
A literature review on the anomalies observed in the newsvendor ordering behaviour

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Abstract: In a classical newsvendor setting, the retailer places an optimal order quantity by finding a trade-off between overstocking and understocking of products. However, it has been observed that even the experienced managers do not always order an optimal quantity. In the early 2000s, researchers in the area of behavioural economics have taken roots to analyse the behavioural dynamics influencing the inventory ordering decisions in newsvendor settings. Later, a large number of research studies has focused its attention on understanding the cognitive biases and heuristics involved in the process of inventory decisions. The influence of individual heterogeneity such as gender differences, cultural differences, and hierarchical differences on the ordering pattern of individuals are also analysed. This article provides a detailed summary of the research progress in the behavioural newsvendor problem. It also provides a framework of the existing literature and identifies the research gaps to point future research possibilities.

Keywords: behavioural economics; behavioural operations; experimental economics; newsvendor ordering; bounded rationality; cognitive biases and heuristics.

Reference to this paper should be made as follows: Yamini, S. (2021) 'A literature review on the anomalies observed in the newsvendor ordering behaviour', *Int. J. Enterprise Network Management*, Vol. 12, No. 1, pp.32–55.

Biographical notes: S. Yamini holds a PhD and MS (by research) degree from the Indian Institute of Technology Madras. She has publications in reputed international journals and has presented her research papers in various leading international conferences of repute. She has also received several awards including the 'Emerging Economics Doctoral Student Award' from POMS (USA), the EthOR Award from the EURO Working Group on Ethics and OR, and the Highly Commended Award in the 'Operations and Production Management' category at the 2018 Outstanding Doctoral Research Awards by Emerald publishers and European Foundation for Management Development (EFMD).

1 Introduction

1.1 *The traditional newsvendor problem*

The newsvendor problem is one of the customary and most important problems in operations and supply chain management. The standard newsvendor problem first modelled by Arrow et al. (1951) solves the dilemma of a newsvendor, who every day decides on the number of newspapers to buy from his supplier in order to satisfy the daily demand, without knowing the demand of the newspaper. The newsvendor will face a trade-off between overstocking and under-stocking, where there will be a loss if the demand is underestimated; or else, there will be an operating cost for the unsold goods if the demand is overestimated. Thus, the newsvendor model captures the stochastic inventory problem, where the newsvendor has to place an order for a seasonal product that has to be sold before it becomes obsolete without knowing the exact demand during that season. The standard newsvendor model in inventory management literature is based on risk-neutral decision-making with an objective of maximising expected profit for a single selling period while the demand is considered to be exogenous (Porteus, 1990; Khouja, 1999; Cachon, 2003). The classical newsvendor problem (Porteus, 1990; Khouja, 1999; Cachon, 2003) for detailed review of the newsvendor problem and its extensions) is represented in the form of an influence diagram in Figure 1.

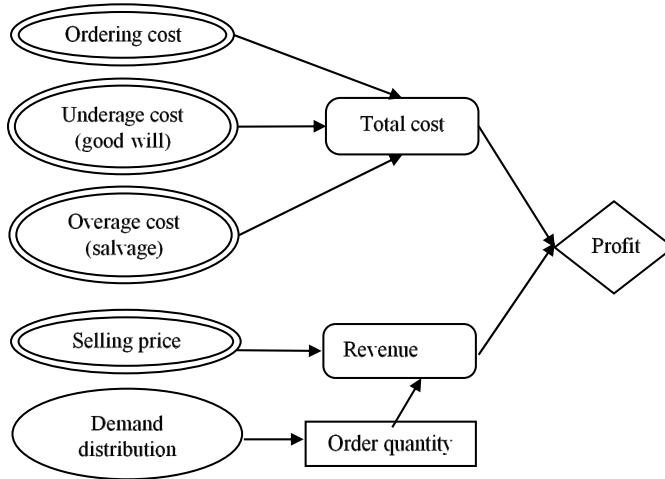
1.2 *Applications of newsvendor problem*

Newsvendor problem is one of the well-researched and widely-used models in supply chain management, as the structure of the problem is closely related to many real-life business problems (Moritz et al., 2013). The model began with Edgeworth (1888), who considered the money that the bank has to hold in reserve as a product and its inventory has to be well-managed, so that it can satisfy random cash withdrawals from depositors. It finds applicability in many contexts, both large and small, with a wide spectrum of management decision-making scenarios such as inventory management, capacity planning, yield management, pricing and revenue management, supply chain contracts, insurance, and finance (Su, 2008). The insights from the analysis of this problem have a wide range of implications for handling a variety of industry problems including operating-room management in hospitals (Olivares et al., 2008; Wachtel and Dexter, 2010), airline schedule management (Deshpande and Arikan, 2012) and fashion goods industry (Donohue, 2000).

The operating-room managers who plan for staffing and the airline schedulers who block the actual travel time for flights face a scenario which is analogous to the newsvendor decision-making problem. In case of operating-room planning, the managers either schedule additional staffing even if it is unnecessary or would plan below optimal levels leading to a shortage of staff. In the airline scheduling problem, allocating too much scheduled block time creates leftover inventory (overage) costs for the airline that may include the cost of aircraft on ground (being idle) and pilot compensation. On the other hand, if too little scheduled block time is allocated for a flight, then the actual block time is likely to exceed the scheduled block time resulting in flight delays and shortage (underage) costs for the airline including overtime costs and the cost of dealing with unhappy customers. Retail stores such as small coffee shops have to order pastries from

bakeries without knowing the number of customers who will make a purchase that day. In other similar scenarios decision-makers must decide the inventory of fashion goods, repair parts, cars and computers without knowing the demand. Revenue management is also a closely related problem which involves decision-makers who have a set of goods (like the number of aircraft seats or hotel rooms) and must make pricing decisions so as to maximise the expected revenue (Bitran and Caldentey, 2003).

