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Implicit Attitudes Towards Risk: Influences on Newsvendor Inventory Decisions

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Abstract — This study addresses the role of implicit attitudes toward risk in inventory management, specifically in the context of the newsvendor problem (NVP). Using the Implicit Association Test (IAT), we explore how implicit attitudes toward risk influence newsvendors' ordering decisions, focusing on deviations from profit-maximising solutions. Our methodology combines the NVP inventory exercise with IAT measurements. We find a negative correlation between participants' implicit attitudes toward risk and the absolute deviation from the optimal order quantity, indicating that individuals with implicit attitudes toward risk are closer to neutrality deviate less from the profit-maximising solution. This supports our hypothesis that implicit risk attitudes impact such deviations. Our findings emphasise the importance of considering implicit attitudes toward risk in decision support systems for inventory management. Future research directions should explore the interplay of implicit attitudes toward risk with cognitive factors and its applicability in diverse contexts.

Keywords- Implicit attitudes toward risk; Newsvendor Problem; Optimal inventory ordering.

I. INTRODUCTION

For decision-making under uncertainty, implicit attitudes toward risk plays a pivotal yet often overlooked role, particularly in the context of inventory management. An individual's implicit attitudes toward risk refer to their subconscious or automatic associations, beliefs, or biases regarding the concept of risk, which may influence their decision-making and behaviour without their conscious awareness [1]. While explicit measurements such as risk tolerance provide valuable insights, the inherent limitations of self-reported data call for innovative approaches to capture individuals' true implicit attitudes toward risk. Implicit measurement strategies, with their ability to uncover underlying mental processes that escape introspective awareness, offer a powerful means to address this challenge [2], [3]. In the domain of implicit attitudes toward risk, the Implicit Association Test (IAT), is a valuable tool enabling the measurement of implicit attitudes without relying on individuals' willingness or ability to report [4], [5]. This method reveals the interplay between affective valences and concepts, shedding light on hidden biases and preferences that might not surface through explicit measures [6]. In inventory management, the newsvendor problem (NVP) poses a classic challenge, requiring decision-makers to balance between ordering enough inventory to meet uncertain demand while minimising holding costs. Despite its theoretical relevance, empirical research on the specific influence of implicit attitudes toward risk on inventory ordering behaviour, particularly within

the newsvendor context, remains limited. Our study aims to address this gap by exploring how a newsvendor's implicit attitude toward risk impacts their ordering decisions, with a focus on deviations from the profit-maximising solution.

As demonstrated in the literature, the utilisation of implicit measurement techniques, coupled with the "affect" heuristic, offers a multifaceted lens for comprehending the interplay between implicit attitudes toward risk, decision-making, and ordering behaviour in the newsvendor context. Our study seeks to highlight these relationships and contribute to this essential field of study. Consequently, in section 2 of this paper, we formulate our hypothesis: A subject's implicit attitude towards risk influences the deviation from the profit-maximising solution in the context of the NVP. Our experimental methodology, in section 3, combines the dynamic NVP inventory ordering exercise with the robust IAT measurements. By examining the interaction between implicit attitudes toward risk and inventory ordering decisions, we aim to uncover the underlying mechanisms that drive deviations from the profit-maximising solution. Moreover, the experiment employs control and experimental groups to observe the impact of additional external information on order quantity and profit, allowing to isolate the effect of implicit attitudes towards risk by comparing the groups. The unique context of the NVP, coupled with the application of the IAT, provides a rich setting to explore the relationship between implicit attitudes toward risk and ordering behaviour. The results of our study, in section 4, shed light on the impact of implicit attitudes toward risk on newsvendors' inventory ordering decisions, revealing the extent to which deviations from the profit-maximising solution can be attributed to individuals' implicit attitudes toward risk. The study aims to determine whether implicit attitudes towards risk affect order quantity with and without the presence of additional information, and whether external information influences the decision-making process. By bridging the gap between theoretical discussions and empirical evidence, our research contributes to the understanding of how implicit attitudes toward risk shapes inventory management outcomes. The practical implications of our findings emphasise the importance of considering implicit attitudes toward risk in decision support systems and strategies aimed at optimising inventory management practices. Through the exploration of future research directions in section 5, we seek to advance our insights and drive further innovations in this domain.

