):

I never take decisions in the game that may put me at the risk of a stock-out.

Participants in the game provided their assessment on a Likert scale from 1 (=I do not agree at all) to 5 (=I agree completely). The measure of overestimation was built by comparing the Likert score, representing the perceived degree of control over stock-outs, with the actual success of the player in controlling stock-outs. To this end, we clustered the periods of the game in which backlogs had occurred into five groups of the same length (36/5 or 20/5 according to the periods played by students and managers). Thus, for the student (manager) we assumed that if the number of stock-outs was less or equal to 7 (4) this corresponded to a score of effective success equal to 5 (the greatest ability to actually control for the stock-outs), if it was greater than7 (4) but less or equal to 14 (8), the score was 4, and so on. If the number of stock-outs was greater than 28 (16) the score was 1 (the lowest ability to control for the stock-outs). For each player, we then subtracted the score corresponding to the actual control from the score expected by the respondent, and normalised it, to yield an overestimation index for each player comprised between -1 and $+1$, as follows: NormScor=[(Likert score for expected control – score for actual control)/4]. As above, in order to allow for players' small estimation errors, players exhibiting under (over) estimation were defined as those whose estimation score was lower than -0.1 (higher than 0.1).

5. Findings

5.1. Evidence of overconfidence

In order to test the first two hypotheses concerning overplacement and overestimation and their relation with the degree of environmental uncertainty, Fig. 1 reports the proportion of participants in the beer game who exhibited under/over placement and estimation. The left-hand side of Fig. 1 presents the percentage of players exhibiting over (under) placement. Overplacement is more frequent in the control condition in which uncertainty is lower, thus confirming Hypothesis 1. Differences in the frequency of over and under placement between the two student groups playing in the two conditions are statistically significant by a chi-square test (7.08, $p<0.05$). The right-hand side of Fig. 1 reports the percentage of either players who exhibited under- or overestimation. Consistent with Hypothesis 2, overestimation is more frequent when the decision task takes place under conditions of higher uncertainty, i.e. under treatment S_U. The differences in the proportions of under/overestimation for the two students groups are significant by a chi square test (14.15, $p<0.05$). Underestimation is the modal behaviour among professionals.

These preliminary results support Hypotheses 1 and 2 and confirm that the pattern of overplacement and overestimation observed under low/high uncertainty is in line with results reported in the literature with reference to easy/hard decision tasks. In addition, results lend support to the hypothesis that the two biases affect also purchasing professionals, who tend to over-rate their performance with respect to others, but to under-rate their ability to control.

In order to get a more nuanced picture of overconfidence, Fig. 2 presents the frequency distribution of the overplacement and overestimation measures for students in the two experiments and for the managers' experiment. Whereas the analysis based on dichotomization allows getting a more intuitive picture of overconfident attitudes (how widespread they are), from a managerial point of view it is of interest to assess how much overconfident a decision maker is. In fact, based on the results of the overconfidence literature (Li and Tang, 2010), it is plausible to assume that the negative consequences of overconfidence (if any) will be an increasing function of the degree of overconfidence.

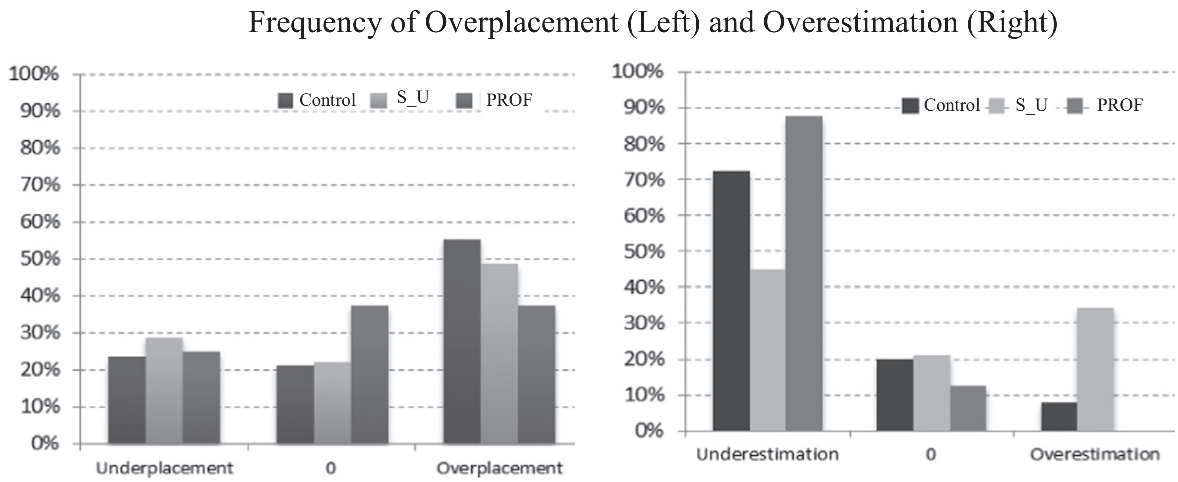

Fig. 1. Frequency of overplacement (Left) and overestimation (Right).