Figure 1 Influence diagram for newsvendor problem



1.3 Extensions of the newsvendor problem

Porteus (1990) provided an exceptional review on the newsvendor models which minimises the expected cost and improves the operational efficiency, where the demand is considered as an exogenous parameter. Later, the classical newsvendor problem has been extended by considering the customers' purchasing decision as well as the newsvendor's stocking decision which is called as inventory dependent demand in the operations and supply chain literature. Petruzzi and Dada (1999) reviewed a broad range of literature which incorporates pricing into the single period and multi-period newsvendor model. Khouja (1999) reviewed the extensions of newsvendor problem dealing with different objectives and utility functions including risk preferences (Arcelus et al., 2012), different supplier pricing policies, different news-vendor pricing policies and discounting structures, different states of information about demand, constrained multi-products, multiple-products with substitution, random yields, and multi-location models. Recently, supply chain models with multiple parties having conflicting objectives are seeking the attention of many researchers in the area of supply chain. Game theory has become an important tool to solve these models.

Cachon (2003) referred to a variety of newsvendor problems in supply chain setting which primarily focuses on contractual mechanisms. Netessine and Tang (2009) presented a review of literature in supply chain management that challenge the traditional assumptions related to exogenous demand, fully observable information and actions, and the counter-intuitive results that are more impactful (Cachon, 2012). They also discussed about the economic analytical models which uses game theory, theory, mechanism design

to capture the hidden information and highlighting the importance of information sharing (Kumar et al., 2017). Qin et al. (2011) have provided an extensive analysis by relaxing some of the traditional assumptions in newsvendor setting,

- 1 analysing the association of demand with market price, marketing effort exerted by the buyer and quantity stocked by the buyer
- 2 studying the impact of supplier's alternative price-discounting schemes on buyer's optimal order quantities, where a fixed supplier's price per unit is set in newsvendor setting
- 3 examining the effect of buyer's risk profiles on sourcing decision, where the basic newsvendor model assumes that the buyers are risk neutral.

These parameters will also play an important role in manipulating other related decisions of the organisation.

1.4 Behavioural concerns in newsvendor decision-making

The traditional OM focuses on the equipment induced causes for any form of poor performance or low efficiency rather than the people who are involved in the process. When it comes to inventory management, the newsvendor research has turned its attention towards understanding the anomalies in making inventory related decision (particularly in newsvendor ordering) due to the behavioural biases of the stakeholders and it has moved into looking at the alternative models that incorporate bounded rationality. Many decision-makers who has repeated exposure to the newsvendor problem make sub-optimal choices, even though they are accustomed to the problem (Bolton and Katok, 2008; Becker-Peth and Thonemann, 2018). Because of the lack of historical data and also the unforeseen fluctuations in cost parameters, the real-time managers make subjective judgements in newsvendor-type decisions (Fisher and Raman, 1996). The traditional OM focuses on the equipment induced causes for any form of poor performance or low efficiency rather than the people who are involved in the process. Later, a variety of research studies in OM related problems including revenue management, supply chain management, product development, procurement, quality management, strategic sourcing, risk analysis and process improvement have looked into its behavioural aspect. Hence, understanding the decisions concerning newsvendor using a behavioural lens is very important. Recently, operations management (OM) focuses on human decision-making and its association with OM theory and practice.

The significance of behavioural operations could be well understood only if the researchers realise that people are integrated in most of the contexts studied within OM. Right from the managers – who make decisions, to the customers – who buy the products, the entire process involves humans including the employees who strive to improve the practices (Boudreau et al., 2003; Loch and Wu, 2007; Bendoly et al., 2010). A significant amount of research studies have analysed the behavioural foundations of bull-whip effect (Serman, 1989; Croson and Donohue, 2002, 2006), negotiations, auctions and other bargaining systems (Bolton et al., 2003). These anomalies were better explained from a behavioural perspective than from an operations perspective. Behavioural operations management (BOM) ranges from understanding an individual's behaviour to eventually supporting in the designing and improving of processes and

supply chains (Croson et al., 2013). It also realises that human beings have a limited ability and limited capacity to understand and process and the information they have. People's judgements and choices are affected as a consequence of these cognitive limitations in the form of errors and biases.

Even though the studies on behavioural operations literature often seems to be associated with the inventory management and production practices, Croson et al. (2013) notes that only a less number of articles (approximately 18%) recently focuses on integrating the OM and human resource management in the fields of inventory and production management (Kundu et al., 2015). The detailed systematic review of the research in the field of behavioural operations and supply chain management by Fahimnia et al. (2019) categorised the articles into 12 emerging topics in the context of operations. Their analysis show that inventory management is one of the most popular context for behavioural operations researchers. Particularly in inventory management, the newsvendor research has turned its attention towards understanding the anomalies in making inventory related decision due to the behavioural biases of the stakeholders and it has moved into looking at the alternative models that incorporate bounded rationality. The goal of this paper is to provide an extensive review of the research which focuses on the behavioural issues related to newsvendor problem that can benefit the researchers. It is comprehensively put forth to document the insights from the behavioural aspects of newsvendor related research post year 2000. Further, it identifies fruitful venues which are not touched upon by the current literature, for future research that can enrich the existing knowledge base.

2 Anomalies observed in the newsvendor ordering pattern

The observations from the newsvendor experiments suggested that the decisions made by real people were substantially different from the optimal decisions predicted solely based on mathematics. The findings from Fisher and Raman (1996) suggested that decision-makers do not solve the inventory problems as the theory predicts, where a manager may not maximise the expected profit. In contrast to the traditional newsvendor problem which suggested that the decision-maker is a perfect optimiser, the actual decision-makers systematically deviate from the critical fractile solution, as they are boundedly rational. The biases described in cognitive psychology, which studies the mental processes that trigger behaviour, thinking, deciding, reasoning, and to some extent motivation and emotion, are the major causes of this boundedly rational behaviour (Gilovich et al., 2002). Etzioni (1986) claimed that the rational behaviour is actually stimulated by the definition of cost. In fact in reality, the human behaviour is largely administered by emotions and other inconsistent values that are highly irrational.