II. LITERATURE REVIEW

Implicit measurement strategies serve as a tool for revealing a participant's internal constructs of interest without the need for self-reporting [2]. This feature of implicit cognition, as defined by Greenwald and Banaji, refers to the subtle experiences that shape judgments in ways that escape introspective awareness [2], [7]. Understanding explicit and implicit attitudes in terms of their underlying mental processes contributes to a more comprehensive perspective [8]. [9] highlight the independence of the IAT from explicit attitudes, providing a crucial distinction.

Direct measurement methods, while informative, come with a significant limitation; the participant's responses are constrained by their willingness and ability to report [10]. [8] argue that implicit measurement methods, such as the IAT, offer valuable insights into the underlying processes of social judgment, offering a deeper understanding of an individual's implicit attitude toward an object. The implicit association methods, notably the IAT, have the unique capability to uncover associations and attitudes that individuals might not explicitly report, either due to choice or lack of awareness [4]. This experimental approach, rooted in response time, reveals the relative strength of affective valences, both positive and negative, associated with objects [4].

There are several publications in the domain of decision-making under external risk [11], however this paper focuses on the implicit risk of individuals. [1] introduce a novel method for implicit measurement of individual differences in implicit attitudes toward risk, demonstrating the automatic associations with the concept of risk using the IAT. More specifically, risk averse subjects perceive the same risk as lower when compared to risk seekers, revealing the disconnect between risk behaviour and implicit attitudes toward risk [1]. [12] explore how individuals perceive the riskiness of alternatives in a given situation, highlighting that differences in implicit attitudes toward risk are primarily linked with individual differences in probable risk-taking rather than constant risk preferences. [13] shed light on the "affect" heuristic as a key driver of differences in implicit attitudes toward risk. This heuristic relates to an individual's "good" (positive) or "bad" (negative) feelings toward an object, as further corroborated by [14] linking judgments to the strength of the positive or negative "affect" associated with an activity [15]. [16] also acknowledge that the "affect" heuristic can lead to differences in implicit attitudes toward risk through a format effect, further influencing the implicit attitude toward risk.

Within the context of ordering behaviour in the NVP, [17] have attempted to adjust individuals' implicit attitude toward risk through framing but found this approach ineffective in inducing better inventory ordering behaviour. [18] demonstrate the positive economic impact of considering a judgmentally updated demand forecast for inventory ordering in the context of the single-item NVP model. [19] extend the previous model by introducing a distribution-free demand and multiple items in the NVP, and illustrate the effectiveness and profitability of contextual information in NVP inventory ordering. Moreover, several articles highlight the importance of the trust of the information related to product demand for inventory ordering in the NVP [20]. Importantly, despite theoretical indications of the impact of

implicit attitudes toward risk on decision-making, experimental research on the specific influence of implicit attitudes toward risk on ordering quantity in the newsvendor context remains scarce, underscoring the significance of our study. Consequently, this study proposes that a newsvendor's implicit attitudes toward risk in an NVP scenario has a substantial impact on their non-rational ordering behaviour, leading to our hypothesis:

HYPOTHESIS: A subject's implicit attitude towards risk influences the deviation from the profit-maximising order quantity in the context of the newsvendor problem.

The existing literature reveals notable gaps in the understanding of how implicit attitudes toward risk influences inventory ordering decisions, particularly within the context of the NVP. While theoretical discussions emphasise the relevance of implicit attitudes toward risk in decision-making, there is a significant lack of empirical research specifically addressing this influence in the newsvendor context. One significant gap revolves around individual differences in implicit attitudes toward risk among newsvendors. While a few studies touch upon the differences between risk-averse and risk-seeking individuals, there is a need for a broader exploration of diverse implicit attitudes toward risk and their effects on ordering decisions. Implicit attitude measurement methods, such as the IAT, are highlighted as valuable tools for capturing subtle aspects of implicit attitudes toward risk that might go unreported. However, these methods have yet to be extensively applied to investigate the impact of implicit attitudes toward risk on inventory ordering decisions in the NVP. Moreover, the proposed hypothesis suggesting that implicit attitudes toward risk impact deviations from the profit-maximising solution highlights a crucial yet untested area. Empirical evidence supporting this hypothesis and the underlying mechanisms that drive these deviations are not well-established. Lastly, the unique context of the NVP with its focus on order quantity decisions has received limited attention concerning implicit attitudes toward risk, necessitating research that look into how newsvendors perceive risk and how this perception directly affects their ordering decisions. Addressing these gaps through empirical research that explores the interactions between implicit attitudes toward risk, individual differences, deviations from profit-maximising solutions, and the newsvendor-specific context is essential to advance our understanding of how implicit attitudes toward risk shapes inventory ordering decisions.