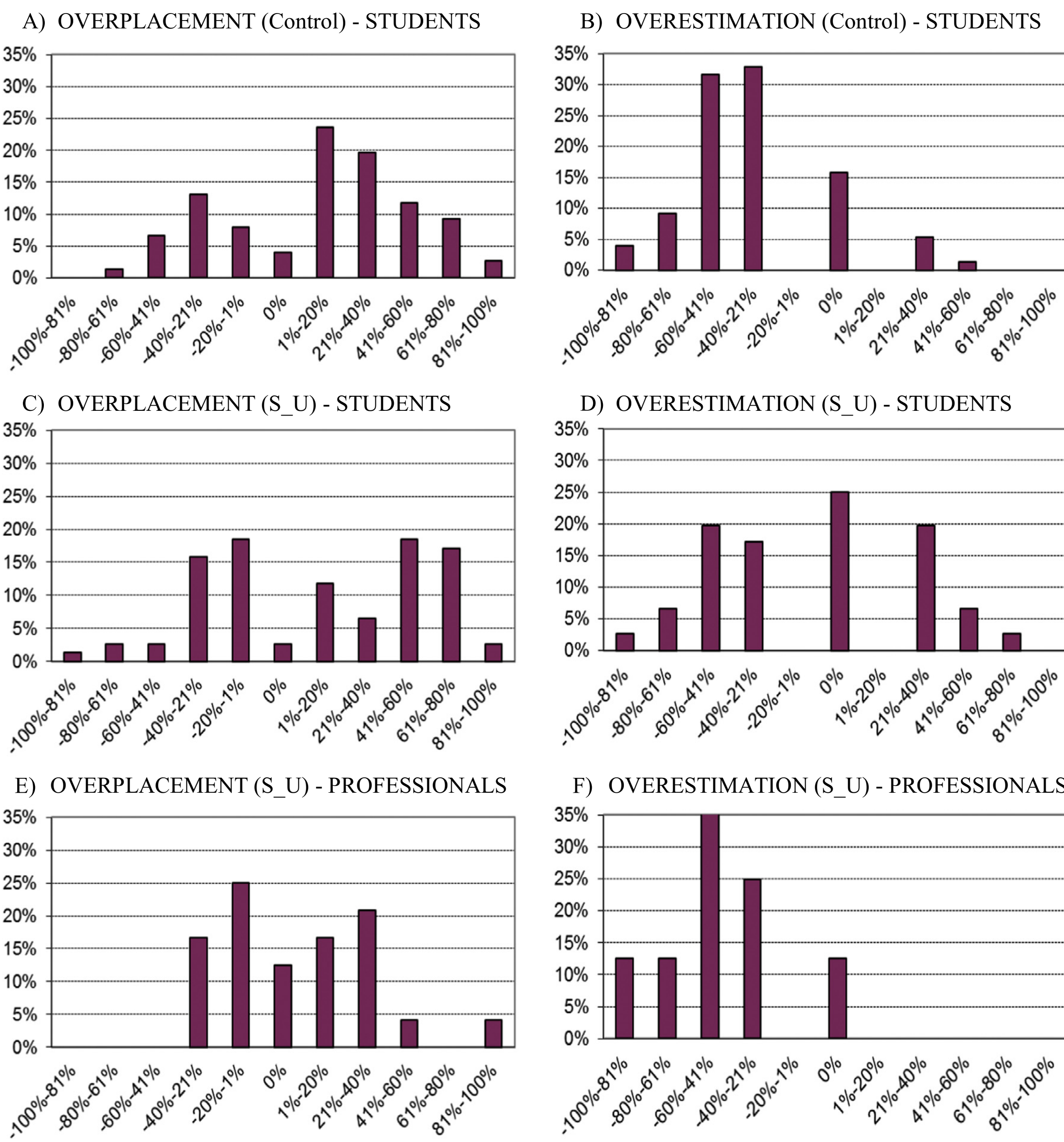

Fig. 2. Overplacement (left) and overestimation (right).

A within-treatment analysis confirms the pre-dominance of overplacement and underestimation for the low uncertainty game (Fig. 2(a) and (b)). In the case of the S_U treatment, the difference between the two measures of overconfidence is less marked (Fig. 2 (c) and (d)). There is relatively more underestimation than underplacement, however there is also a high proportion of respondents who markedly over-placed themselves with respect to others.