The deviation of newsvendor's optimal order quantity from the profit maximisation order quantity is referred as decision bias in the newsvendor problem. Research from psychology (judgment and decision-making field) showed that most individuals use heuristics and suffer from a variety of biases in their decision-making process (Ren and Croson, 2013). The recent extensions in the newsvendor literature is the adoption of alternative choice models which considered the impact of various behavioural biases on the newsvendor's stocking and pricing decisions. There are only a very few review articles available in BOM that discuss about the experimental research in operations and

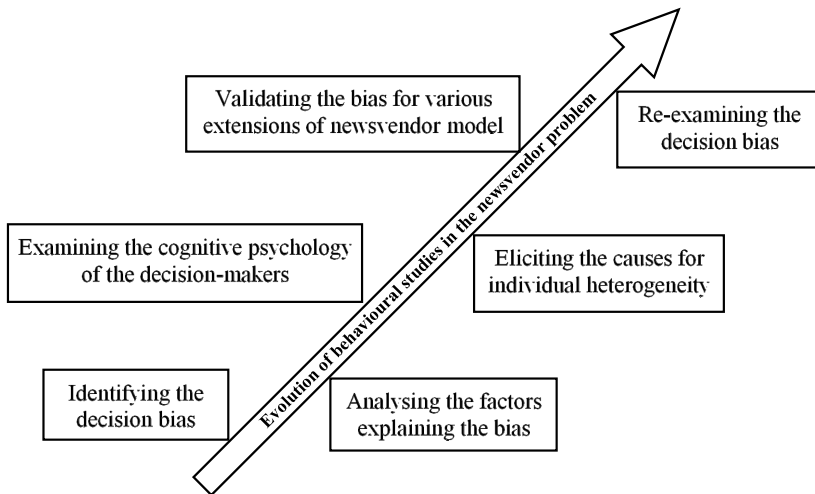
supply chain management (Boudreau et al., 2003; Bendoly et al., 2006; Gino and Pisano, 2008; Bendoly et al., 2010).

Many other anomalies related to standard supply chain settings that challenge the validity of theoretical results have also been identified by the experimental research studies. It is important to understand these deviations, because in reality many of these decisions are made by human decision-makers who suffer from similar psychological biases (Brucoleri et al., 2014). The motivation of this paper is to review the experimental studies of newsvendor that discuss about the deviation from traditional results in various alternative settings.

2.1 Evolution of behavioural studies in the newsvendor problem

The evolution of this research is divided into various phases based on the advancements made in an effort to comprehend the newsvendor decision-making behaviour. Figure 2 shows the progress made in the experimental studies of newsvendor over time.

Figure 2 Evolution of behavioural studies in the newsvendor problem



a Identification

The identification phase contains research studies which evidences the sub-optimal preferences of the newsvendor. A number of experimental studies have confirmed the existence of decision bias by repeating the experiment for many rounds.

b Analysis

In this phase, the effects of learning and feedback on the decision-making behaviour of the manager is analysed. Further adaptive learning model and bounded rationality models are developed to incorporate the effects of experience and training.

c Examination

Later, many research studies have attempted to examine the psychological aspects and the role of cognitive heuristics that describe the decision bias. Further, they also

investigate the impact of environmental factors such as demand on newsvendor decision-making.

d Elicitation

The decision-making trend observed in newsvendor research indirectly admits that the decision-makers are homogenous. Then, research has progressed in the direction of eliciting the causes for individual differences in the newsvendor type decisions.

e Validation

Well ahead, researchers in this area wants to validate the existence of the decision bias in various extensions of the newsvendor model where the traditional assumptions are not followed. Similarly, the presence of the bias in different supply chain and contract settings are also confirmed.

f Re-examination

The effect of the decision bias is revisited to understand its effects on the performance metrics. Only a very few studies propose remedies or strategies to overcome the newsvendor decision bias.

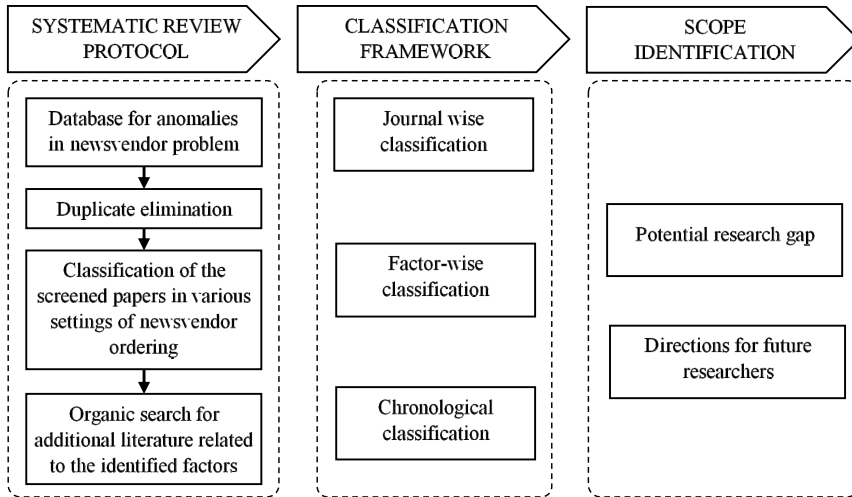
2.2 *Objectives of this study*

A total of 95 research papers published in reputed journals between 2000 and 2019 in the field of behavioural operations addressing the anomalies observed in the newsvendor problem is considered to write this review article. The journals which frequently publishes the behavioural newsvendor research is highlighted in Table 1. The summary of the results observed from these work can make the future researchers understand that the pull-to-centre (PTC) effect is not just applicable to a classical newsvendor setting, but also to various other alternative conditions. It also gives the readers a flavour of the possible individual differences influencing the decision-making behaviour. The research studies reviewed in this paper borrow the theories and conceptions from organisational behaviour and behavioural economics to investigate their impact on inventory decisions. The experimental studies on the newsvendor problem answered the following questions regarding the decision-making behaviour of managers.