III. METHODOLOGY

In our methodology, we evaluate the hypothesis derived from the existing literature gaps, focusing on the context of the NVP inventory ordering exercise and utilising IAT measurements.

The NVP and the influence of implicit risk perception: In the context of the NVP, the goal is to find the optimal order quantity, Q^* for a perishable product such that it maximizes the expected profit. The NVP is represented using probability distributions for product demand (D), product cost (c), selling price (p), the holding cost per unit (h), and the salvage value per unit (s), which is the amount received for unsold units. The critical fractile ratio (r) is

the proportion of demand that is satisfied by the order quantity Q ($0 \leq r \leq 1$). The optimal order quantity, Q^* , is the one that maximizes expected profit (π). The profit is calculated as the revenue from selling Q units minus the cost of ordering Q units and holding the inventory until the end of the selling period. It can be represented as follows:

$$\pi(Q) = \left[\min(Q, D)p - cQ - h\left(\frac{Q}{2}\right)(1-r) \right] + [\max(D - Q, 0)s] \quad (\text{Equation 1})$$

Where: $\min(Q, D)$ represents the quantity sold (either Q or the demand, whichever is smaller); $\max(D - Q, 0)$ represents the quantity unsold (demand minus the quantity sold, capped at 0); and $r = (p-c)/p$.

The main influence of implicit risk perception on the profit-maximizing order quantity is expected to manifest in the risk-taking behaviour of the newsvendor.

In this study, the influence of the individual's implicit risk perception can be represented by the GNB score which is a measure of implicit attitudes calculated using the IAT. The GNB score is based on the algorithm in [21] and quantifies the strength of associations between concepts such as risky and safe attributes with positive and negative attributes. The GNB score is calculated based on participants' reaction times during the IAT. It measures how quickly and accurately individuals can categorise items related to the concepts being tested. Specifically, the score reflects the mean reaction times for correct responses, the variability of these reaction times, and the correction of initial incorrect responses. The GNB score ranges from -2 to 2, where -2 signifies a maximum aversion to risk, 2 represents a maximum tolerance for risk, and 0 indicates a neutral stance with no significant bias.

The hypothesis suggests that a more negative GNB score, indicating higher risk aversion, results in greater deviations from the profit-maximizing solution. This study examines the impact of the GNB score on order quantity and expected profit to understand the relationship between implicit risk perception and its effects on ordering decisions and financial outcomes within the NVP context. To determine the individuals' implicit attitudes toward risk the open-source application FreeIAT, known for its reliability and customisation capabilities, is employed [22]. This tool employs Greenwald's algorithm [21], measuring the strength of associations between positive/negative attributes and risky/safe attributes based on a reaction time measurement approach. In the IAT, participants rapidly classify attributes into corresponding categories using the "e" and "i" keys on the keyboard, aiming for efficient performance to obtain interpretable scores. The category labels and items are presented on the screen before the exercise, ensuring clarity in task instructions.

Experimental setup: The experimental setup consists of three main components as in Figure 1: splitting the participants into four groups, the NVP inventory ordering exercise and the IAT assessment, with all participants completing the IAT following the completion of the NVP exercise. This exercise encompasses both control groups and experimental groups, each facing scenarios with varying profit margin levels (High Profit Margin, HPM, and Low Profit Margin, LPM), as illustrated in Figure 2.