The between-experiment comparison with respect to overplacement shows that respondents exhibiting underplacement increase with uncertainty (Fig. 2(a) and (c)). A regression of the overplacement measure on the treatment variable returns a coefficient that is positive but not statistically significant. The between treatment comparison for overestimation confirms the pattern reported in the case of the easy-hard effect proposed in the literature, namely that overestimation increases with uncertainty (Fig. 2(b) and (d)). A regression of the overestimation measure on the treatment variable (presence/absence of supply uncertainty) returns a positive and significant coefficient (beta $=0.29$, $p<0.00$).

Analysis of the S_U treatment condition allows a test of Hypothesis 3 through the comparison of students and professionals. These latter participated only in the S_U version of the game. Purchasing professionals exhibit overplacement less frequently than graduate students do, and are better able to evaluate their position with respect to others, consistent with Hypothesis 3. The difference in the frequency of over/under placement is statistically significant (17.96, $p<0.01$). However, still over 30% of managers exhibit overplacement in their evaluations, thus confirming that overconfidence is a problem affecting also professionals. Professional buyers exhibit overestimation less frequently and underestimation more frequently with respect to the student group, with the difference being significant under a chi-square test (32.36, $p<0.01$). This again confirms Hypothesis 3 concerning the impact of experience in related tasks. The very high frequency of underestimation among professional buyers indicate that they tend to underrate their ability to manage inventories.

In summary, overplacement diminishes with uncertainty and a significant proportion of professional buyers underplace their performance, although these effects are not statistically significant. Our measure of overestimation supports the hypotheses concerning the effect of environmental uncertainty and professional experience. Overestimation increases with uncertainty, while professional buyers exhibit a sort of reverse confidence bias, since they underestimate their prospective performance.

5.2. *Impact of overconfidence on supply chain performance*

The presence of overplacement and overestimation do not represent per se evidence that overconfidence affects supply chain performance. In order to test if overconfidence worsens Beer Game outcomes (Hypothesis 4), we consider three different measures of performance: costs (inventory + stock-out costs) for each echelon, backlogs occurred in the game, and variance of orders during the game calculated over a horizon of 36 periods. Regression analysis was used to explore the relation between each of these dependent variables and a set of explanatory variables, including the measures of overplacement (Over_placement) and overestimation (Over_estimation) described above.

A well-known outcome of Beer Game experiments is the so called Bullwhip Effect (Sterman, 1989; Croson and Donohue, 2002), whereby the variance of orders escalates as one moves up the supply chain. This implies that role played in the chain (retailer, wholesaler, distributor, and factory) is a powerful determinant of performance. To keep this variability into account, separate linear regressions were run for each echelon.

Besides overconfidence measures, the other explanatory variables used were:

1. Supply Uncertainty (0 = control, 1 = S_U) accounting for outcome differentials caused by the different degree of uncertainty in the environment associated with the two experimental conditions.
2. Average Backlog per period of the upper echelon with respect to the one considered in the equation (Backlog_S), capturing the fact that in any serial supply chain outcomes are not determined solely by individual ordering and inventory decisions but also by the behaviour of other participants. In particular, backlog costs are bound to be affected by the inability of upstream layers to supply their customers, due to insufficient stock.
3. Confidence measures of the supplier in the customer's equation (Over_placement_S and Over_estimation_S). These variables keep into account the team-dependence of costs. In fact, an overconfident supplier may hold fewer inventories and incur backlogs more frequently, leading to higher costs not only for himself but also for the customer.

The regression analysis refers only to the experiments involving graduate students. The different length of the game for the two sub-groups (36–50 periods for students and 20 periods for professional buyers) makes overall costs not strictly comparable. At the same time, the small size of the buyers' group makes it unsuitable to run a separate regression analysis.

Table 1 summarises regression results by reporting standardised coefficients and p-values in parenthesis for each of the twelve equations (4 echelons X 3 measures of performance) estimated. We discuss the cost equation first. The coefficient for the S_U treatment is always positive and statistically significant except for the distributor, pointing to the fact that higher uncertainty generally translates into higher costs. The overplacement coefficient is positive and statistically significant for all echelons but for the distributor, whereas the overestimation coefficient is a significant determinant of costs only for the Retailer. This latter finding is of interest recalling that the overestimation measure in this study refers to expected ability to control the occurrence of backlogs. The significance of overestimation only for the retailer may capture a well-known result of beer game studies: the retailer fails to estimate the variance of external demand, thus under-estimating the risk of running out of stocks. Consequently, orders to the upper echelons will be too small in the first phase of the game, setting in motion unstable dynamics of the chain, whereby upper echelons will present increasing variability of orders. The overconfidence of the supplier is statistically significant only for the retailer and for the overestimation measure, pointing to the fact that generally costs depend mainly on the management of own inventory, rather than on backlogs created by the mismanagement of supplier's inventory. Consistent with this finding, backlogs of the upper echelon are a statistically significant determinant of costs only in one equation. The backlog equation provides substantially similar results.