- 1 What were the frequently observed behavioural biases exhibited by the decision-makers in a newsvendor problem?
- 2 What kind of information helped in learning and making better inventory decisions?
- 3 What was the impact of individual heterogeneity in decision-making behaviour?
- 4 How the supply chain settings and parameters influenced the ordering and pricing behaviour of decision-makers?

3 **A framework for the review**

The framework for the review (refer Figure 3) shows the steps followed in the review process, followed by a framework of the taxonomy to build an outline for future research.

Figure 3 Framework for the review

This paper develops a three-fold classification framework based on the journals, chronology and the factors influencing the decision-making behaviour. First a fundamental classification is provided based on the overview of the reviewed journal papers. Second, a classification based on the research contribution was performed to know the anomalies in various newsvendor settings. Third is a chronological classification to understand the evolution of behavioural studies on the newsvendor problem. This classification framework developed from literature is intended to help the future researchers who are planning to work on the PTC effect or any other behavioural aspects of the newsvendor problem. It helps them to appreciate and explore the research that has been carried out in this area and also to get a fair idea about the possible research gaps to look forward.

The remainder of this paper is organised as follows. In Section 5, the deviation in the newsvendor ordering pattern and the possible behavioural biases are explained. It also focuses on showing the number of papers published in the area of newsvendor decision bias over the years and the major journals which publishes research studies related to the behavioural aspects of the newsvendor. This section is followed by a detailed discussion to understand learning adaptability, impact of feedback information and its frequency on the inventory decision-making. Section 6 highlights on the anomalies observed in the ordering pattern due to individual heterogeneity. Section 7 elaborates the behaviour of a decision-maker in a supply chain or newsvendor settings where the traditional assumptions are not followed. It also confirms the existence of newsvendor decision bias in these settings. It is followed by a classification in the chronological order to know the direction in which the work is progressed in this area. Section 8 highlights on the scope for future research pertaining to the extensions of newsvendor problem and the inconsistencies observed in the newsvendor decision-making. Section 9 highlights on the limitations of the study and the inferences from a practitioners' perspective. Section 10 covers the concluding portion that gives a summary of the review.

Figure 4 shows the growing number of research articles published in the area of behavioural newsvendor problem. The journals which shows an increasing interest by

offering special edition and frequently publishes research articles related to the behavioural operations include *Management Science*, *Production and Operations Management*, *International journal of Production Economics*, *Manufacturing and Service Operations Management*, *Operations Research*, *European Journal of Operations Research*, *Omega*, *Journal of Operations Management*, *International Journal of Production Research* and *Decision Sciences*. This classification will guide academicians who wish to explore and conduct research in this area. One can also notice an increase in the number of publications over the years.

Figure 4 Number of research articles published in the behavioural aspects of newsvendor (see online version for colours)

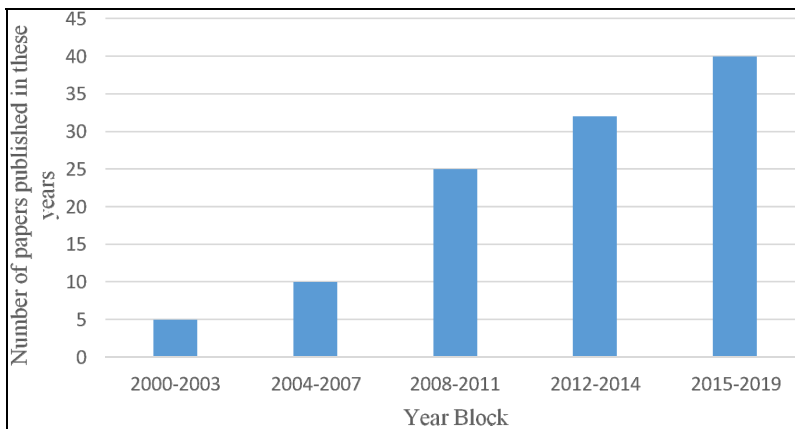


Table 1 Publications across journals related to anomalies in the newsvendor problem

<i>Journals</i>	<i>No. of papers</i>
<i>Management Science</i>	14
<i>Production and Operations Management</i>	9
<i>International Journal of Production Economics</i>	2
<i>Manufacturing & Service Operations Management</i>	9
<i>Operations Research</i>	4
<i>European Journal of Operational Research</i>	2
<i>Omega</i>	4
<i>Journal of Operations Management</i>	6
<i>International Journal of Production Research</i>	1
<i>Decision Sciences</i>	2
<i>Computers & Industrial Engineering</i>	1
<i>Decision Support Systems</i>	1
<i>Economics Letters</i>	1

4 Newsvendor decision bias: PTC effect

Regardless of the antiquity of the newsvendor model, a behavioural perspective of the newsvendor problem is very recent, which evidences that inventory managers often deviate from the optimal newsvendor solution. The seminal study of Schweitzer and Cachon (2000) show how individuals make biased newsvendor ordering decisions in a controlled laboratory experiment. They found that individuals consistently ordered lesser than the expected profit-maximising quantity under high-safety stock or high-profit settings. On the other hand, they ordered more than the optimum under low-safety stock or low-profit settings. This bias is also known as the ‘*PTC*’ effect, since the individuals order a quantity between the mean of the demand distribution and the expected profit maximising quantity.

Starting from Schweitzer and Cachon (2000), a number of newsvendor experiments conducted by several researchers with the undergraduate business or management students and executive MBA students (ranging from 30 to 250 participants) confirmed the existence of PTC effect (Bolton and Katok, 2008; Benzion et al., 2008; Bostian et al., 2008; Lurie and Swaminathan, 2009; Gavirneni and Isen, 2010; Bolton et al., 2012; Rudi and Drake, 2014). This average tendency of placing an order outside the normative order quantity is referred as level bias (Rudi and Drake, 2014). In most of the newsvendor experiments, participants were given a uniform or normal demand distribution functions under high and low profit margin conditions to make inventory decisions. In other words, a symmetric demand distribution is used to explain the PTC effect. The future researchers can explore to differentiate the model by modifying the demand distribution (Köster and Schenk-Mathes, 2016).