Participants engage in a simulated decision-making task within the context of a Music Festival spanning 6 days, involving the

ordering of festival t-shirts. These t-shirts, with stochastic demand uniformly distributed between 10,000 and 26,000 units per festival year (historical mean of 18,669 t-shirts, standard deviation of 4,100), are only available for sale during the festival's duration. The input data consists of the price, $p=40$ CHF, cost for the high profit margin scenario, $c_{\text{HPM}}=10$ CHF for a critical fractile ratio, $r=0.75$, and $c_{\text{LPM}}=30$ CHF for the low profit margin scenario for $r=0.25$. The critical fractile ratio determines the profit margin scenarios (HPM or LPM) for the groups, with p as the selling price per unit and c as the cost per unit, leading to optimal order quantities of 22,000 for HPM and 14,000 for LPM groups. Two control groups, Group C_H (HPM control) and Group C_L (LPM control), are contrasted with two experimental groups, Group E_H (HPM experimental) and Group E_L (LPM experimental). The output information is the order quantity selected by the individual and the profit.

The experiment uses control and experimental groups to validate results and ensure reliability. The control group serves as a baseline, representing outcomes under normal conditions without the additional information provided in the experimental group. In contrast, the experimental group receives additional information which consists of external information from social media, in the form of the number of likes and comments on a post with the festival t-shirt, as social media information has been shown to influence sales [23]. This allows to observe the influence of the external information on outcomes such as order quantity or profit and compare it to the control group to isolate the effect of the individual's implicit attitude towards risk.

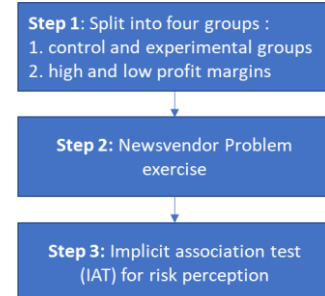


Figure 1: Experimental methodology

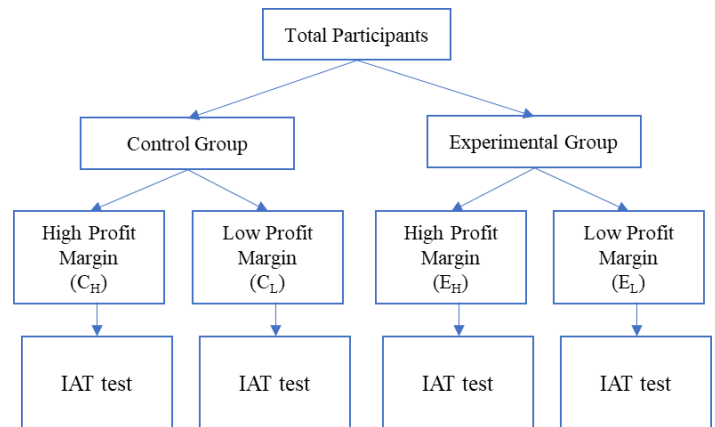


Figure 2: Groups distribution

Participants iteratively make order quantity decisions for 15 festival years, receiving feedback on actual demand, profits for the preceding round, and total profits. The Experimental groups also received external information regarding the number of likes and comments on a social media post of the festival t-shirt in order to analyse whether the impact on order quantity decision is due to the implicit attitude towards risk, or whether external information perceived to help in decision making mediates this effect. Overall, our methodology combines the dynamic NVP inventory ordering exercise with the robust IAT measurements, providing a comprehensive framework to investigate the influence of implicit attitudes toward risk on inventory ordering decisions in the NVP context.

IV. RESULTS AND DISCUSSION

In our study, a total of 117 participants, all Bachelor students in their second and third years, took part in the experiments as part of their Supply Chain class. The participant distribution among the various groups is outlined in Table 1. The primary objective for each participant was to maximise profit across 15 rounds of the exercise. Participants were incentivised through extra credit rewards, a proven method that has demonstrated results comparable to economic remuneration [24], [25], and it has been effectively employed in previous NVP experiments in the literature [26]. The experiments took place in a computer laboratory and lasted approximately 1 hour. Participants were granted the flexibility to progress at their own pace in the NPV exercise while aiming for swift completion in the IAT component. We accumulated a total of 1714 usable observations after excluding outlier responses, which encompassed order quantities above or below the interval of 10'000 and 26'000, as well as IAT responses that were excessively slow or fast. The results demonstrate that the profit margin scenario had a significant impact on average total profits. Groups in the HPM scenario (Group C_H and Group E_H) achieved substantially higher average total profits compared to groups in the LPM scenario (Group C_L and Group E_L). This indicates that the profitability of the product significantly influenced participants' decisions.