In the variance of orders equation uncertainty always leads to higher volatility of orders, while there is mixed support for the impact of overconfidence measures. Consistent with previous literature on the beer game, the variance of orders is strongly affected by the upper level backlogs.

6. Discussion

Results from the beer game experiments provide answers to the three research questions relating to the overconfidence exhibited by buyers, the impact of environmental uncertainty on

Table 1.
Relation between Performance Measures and Overconfidence (number of chains = 38).

Supply chain echelon	Retailer			Wholesaler			Distributor			Factory		
Variables	**Cost**	**Variance of orders**	**Backlogs**	**Cost**	**Variance of orders**	**Backlogs**	**Cost**	**Variance of orders**	**Backlogs**	**Cost**	**Variance of orders**	**Backlogs**
Supply Uncertainty (S_U)	0.41 (0.01)***	0.20 (0.08)*	0.43 (0.01)***	0.36 (0.03)**	0.27 (0.07)*	0.25 (0.12)	0.13 (0.36)	0.26 (0.04)**	0.14 (0.24)	0.38 (0.01)***	0.40 (0.03)**	0.35 (0.01)***
Over_placement	0.36 (0.01)***	0.15 (0.09)*	0.29 (0.03)**	0.36 (0.02)**	0.23 (0.11)	0.27 (0.07)*	0.17 (0.21)	0.23 (0.07)*	0.22 (0.06)*	0.52 (0.00)***	0.38 (0.04)**	0.29 (0.02)**
Over_estimation	0.30 (0.05)**	0.14 (0.17)	0.34 (0.03)**	0.17 (0.37)	−0.32 (0.05)**	0.27 (0.15)	0.20 (0.16)	0.03 (0.82)	0.04 (0.71)	0.09 (0.49)	0.37 (0.05)**	0.50 (0.00)***
Over_placement_Supplier	−0.01 (0.94)	0.02 (0.83)	0.02 (0.83)	0.13 (0.58)	0.10 (0.45)	0.17 (0.23)	0.03 (0.81)	0.28 (0.03)**	−0.01 (0.92)	–	–	–
Over_estimation_Supplier	−0.41 (0.02)**	−0.12 (0.32)	−0.42 (0.02)**	−0.09 (0.52)	−0.13 (0.33)	−0.16 (0.26)	−0.03 (0.86)	0.06 (0.65)	−0.15 (0.28)	–	–	–
Backlog_Supplier	0.23 (0.16)	0.74 (0.00)***	0.21 (0.21)	0.09 (0.62)	0.66 (0.00)***	0.16 (0.34)	0.69 (0.00)***	0.39 (0.02)**	0.74 (0.00)***	–	–	–
R^2	0.47	0.72	0.45	0.40	0.48	0.41	0.47	0.56		0.40	0.45	0.46

* $p < 0.10$.
** $p < 0.05$.
*** $p \leq 0.01$.

overconfidence, and the impact of overconfidence on inventory management. Results in both experimental manipulations (low/high uncertainty) provide evidence that decision makers exhibit overconfidence in their ordering decisions. Further, the study underlines the effect of uncertainty as a relevant contextual variable affecting the presence and strength of overconfidence. Finally, the study supports the view that overconfidence may lead purchasing professionals to be less careful in the management of supplies and thus incur more costs. In what follows, we discuss each of these results, and derive implications for academic research and supply management.

6.1. Buyers' overconfidence biases

Previous experimental research on overconfidence in supply management built on the behaviour of undergraduate students with little knowledge of inventory management (Ren and Croson, 2013). In this experiment, both graduate students, with knowledge of supply and inventory management, and purchasing professionals exhibit confidence biases. This finding aligns with other disciplines that have found evidence of overconfidence in the decisions of professionals (Malmendier and Tate, 2005; 2008; Odean, 1998). However, purchasing professionals exhibit less overconfidence than students do, lending support to the hypothesis that professional experience matters (Burson et al., 2006) (Hypothesis 3).

The experiments show that both students and professionals overrate their performance relative to others, whereas they mostly underestimate their ability to control backlogs. This overplacement/underestimation pattern is in line with previous findings in the literature (Moore and Healy, 2008). In particular, according to Griffin and Tversky (1992), overplacement arises because the performance of others is considered to be predictable from their traits, needs and interests. In our experiments, this predictability is plausible both for students and professionals, since they knew their group of peers. Conversely, underestimation derives from the fact that predicting own behaviour/performance is perceived as more difficult, because it is considered contingent on changing external circumstances.