The decision-making bias witnessed in PTC effect can also be noticed in other settings which replicates the newsvendor framework. Castañeda Acevedo (2013) developed a decision-making model for new product development under innovation uncertainty, whose setting is analogous to the newsvendor model. Interestingly, a decision-making bias similar to the PTC effect is noticed in his experiment. The decision-makers exhibit a tendency to underreact, when the innovation costs and uncertainty indicate that more resources with a determined scope is required. However they overreact, when the innovation costs and uncertainty demands for either fewer resources or ambitious scopes. In addition to this, threshold chasing bias is also observed, where the decision-makers chase uncertainty thresholds realised in previous innovation efforts. Zhang et al. (2019) studied the behavioural aspects of inventory decision making in the presence of strategic customers. It shows that the increase in percentage of strategic customers reduces the retailer’s ordering bias under low cost setting, while it increases the bias when the cost is high.

5 Adaptability of the newsvendor decision-making behaviour

A significant number of research studies examine whether experience and training can improve the ordering decisions of the newsvendor. Some of the researchers are interested in finding the information that is relevant for better decision-making. This section provides an overview of these facets that elucidates the decision bias.

5.1 Constraints on learning dynamics

The PTC effect has been replicated by numerous studies, including Bostian et al. (2008), Benzion et al. (2008), Bolton and Katok (2008), Katok and Wu (2009) and Moritz et al. (2013) to illustrate the robustness of this effect and to examine if anything can be done to induce better ordering decisions. These studies examined the impact of learning dynamics in the newsvendor setting and showed that the biased orders are still observed though the behaviour improves over time. The experience-weighted attraction (EWA) framework by Camerer and Hua Ho (1999) is used to model the learning dynamics in newsvendor settings. Bostian et al. (2008) developed an adaptive learning model (Denrell, 2007) that incorporates memory, reinforcement, and probabilistic choice to explain individual decisions. The model suggested that in contrast to the strategic player who anticipates other player's reaction, an adaptive player makes decisions in response to only their own previous experience. They conducted a laboratory experiment integrating their learning model to help the decision-makers for adaptive learning. Tracking the observed data pattern across treatments showed that the PTC effect exists even with doubled pay-off, which signals that pay-off insensitivity is a sufficient justification for this effect.

Contradicting the adaptive learning model provided by Bostian et al. (2008), the experimental results (which consists of 40 decision rounds) of Ho et al. (2010) documented that they were not able to find any significant pattern of learning. Consistent with the results of Bolton and Katok (2008) and Ho et al. (2010) also reported that the orders exhibited a slow movement toward the optimal order only after 30 rounds. Further they suggested momentous directions for the future scholars to carry out behavioural research in supply chain. Benzion et al. (2008) conducted a repeated experiment over 100 periods and found that decision-makers are affected from previous experiment, where they tend to increase their orders if the previous period demand is higher than the order placed in that period and tend to decrease their order otherwise. Though the decision-makers do not converge to the expected value of optimal order in the newsvendor problem, they learn throughout the experiment to reduce this effect. Bolton and Katok (2008) believed that people can learn to solve stochastic problems when they have experience and are given feedback. Hence they investigated whether enhancing the experience or feedback (learning by doing) lead to better inventory decisions. The results implied that learning by doing improves the performance of stocking decisions, yet the bias persists. It was observed from the experiment that drawing conclusions from inappropriately small samples across multiple decision periods and responding to short-term information will hinder the performance as decision-makers may overreact to short-term fluctuations. However, anecdotal evidences showed that this tendency for 'too quick' conclusions based on small samples seems to vary widely between individuals.

5.2 Significance of information availability

Recent advancement in information technology have intensely improved the speed of delivery of information and the possibility for the decision-makers to track real-time information and get frequent feedback about the decision (Lurie, 2004). The information economics and adaptive learning theories suggests that presenting more information is strictly better than giving less information. Though it aids the decision-makers to respond more quickly to the changes in environment by seeing the consequences of their action, Lurie and Swaminathan (2009) found that more frequent information may actually

degrade the performance. Because, the decision-makers may focus more on recent data points, fail to compare multiple time period information and overreact to random noise. Similarly, Serman (1989) also showed that the poor performance of decision-makers is due to the misperceptions of the feedback provided. He suggested that incentives can help in regulating the frequency of feedback and channelising the way in which information is processed by the decision-makers.

The newsvendor decision-making process is classified into three phases namely, information gathering, analysis and final decision, where most of the experimental research focus on the results from final decision stage and less is known about the information gathering or analysis stage (Gavirneni and Isen, 2010). To understand more about this phase, they investigated the newsvendor ordering anomaly using verbal protocol analysis by observing the information gathering efforts exerted by the decision-makers to make their inventory decisions. From the experiment, they found that a majority of the decision-makers were eager to know about the information on product type, industry settings, past decisions and competitor's situation. Bolton and Katok (2004) investigated the impact of providing only relevant information on inventory decision-making. In their experiment, they provided information about demand, history of their orders and feedback after order to see if it can help to mitigate anchoring and make better inventory decisions. From the experimental results, they noticed that enhancements such as providing hands-on learning experience is more effective than providing an upfront statistical analysis that includes all the information. In fact, the study conducted by Becker-Peth et al. (2013) confirmed the inference made by Bolton and Katok (2004). Becker-Peth et al. (2013) conducted an experiment by giving all information related to finding an optimal order quantity for a newsvendor problem. However the information provided to the decision-makers never aided them in finding the exact value.