Table 1: Statistical results from experiment

	Groups			
	C _H	E _H	C _L	E _L
No. participants	23	41	17	36
No. observations	332	615	248	540
Profit scenario	High	High	Low	Low
Average Profit	7'001'436	7'420'555	1'848'174	1'965'559
Mean order quantity/round	18'848	18'537	18'833	18'553
Std deviation order quantity	3'150	3'129	3'561	2'953

The mean order quantity per round was relatively similar across all groups, with only slight variations suggesting that, on average, participants ordered a similar number of units per round regardless of the profit margin scenario, or the presence of additional external information. However, the standard deviation of order quantity indicates variability in participants' ordering behaviour, with Group E_L exhibiting the lowest standard deviation, indicating more consistent ordering. Analysing the mean order quantities across all inventory decisions reveals a pattern mirroring the "too low/too high" phenomenon observed by [27], as depicted in Figure 3. Specifically, the average order for the HPM scenario (18'537) is significantly lower than the expected profit-maximising order quantity of 22'000, while the average order for the LPM scenario (18'553) is significantly higher than the anticipated profit-maximising order quantity of 14'000. This suggests that inventory orders tend to deviate from the optimal order quantity, with orders exceeding the optimum in the high-profit condition and falling below it in the low-profit scenario. Moreover, a statistically significant difference in average profit is observed when comparing the profits of Group E_H to C_H, and Group E_L to C_L. This can be explained by the availability of external information from social media in the experimental groups compared to the control groups. Although the additional information does not result in statistically significant deviations in average order quantity, it reduces the variability of the order quantity from the demand resulting in higher average profit.

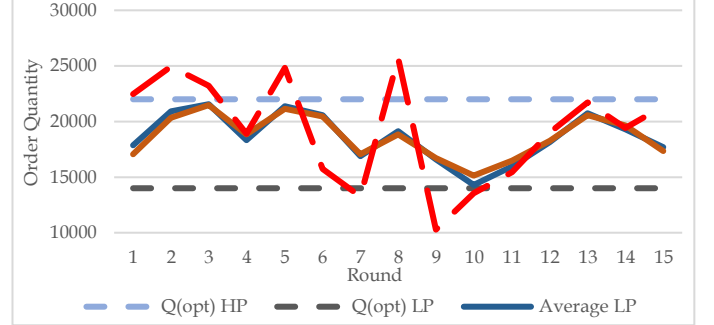


Figure 3: Average Order Quantity in high profit (HP) and Low Profit (LP) Margin Scenarios

We explore the impact of implicit attitudes toward risk, measured by the GNB score from the IAT, on ordering behaviour. While there is no statistically significant correlation between the GNB score and the order quantity, there is a statistically significant correlation between the GNB score and the absolute deviation from the optimal order quantity. A linear regression analysis between order quantities and the GNB score reveals a correlation coefficient (slope) of -0.22 ($p < 0.05$) between implicit attitudes toward risk and absolute deviation from the optimal order quantity, when considering both HPM and LPM scenarios together (Figure 4). The linear regression analysis does not yield statistically significant results when considering HPM and LPM scenarios separately.

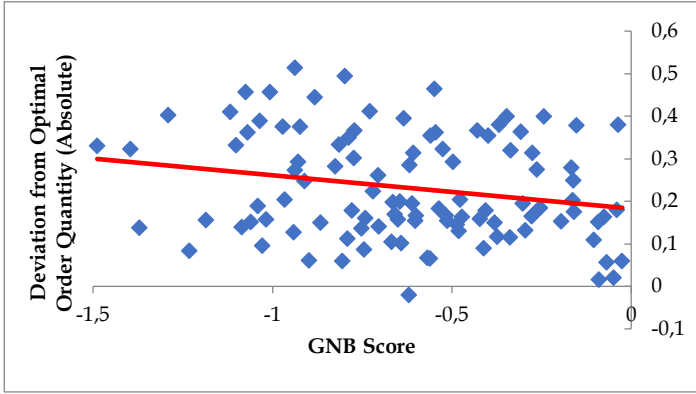


Figure 4: Relation between implicit attitudes toward risk and deviation from optimal order quantity

Our results indicate a negative relationship between implicit attitudes toward risk, as measured by the GNB score, and the absolute variation from the optimal order quantity in each profit margin scenario. This implies that as the GNB score becomes more negative (indicating a more negative implicit attitudes toward risk), the deviation from the optimal order quantity increases. In other words, individuals with implicit attitudes toward risk are closer to neutrality are more likely to deviate less from the profit-maximising solution in their order quantities.