The inability to assess own performance with respect to others has interesting consequences in supply management settings. In competitive environments, where success depends on rank in the population, but where information about the abilities of others may be imprecise, individuals may be able to evaluate themselves in absolute terms but not in relative terms (Grieco and Hogarth, 2009). Inability to assess performance in relative terms may lead to weak efforts to improve the competitive position. This study suggests that this will be true not only when purchasing professionals face more complex and uncertain environments. A first implication for organizations is that buyers should be trained to discount their expectations of success by removing these optimistic biases (Carter et al., 2007). A second is the importance of providing buyers and employees with benchmarks that allow them to assess correctly their performance in relative terms (Russo and Schoemaker, 1992).

With reference to underestimation, our experiments show that it is noticeable among purchasing managers with respect to graduate students. Although the stronger underestimation among professionals should be subject to further research, since the length of the game played by managers was shorter than for students, we conjecture that managers hold larger inventory because they perceive backlogs as a professional failure and not simply an extra cost in the game.

6.2. Environmental uncertainty affects overconfidence

The experimental design compares two decision scenarios differing for uncertainty the buyer faces when deciding his/her order. Consistently with previous literature (Kahneman and Lovallo, 1993; Li and Tang, 2010; Park and Santos-Pinto, 2010), the two facets of overconfidence relate to the degree of environmental uncertainty. More precisely, as predicted by Hypothesis 1, overestimation is relatively more frequent when uncertainty is higher, whereas overplacement is more frequent under lower uncertainty (Hypothesis 2), although this latter effect is weaker. As far as supply management research is concerned, the overestimation result lends support to Carter et al. (2007) who posited that buyers might exhibit overconfidence in the process of supplier evaluation when probabilistic information is vague.

The experiments also contribute to theory since they have allowed testing whether the easy-hard tasks comparison described by Larrick et al. (2007) and Moore and Healy (2008) extends to lower-higher uncertainty settings in inventory management. Results suggest that probabilistic linkages between decisions and outcomes are perceived by the decision maker as characterised by more complexity in terms of information processing requirements.

From a managerial viewpoint, it is noteworthy that in higher uncertainty conditions players become significantly more overconfident in their ability to control backlogs. These results suggest that when locus of control is high buyers will underestimate their abilities, whereas when locus of control is low, such as in turbulent markets or with unreliable suppliers, buyers will overrate their chances to control for disruptions. Although higher levels of uncertainty lead to a decrease in overplacement, still a significant portion of players (about 50%) exhibit overplacement, thus suggesting that this facet of overconfidence is also at issue under uncertainty. Therefore, it is important for organizations to design appropriate monitoring systems and risk plans that apply in cases of high turbulence, in order to counterbalance any potential optimistic bias of the decision maker.

6.3. *Overconfidence and inventory management*

This study is the first to have explored the impact of overconfidence on purchasing decisions within a serial supply chain. Regression analysis shows that costs of different tiers of the supply chain are positively related to measures of overconfidence, thus confirming Hypothesis 4 and general findings from other disciplines according to which overconfidence leads to suboptimal decisions. Thus, the study suggests that the psychological characteristics of decision makers matter for organizational performance, thereby extending to operational activities such as inventory and ordering decisions, the findings of Upper echelon theory (Hambrick, 2007) concerning the “hubris” of CEOs (Li and Tang, 2010; Malmendier and Tate, 2005).

Next, overconfident behaviour often substantiate into higher risk taking (Li and Tang, 2010; Simon and Houghton, 2003). Experimental results show that this is true also in inventory management, since overconfident individuals incur not only more costs (which may stem from higher inventory) but also more backlogs, thus showing that higher costs are determined by insufficient stock. Therefore, overconfident buyers increase the risk of a breakdown of the supply chain and put the reliability of their firm at risk. Further, since overconfidence affects also the variance of orders, it qualifies as one of the behavioural causes of the “bullwhip effect” (Sterman, 1989), which is considered a key determinant of supply chain costs.

Finally, regression analysis suggests that it is the overconfidence of the decision maker that affects performance the most, whereas the overconfidence of the upstream tier of the chain has an insignificant effect. This entails that if each tier's decision maker correctly assesses her own performance and her standing with respect to competitors, this should minimise the impact of possible biases existing in the supply chain.

7. Limitations and future research directions

This study has presented the results from human experiments aimed at analysing the impact of overconfidence on inventory decisions. Experiments represent a useful approach since they allow isolating causal links and capturing behavioural characteristics that cannot be easily reconstructed from field data. In addition, the use of multi-player business games is important to detect network effects in interdependent decisions. While these represent the opportunities offered by human experimentation in the operational management discipline, the challenge remains that of ascertaining that high internal validity is not at the cost of low external validity. To this end, higher external validity can be achieved either through the involvement in experiments of professionals, or by comparing field outcomes and experimental results.