Ho et al. (2010) illustrated that the number of orders decreased when the decision-makers have to make a decision by calculating the cost of left over inventory and the orders increased when they are supposed to calculate the cost of stock-outs. Hoskin (1983) demonstrated that giving a feedback about opportunity cost to the decision-makers improves their learning and decision-making. Later, Schiffels et al. (2014) examined if the assessment of costs (a biased perception of opportunity costs and penalty costs) can explain the newsvendor decision-making behaviour. The experimental results demonstrated that the decision-makers are more sensitive to penalty costs and their average order quantities are more than the newsvendor problem with opportunity costs. Gavirneni and Isen (2010) also observed that the sequence in which the costs are revealed has a significant impact on the order quantity chosen. Deviations from optimal values may also be affected by the contextual factors such as the information available to the newsvendor, the acknowledgement after every period in the form of feedback and the overall experience gathered (D'Urso et al., 2017).

6 Implications from individual heterogeneity

Recently, the newsvendor literature is keen on measuring the individual traits to ascertain the discrepancy in the decision made by every individual. In the process of understanding how people make inventory decisions, several studies have observed wide variation in

ordering between the individuals. Though a lot of studies reported that human decision-making is constrained by bounded rationality (Kahneman, 2003), individual differences in cognitive abilities and skills predict normatively superior judgment and decision-making (Frederick, 2005). Wu and Chen (2014) suggested that more behavioural acumens can be revealed by examining the decisions at the individual level. Research in various disciplines are also keen on measuring the attributes of individual respondents (known as individual differences) to identify the variance in results (Stanovich and West, 2000). Nevertheless, traditionally research on newsvendor problems assumed that the decision-makers were homogenous. Later, few studies have documented the causal factors explaining the discrepancy in individuals. This section provides a summary of the research carried out in this arena.

6.1 Similarities between multiple subject pools

It is believed that higher the level of education and their level in organisational hierarchy, the higher will be the performance of managers (Child, 1972). However, it is observed that the newsvendor ordering bias persists in multiple subject pools, where the bias is not only observed with the managers who have similar ordering experience but also with the students in laboratory experiments (Bolton et al., 2012). The only difference between both of them is that the students may not experience any organisational factors or personality issues as a consequence of the decision made by the managers. In other words, the knowledge or experience in management does not improve the decision-making in a newsvendor environment. Since the students are not tested to react for their individual life experiences, it is not necessary to use the actual workers as subjects (Bendoly et al., 2006). The experimental studies of Brown and Tang (2006) demonstrated that both students and professional buyers select an order quantity lesser than the newsvendor solution, while most of the students order according to the mean demand forecast and professional buyers tend to order below the mean demand forecast. Their analysis indicated that performance metrics other than maximising expected profit or minimising expected cost should be considered in the objective function to understand the influence of individual differences on ordering decisions. Katok et al. (2008) conducted a newsvendor experiment with students as well as managers focusing on the service level agreement and the effect of review period on ordering decisions. They also observed that the students and managers do not behave substantially different. A number of other studies that compared subject pool performance (comparison between students and professionals) on a variety of tasks found no difference or only a small difference (Ball and Cech, 1996; Fréchette, 2016). Robinson et al. (2017) discussed about obtaining a sufficient sample size for laboratory based experimental studies in newsvendor setting. Though the laboratory experiments can only use a small number of participants, they show that the interaction between multiple players can then be simulated using an agent based simulation to generate a large sample set of decisions.

6.2 Observations from cultural differences

The laboratory experiments conducted by Feng et al. (2011) on classic newsvendor problem showed that PTC effect is more prominent for Chinese than Americans. They found that the average order quantities of Chinese decision-makers were closer to the anchor of mean demand than those of American decision-makers. Cui et al. (2013)

conducted a verbal protocol analysis based newsvendor experiment and noticed that Chinese decision-makers were able to come up with a new number as their decision whereas American decision-makers anchor one of the given numbers as their decision. Moreover, they observed that Chinese decision-makers were more cautious towards their choices and ask more questions before taking decisions. Because of a healthier quantitative training, Chinese are more mathematically competitive and they keenly look for demand distribution information while making newsvendor decisions rather than using heuristics (Stigler and Perry, 1988). Hence Cui et al. (2013) suggested that it is better to provide a decision support system (DSS) that offers complete information to these active information seekers. Heterogeneity can enter the picture in almost all types of settings, because people react differently to their emotions, they also respond differently to their instincts. For example, they may have different degrees of loss aversion or different abilities to compute the optimum. The differences in individuals provides a potential opportunity for the future researchers to explore and analyse the newsvendor decision-making problem from this perspective. Li et al. (2019) find that Chinese subjects engross well in demand chasing than American subjects. Nevertheless, these annotations may not hold when the members in the cross-cultural comparison have the same cognitive reflection test score, implying that the cultural differences also affect how individual differences manifest in newsvendor decisions.

6.3 Expositions from gender differences

The experiment by De Véricourt et al. (2013) on newsvendor ordering behaviour revealed significant gender differences. They demonstrated that in high margin settings, males have a tendency to order more than females and achieve higher profits, while there are no differences in low margin settings. They illustrated that the gender difference in newsvendor decisions is due to the gender difference in risk preferences, where the proclivity of males towards financial risk attitude (not social risk attitude) makes them to order more in high margin settings. They measured the financial risk taking ability of the decision-makers on domain-specific risk taking (DOSPERT) scale. They showed that the financial risk taking ability plays a mediating role in the order quantity decisions. Gender differences in risk preferences has been well documented by Byrnes et al. (1999), Harris et al. (2006) and Croson and Gneezy (2009). The collective remark given by these researchers is that men have a greater desire for risk than female. In fact, this is quite evident in financial studies reported by Barber and Odean (2001) and Dorn and Sengmueller (2009).