In the light of the above line of reasoning, some limitations of this study may provide direction for future research. First, future research may combine building ad hoc experiments with the undertaking of field studies to complement experimental evidence. This multidisciplinary approach may be useful to investigate the relevance of overconfidence also for supply management decisions other than inventory management (supplier selection, supply chain integration, etc.). Second, it would be of interest to widen the sample of purchasing professionals involved in the experiments, taking into account contextual factors (firm/purchasing department size, sector of activity, seniority, etc.) and different cultural/education background in order to better understand the interplay between overconfidence and individuals' training. In fact, the small number of professionals involved in the present study led to their exclusion from regression analysis.

Finally, behavioural studies generally isolate the effect of a single bias/heuristic on behaviour. However, individuals exhibit complex personalities, experiences, and attitudes that affect their behaviour. Thus, it is important to explore whether interactions exist among overconfidence and other behavioural characteristics, for instance, risk attitudes and/or reciprocity, and to identify their joint impact. The investigation of behavioural issues in supply chain management is today acknowledged as extremely relevant, as witnessed by the growing attention paid by the literature. Research efforts in this direction will enrich the study of organizations, but also will suggest ways to innovate supply management.

References

Alicke, M.D., Govorun, O., 2005. The better-than-average effect. In: Alicke, M.D., Dunning, D., Krueger, J. (Eds.), The self in social judgment: 85–106. Psychology Press, New York.

Ancarani, A., Di Mauro, C., 2011. The human side of supply chains: a behavioural perspective of supply chain risk management. In: Evangelista, P., McKinnon, A., Sweeney, E., Esposito, E. (Eds.), Supply Chain Innovation for Competing in Highly Dynamic Markets: Challenges and Solutions: 290–314. ICI Global, Hershey (USA).

Ancarani, A., Di Mauro, C., D'Urso, D., 2013. A human experiment on inventory decisions under supply uncertainty. Int. J. Prod. Econ. 142 (1), 61–73.

Aspinwall, L.G., Sechrist, G.B., Jones, P.R., 2005. Expect the best and prepare for the worst: anticipatory coping and preparations for Y2K. Motiv. Emot. 29, 357–388.

Åstebro, T., Jeffrey, S.A., Adomdza, G.K., 2007. Inventor perseverance after being told to quit: the role of cognitive biases. J. Behav. Decis. Mak. 20, 253–272.

Ben-David, I., Graham, J.R., Harvey, C.R., 2010. Managerial miscalibration. NBER.

Ben-David, I., Graham, J.R., Harvey, C.R., 2007. Managerial Overconfidence and Corporate Policies. NBER.

Bendoly, E., Croson, R., Goncalves, P., Schultz, K., 2010. Bodies of knowledge for research in behavioral operations. Prod. Oper. Manag. 19 (4), 434–452.

Bendoly, E., Donohue, E., Schultz, K.L., 2006. Behaviour in operations management: assessing recent findings and revisiting old assumptions. J. Oper. Manag. 24 (6), 737–752.

Bolton, G.E., Ockenfels, A., Thonemann, U.W., 2012. Managers and students as newsvendors. Manag. Sci. 58 (12), 2225–2233.

Boyer, K.K., Swink, M.L., 2008. Empirical elephants—why multiple methods are essential to quality research in operations and supply chain management. J. Oper. Manag. 26, 337–348.

Bozarth, C.C., Warsing, D.P., Flynn, B.B., Flynn, E.J., 2009. The impact of supply chain complexity on manufacturing plant performance. J. Oper. Manag. 27 (1), 78–93.

Please cite this article as: Ancarani, A., et al., Measuring overconfidence in inventory management decisions. Journal of Purchasing and Supply Management (2016), http://dx.doi.org/10.1016/j.pursup.2016.05.001

Brenner, L., 2003. A random support model of the calibration of subjective probabilities. Organ. Behav. Human. Decis. Process. 90, 87–110.
Burson, K.A., Larrick, R.P., Klayman, J., 2006. Skilled or unskilled, but still unaware of it: how perceptions of difficulty drive miscalibration in relative comparisons. J. Pers. Social. Psychol. 90 (1), 60–77.
Camerer, C.F., Lovallo, D., 1999. Overconfidence and excess entry: an experimental approach. Am. Econ. Rev. 89, 306–318.
Campbell, D.J., 1988. Task Complexity: A Review and Analysis. Acad. Manag. Rev. 13 (1), 40–52.
Carter, C.R., Kaufmann, L., Michel, A., 2007. Behavioral supply management: a taxonomy of judgment and decision-making biases. Int. J. Phys. Distrib. Logist. Manag. 37 (8), 631–669.
Chatfield, D.C., Kim, J.G., Harrison, T.P., Hayya, J.C., 2004. The bullwhip effect – Impact of stochastic lead time, information quality, and information sharing: a simulation study. Prod. Oper. Manag. 13 (4), 340–353.
Croson, D., Croson, R., Ren Y., 2008. How to manage an overconfident newsvendor. Working paper, Cox School of Business, Southern Methodist University, Dallas, USA.
Croson, R., Donohue, K., 2002. Experimental economics and supply chain management. Interfaces 32 (5), 74–82.
Croson, R., Donohue, K., 2006. Behavioral causes of the bullwhip effect and the observed value of inventory information. Manag. Sci. 52 (3), 323–336.
Duncan, R., 1972. Characteristics of organizational environments and perceived environmental uncertainty. Adm. Sci. Q. 17, 313–327.
Erev, I., Wallsten, T.S., Budescu, D.V., 1994. Simultaneous over- and underconfidence: the role of error in judgment processes. Psychol. Rev. 101, 519–527.
Forrester, J., 1958. Industrial dynamics: a major breakthrough for decision makers. Harv. Bus. Rev. 36, 37–66.
Forrester, J., 1961. Industrial dynamics. MIT Press And John Wiley & Sons, Inc., New York.
Gervais, S., Goldstein, I., 2007. The positive effects of biased self-perceptions in firms. Rev. Financ. 11 (3), 453–496.
Gino, F., Pisano, G., 2008. Toward a theory of behavioral operations. Manuf. Serv. Oper. Manag. 10 (4), 676–691.
Glaser, M., Weber, M., 2007. Overconfidence and trading volume. Geneva Risk Insur. Rev. 32 (1), 1–36.
Grieco, D., Hogarth, R.M., 2009. Overconfidence in absolute and relative performance: the regression hypothesis and Bayesian updating. J. Econ. Psychol. 30, 756–771.
Griffin, D.W., Tversky, A., 1992. The weighing of evidence and the determinants of confidence. Cognit. Psychol. 24, 411–435.
Hada, M., Grewal, R., Lilien, G.L., 2013. Purchasing managers' perceived bias in supplier-selected referrals. J. Supply Chain Manag. 49 (4), 81–95.
Hambrick, D., 2007. Upper echelons theory: an update. Acad. Manag. Rev. 32, 334–343.
Hambrick D., Finkelstein S., 1987. Managerial discretion: a bridge between polar views of organizational outcomes Research in organizational behavior 9 JAI Press Greenwich, CT. 369–406.
Hambrick, D., Mason, P., 1984. Upper echelons: the organization as a reflection of its top managers. Acad. Manag. Rev. 9, 193–206.
Harland, C., Brenchley, R., Walker, H., 2003. Risk in supply networks. J. Purch. Supply Manag. 9 (2), 51–62.
Hayward, M., Shepherd, D., Griffin, D., 2006. A hubris theory of entrepreneurship. Manag. Sci. 52 (2), 160–172.
Hribar, P., Yang, H., 2011. CEO overconfidence and management forecasting. Working Paper Series 47, Social Science research Network.
Kahneman, D., Lovallo, D., 1993. Timid choices and bold forecasts: a cognitive perspective on risk taking. Manag. Sci. 39, 17–31.
Kaufmann, L., Carter, C.R., Buhrmann, C., 2012. The impact of individual debiasing efforts on financial decision effectiveness in the supplier selection process. Int. J. Phys. Distrib. Logist. Manag. 42 (5), 411–433.
Kaufmann, L., Michel, A., Carter, C.R., 2009. Debiasing strategies in supply management decision-making. J. Bus. Logist. 30 (1), 85–106.
Kleindorfer, P., Saad, G., 2005. Managing disruption risks in supply chains. Prod. Oper. Manag. 14 (1), 53–68.
Knemeyer, A.M., Naylor, R.W., 2011. Using behavioral experiments to expand our horizons and deepen our understanding of logistics and supply chain decision making. J. Bus. Logist. 32 (4), 296–302.
Koriat, A., Sheffer, L., Ma'ayan, H., 2002. Comparing objective and subjective learning curves: judgments of learning exhibit increased underconfidence with practice. J. Exp. Psychol.: General. 131 (2), 147–162.