6.4 Consequences of individual attributes

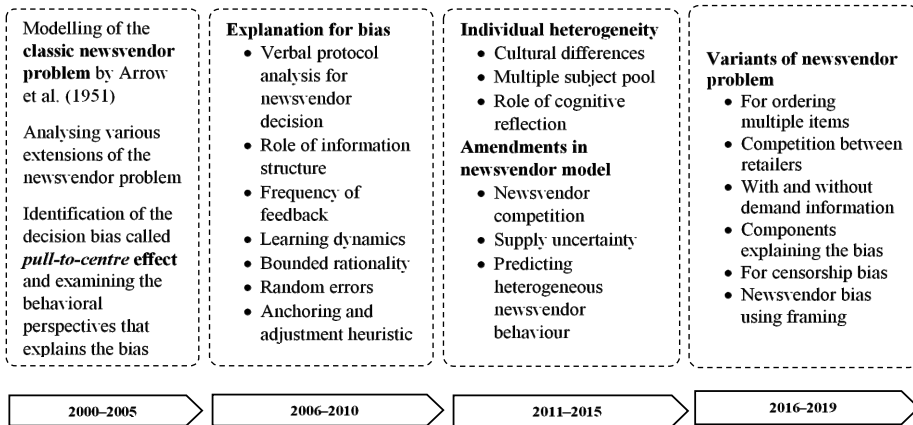
The evidences from the newsvendor experiment show that the major reasons for deviations from optimality are related to individual attributes (Bendoly et al., 2006). For instance, the cognitive reflection approach used by the individuals to intuitively or analytically process a decision affects the final outcome in various critical ratio settings (Frederick, 2005). Moritz et al. (2013) showed that the individuals with high level of cognitive reflection exhibits a lower tendency to chase demand and the ones with low level of cognitive reflection scores are more likely to have greater variance in order quantities. Later, Moritz et al. (2014) showed that the decision-makers with the capability

to balance intuitive judgment with cognitive thoughts (which is also indicated by the measure of cognitive reflection test) tend to have lower forecast errors by controlling for individual intelligence. Further, they provided evidence that the forecasting performance is affected by the decision speed.

7 Newsvendor ordering behaviour under unconventional environment

The PTC effect is observed in a classic newsvendor setting, which is considered for a single period, where there is only one retailer who orders a single product under demand uncertainty, assuming other parameters to be exogenous in nature. However reality may challenge these conditions or assumptions, which motivates the researchers to understand the newsvendor decision-making behaviour under these settings. Recent research studies focuses on knowing the factors impacting the ordering preferences in such environment. Tong (2012) conducted an experiment where the participants have to make ordering decisions when there is a diversified portfolio consisting of high to low profitability items. Castañeda Acevedo (2013) studied the impact of cognitive dissonance effects on ordering behaviour when there are multiple items. The results show that bundling important with non-important items increased the important items’ service level. Later Castañeda and Gonçalves (2017) extended their study to understand the behavioural biases exhibited by a budget constrained newsvendor ordering multiple items under high and low profit conditions.

Figure 5 Chronological classification of the experimental studies on newsvendor



The ordering pattern of newsvendors who have the ability to determine both the selling price and the order quantity of a given item is also studied. Most of the experimental research on understanding behavioural biases of newsvendor ordering pattern considers the impact of a single newsvendor. However in reality, the firms rarely sell in a monopoly market and they often compete with their rivals. There are also studies that analyse the behaviour of newsvendor in a competitive environment. The investigation made by Jiang et al. (2011), Ovchinnikov et al. (2015), Quiroga et al. (2016), Zhao and Zhao (2016) and Feng and Zhang (2017) are notable.

Most of the experimental research on understanding behavioural biases of newsvendor ordering pattern considers the impact of a single newsvendor. However in reality, the firms rarely sell in a monopoly market and they often compete with their rivals. Jiang et al. (2011) find that having better demand information about them than their competitors may not help the managers. The experimental results of Ovchinnikov et al. (2015) concluded that human decision-makers fail to strategically anticipate and respond to other players' actions at an aggregate level. Zhao and Zhao (2016) analysed in a competitive environment where two newsvendors compete for a common market. On contrary to the PTC effect, their results show that high-profit group increase their ordering levels, while low-profit group reduce their orders because of the influence of their competitors. Feng and Zhang (2017) demonstrated that the orders of two identical newsvendors (who are selling the same perishable goods in a common market) exhibit a PTC effect similar to the one observed in the classic non-competitive newsvendor experiments. Table 2 provides a summary of the different conditions that affects the ordering behaviour of newsvendor.

Table 2 Alternative settings affecting the Newsvendor ordering behaviour

<i>Factors</i>	<i>Authors</i>	<i>Deductions</i>
Learning dynamics	Bostian et al. (2008), Benzion et al. (2008), Bolton and Katok (2008), Katok and Wu (2009), Moritz et al. (2013), Ho et al. (2010) and Bolton and Katok (2008)	<ul style="list-style-type: none"> • To develop an adaptive learning model in newsvendor settings.
Information sharing	Bolton and Katok (2004), Lurie (2004), Lurie and Swaminathan (2009), Gavirneni and Isen (2010), Becker-Peth et al. (2013), Schiffels et al. (2014) and D'Urso et al. (2017)	<ul style="list-style-type: none"> • What type of information can be shared to mitigate the ordering bias.
Individual heterogeneity	Rydval and Ortmann (2004), Brown and Tang (2006), Harris et al. (2006), Croson and Gneezy (2009), Katok et al. (2008), Dorn and Sengmueller (2009), Moritz (2010), Feng et al. (2011), Bolton et al. (2012), Moritz et al. (2013), Cui et al. (2013), De Véricourt et al. (2013), Moritz et al. (2014), Wu and Chen (2014), Ockenfels and Selton (2014, 2015) and Fréchette (2016)	<ul style="list-style-type: none"> • How the differences in individual's cognitive reflection, culture, gender, education level and other factors contribute to the newsvendor ordering bias? • Is there any difference in the decision-making behaviour of students and managers?
Unconventional supply chain settings	Jiang et al. (2011), Tong (2012), Castañeda Acevedo (2013), Becker-Peth et al. (2013), Chen et al. (2014), Lau et al. (2014), Ovchinnikov et al. (2015), Kocabiyıkoğlu et al. (2016), Quiroga et al. (2016), Zhao and Zhao (2016), Castañeda and Gonçalves (2017) and Feng and Zhang (2017)	<ul style="list-style-type: none"> • How competition between the retailers influences the newsvendor ordering behaviour? • How newsvendors behave while placing orders for multiple items? • Does simultaneous decision-making influences newsvendor ordering preferences?

Figure 5 gives a summary of the progress of research in the behavioural newsvendor problem over the years, which shows the evolution of research studies in the chronological order.

8 Directions for future research

The traditional newsvendor models assume that people do not react to the changes going on around them as it might alter the performance dynamics of the model. However, the decision-maker's choice might vary based on the environmental and situational deviations driven by management rules and decisions. The changes in the parameters due to the dynamics of the system and the interaction effect between these parameters can be captured through mathematical relationships and the insights related to the model can be given using sensitivity analysis, comparative statistical techniques or numerical experiments.

Generally, capacity constraints of the supplier are not considered in the newsvendor setting. Considering an effective sourcing strategy with uncertainty in both supply and demand is necessary for successful supply chain management. Burke et al. (2007) and Burke et al. (2009) analysed the optimal order quantity in a newsvendor setting with a fixed capacity constraint and integrating the stochastic demand and stochastic supply. However, the studies to understand the ordering behaviour of the newsvendor when there are any restrictions from the supplier is not available in the newsvendor literature.

8.1 Extensions of newsvendor problem

Most of the experimental studies investigate the impact of behavioural biases in a traditional newsvendor setting, while it is a high time to analyse the behaviour of newsvendor ordering decisions under alternative settings. Here are a few instances which needs immediate attention.

- 1 Majority of the experimental studies examine the ordering behaviour of newsvendor for a single period model. It is also important to enrich the existing literature by empirically investigating the inventory decision-making behaviour in various alternative settings, since its impact on the supply chain performance is an important, but understudied, problem.
- 2 Out-of-stock is a common situation that is estimated to occur more frequently for perishable products. In such a situation, if the customer leaves the store without purchasing the product, it leads to lost sales to that store in the long-term. For certain products, it can be substituted with a similar product from the same product category. The product substitution inflates the sales of other similar items in that category leading to a misrepresented demand. Similar to the censorship bias, retailers might use some shortcuts or rules of thumb to determine the optimal inventory level. Researchers can explore the behavioural anomaly of the decision-maker in this circumstance as well.

8.2 Influence of behavioural anomalies on the newsvendor decision-making

The customer's behaviour to firm's practices also play an important role in the ordering decisions. It is equally important to characterise the customer responses by understanding their decision process in evaluating the alternatives and making choices (in determining which product to buy and when to buy). Ignoring these aspects may have serious repercussions on the demand side since the firm's action is a reflection of the customer's behaviour in any market (Shen and Su, 2007). In the contemporary world, the customer relationship management systems (e.g., Siebel, e-piphany) eases the collection and storage of customer transaction information. B2C firms have been the front-runners in customer analytics initiative and they rely on predictive analytics to identify the likely customers. Also the technological advancements allows the retailers to collect information not only about the sales, but also about demographic data and customer preferences, resulting in the improvement of marketing, sales, and customer service. The significance of customer behaviour modelling is well recognised in auction, dynamic pricing and revenue management literature. However, the newsvendor model still uses the historical data and market size to determine the demand distribution. There is scope for researchers to design a DSS that incorporates the behaviour-driven demand pattern of the strategic customers while making the inventory decisions. Further, the manager should also examine the influence of strategic interaction between customers on the demand distribution and their ordering behaviour. In fact, one cannot argue that all customers have strategic decision-making behaviour. The customers might make strategic decisions about the quantity and time of their purchase with the help of intelligent decision-support tools that can analyse data and give recommendations.

Researchers can also explore the decision-making behaviour in newsvendor related settings such as airline booking operations, hotel room reservation, human resource allocation, scheduling of operating room, employee recruitment and other service sectors. Though the behaviour of people involved in these services highly influence their decision-making, it has not been thoroughly investigated. Further, researchers can investigate if there is any consistency in the cognitive biases or heuristics exhibited by the decision-makers in these service settings and in the newsvendor settings.

9 Limitations and implications for practicing managers

Many operations research consultant or managers think that they are aware of the dynamics involved while making an inventory decision and they can make better decisions with the help of the information available to them. The pressure to reduce the variability in costs and minimising the budget often leads to overstocking and understocking, which either reinforce or counter the biases that influence the decision-making. Laboratory experiments clearly show that people do not make decisions that maximise the profit, instead their decisions are affected by psychological biases which also reflect the risk preferences of the individual. In fact, the experimental studies show that the results remains the same even there when is no sophisticated mathematics involved. The results emphasise the conclusions that managers were unable to interpret an optimal order quantity even after giving a complete information of the probability distribution and relative cost values. However, providing information about optimal order quantity will be used by many. Although managers with better cognitive reflection and

memory have made risky choices closer to the expected value, their decisions are still affected by the biases. Even any DSSs cannot help to take a decision that can mitigate the biases. It is important for the practicing managers and software tool vendors to design a DSS that can overcome these limitations. Another major limitation of these experimental analysis is that the time given for each round is shorter which lasts only for few minutes and other external factors that may influence the ordering decisions in reality are not present.

10 Summary and conclusions

The paper presents a review of experimental studies of the newsvendor problem and its variants, with an objective to highlight the implications of stakeholders' behaviour on the decision-making process. The seminal study of Schweitzer and Cachon (2000) identified the decision bias of managers in the newsvendor settings. This work paved way for many research studies to explore the learning effects, effects of information sharing that induced the decision-making behaviour. Later, the research proceeded in the direction of validating the behaviour of the newsvendor in unconventional settings. This paper provides a framework for review consisting of a classification framework that guides potential researchers who intend to explore various settings in which the managers exhibit newsvendor bias. The paper provides valuable insights for the future researchers that assist them to develop effective strategies to mitigate the newsvendor bias. Furthermore, the directions for future examinations will help in widening the unexplored paths in understanding the newsvendor and supply chain related decisions. This can provide room for better stocking decisions in the future.

Acknowledgements

I thank the editor and the reviewers for their valuable comments and suggestions, which helped to improve the quality of the paper.

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