Krueger, J.I., Mueller, R.A., 2002. Unskilled, unaware, or both? The better-than-average heuristic and statistical regression predict errors in estimates of own performance. J. Pers. Social. Psychol. 82 (2), 180–188.
Kumar, A., 2009. Hard-to-value stocks, behavioural biases, and informed trading. J. Financ. Quant. Anal. 44 (6), 1375–1401.
Larrick, R.P., Burson, K.A., Soll, J.B., 2007. Social comparison and confidence: when thinking you're better than average predicts overconfidence and when it does not. Organ. Behav. Human. Decis. Process. 102, 76–94.
Li, J., Tang, Y., 2010. CEO hubris and firm risk taking in China: the moderating role of managerial discretion. Acad. Manag. J. 53 (1), 45–68.
Lichtenstein, S., Fischhoff, B., 1977. Do those who know more also know more about how much they know? Organ. Behav. Human. Decis. Process. 20, 159–183.
Loch, C., Wu, Y., 2008. Behavioural operations management. Found. Trends Technol. Inf. Oper. Manag. 1 (3), 121–132.
Lowe, R., Ziedonis, A., 2006. Overoptimism and the performance of entrepreneurial firms. Manag. Sci. 52, 173–186.
Lu, X., Shang, J., Wu, S.Y., Hegde, G.G., Vargas, L., Zhao, D., 2015. Impacts of supplier hubris on inventory decisions and green manufacturing endeavors. Eur. J. Oper. Res. 245 (1), 121–132.
Machuca, J.A.D., Barajas, R.P., 2004. The impact of electronic data interchange on reducing the bullwhip effect and supply chain inventory costs. Transp. Res. E 40 (3), 209–228.
Malmendier, U., Tate, G., 2005. CEO overconfidence and corporate investment. J. Financ. 60 (6), 2661–2700.
Malmendier, U., Tate, G., 2008. Who makes acquisitions? CEO overconfidence and the market's reaction. J. Financ. Econ. 89, 20–43.
March, J., Shapira, Z., 1987. Managerial perspectives on risk and risk taking. Manag. Sci. 33, 1404–1418.
Moore, D., Healy, P.J., 2008. The trouble with overconfidence. Psychol. Rev. 115 (2), 502–517.
Nienhaus, J., Ziegenbein, A., Schoensleben, P., 2006. How human behaviour amplifies the bullwhip effect. A study based on the beer distribution game online. Prod. Plan. Control 17 (6), 547–557.
Odean, T., 1998. Volume, volatility, price, and profit when all traders are above average. J. Financ. 53 (6), 1887–1934.
Park, Y.J., Santos-Pinto, L., 2010. Overconfidence in tournaments: evidence from the field. Theory Decis. 69, 143–166.
Presson, P.K., Benassi, V.A., 1996. Illusion of control: a meta analytic review. J. Social. Behav. Pers. 11, 493–510.
Radzevick, J.R., Moore, D.A., 2011. Competing to be certain but wrong: market dynamics and excessive confidence in judgment. Manag. Sci. 57 (1), 93–106.
Ren, Y., Croson, R., 2013. Overconfidence in newsvendor orders: an experimental study. Manag. Sci. 59 (11), 2502–2517.
Russo, J.E., Schoemaker, P.J., 1992. Managing overconfidence. Sloan Manag. Rev. 33 (2), 7–17.
Shefrin, H., 2001. Behavioural corporate finance. J. Appl. Corp. Financ. 14, 113–124.
Shipman, A.S., Mumford, M.D., 2011. When confidence is detrimental: influence of overconfidence on leadership effectiveness. Leadersh. Q. 22, 649–665.
Simon, M., Houghton, S.M., 2003. The relationship between overconfidence and the introduction of risky products: evidence from a field study. Acad. Manag. J. 46 (2), 139–149.
Soll, J.B., Klayman, J., 2004. Overconfidence in interval estimates. J. Exp. Psychol.: Learn. Mem. Cogn. 30, 299–314.
Sterman, J., 1989. Modelling managerial behaviour: misperceptions of feedback in a dynamic decision making experiment. Manag. Sci. 35 (3), 321–339.
Tang, C.A., Tomlin, B., 2008. The power of flexibility for mitigating supply chain risks. Int. J. Prod. Econ. 116 (1), 12–27.
Thompson, S.C., Armstrong, W., Thomas, C., 1998. Illusions of control, underestimations, and accuracy: a control heuristic explanation. Psychol. Bull. 123, 143–161.
Tokar, T., 2010. Behavioural research in logistics and supply chain management. Int. J. Logist. Manag. 21 (1), 89–103.
Truong, T.H.D., Luong, H.T., Kim, Y., 2008. A measure of the bullwhip effect in supply chains with stochastic lead time. Int. J. Adv. Manuf. Technol. 38, 1201–1212.
Wagner, S.M., Neshat, N., 2010. Assessing the vulnerability of supply chains using graph theory. Int. J. Prod. Econ. 126 (1), 121–129.
Wu, D., Katok, E., 2006. Learning, communication, and the bullwhip effect. J. Oper. Manag. 24 (6), 839–850.

Please cite this article as: Ancarani, A., et al., Measuring overconfidence in inventory management decisions. Journal of Purchasing and Supply Management (2016), http://dx.doi.org/10.1016/j.pursup.2016.05.001