These findings align with our hypothesis, demonstrating that a newsvendor's implicit attitude towards risk is negatively correlated with their performance in terms of ordering closer to the profit-maximising solution. Although the correlation is relatively weak, it is statistically significant. This suggests that individuals with implicit attitudes toward risk are closer to neutrality may potentially achieve better financial performance by making ordering decisions that align more closely with the profit-maximising solution.

Both experimental groups outperform the control groups in terms of overall profit, even though their mean order quantities do not exhibit significant differences under the same HPM or LPM conditions. This observation aligns with the findings from our literature review, where we identified a lack of empirical research focusing on the influence of implicit attitudes toward risk on inventory ordering decisions in the context of the NVP. By employing IAT measurements, our study offers a nuanced understanding of how implicit attitudes toward risk impact decision-making. The IAT results reveal a predominantly negative implicit attitude toward risk across all subjects, albeit with varying degrees of negativity.

Importantly, a statistically significant negative correlation is observed between the GNB score, representing implicit attitude toward risk, and the deviation from the profit-maximising solution in both HPM and LPM scenarios. This correlation indicates that a subject's implicit attitude toward risk significantly influences their ordering behaviour. Subjects with more negative implicit attitudes (closer to GNB score -1.6) tend to order quantities that deviate further from the optimal order quantity and are closer to the mean demand. On the other hand, subjects with more neutral implicit attitudes (closer to GNB score 0) tend to order quantities that align

closer to the optimal order quantity, representing the profit-maximising solution, and move away from the mean demand.

The concept of "mean anchoring" behaviour, as introduced by [27], is evident in our study, where newsvendors anchor their decision-making around the mean demand and adjust their orders towards the optimal order quantity. Notably, our experimental observations demonstrate that the extent of adjustment toward the optimal order quantities in both HPM and LPM scenarios is associated with the newsvendors' implicit attitudes toward risk.

This finding is consistent with our earlier discussion about the relevance of individual implicit attitudes toward risk in inventory ordering decisions. Our results indicate that newsvendors' implicit attitudes toward risk significantly impact their deviations from the profit-maximising solution, providing empirical support for our hypothesis. Although the correlation is relatively weak, its statistical significance highlights the practical implications. Newsvendors with implicit attitudes toward risk are closer to neutrality have the potential to make ordering decisions that better align with the profit-maximising solution, leading to improved financial performance. Our study bridges a critical gap in the literature by directly examining the influence of implicit attitudes toward risk on inventory ordering decisions within the NVP context. The empirical evidence reinforces the theoretical importance of implicit attitudes toward risk in decision-making, highlighting that newsvendors' implicit attitudes toward risk significantly shape their order quantities, with implications for profitability. This highlights the relevance of considering implicit attitudes toward risk in decision support systems and strategies aimed at enhancing newsvendors' inventory management.

V. CONCLUSION

In this study, we have conducted experiments aimed at understanding the impact of implicit attitudes toward risk on inventory ordering behaviour within the challenging framework of the NVP. Our investigations consisted of both high and low profit margins scenarios. The results presented demonstrate a clear relationship between participants' implicit attitudes toward risk and their inventory ordering decisions, shedding light on the critical role of implicit attitudes toward risk in this context.

The influence of implicit attitudes toward risk on inventory ordering decisions is a key finding from our study. We observed that newsvendors exhibiting a more negative implicit attitude toward risk tend to make ordering decisions that deviate further from the profit-maximising solution compared to those with a more neutral implicit attitudes toward risk. Importantly, this trend holds true for both the high and low profit margin scenarios. This evidence highlights the impact of implicit attitudes toward risk on the extent to which newsvendors deviate from the mean demand and move toward the profit-maximising solution.

Our study adds empirical support to the theoretical discussions on implicit attitudes toward risk and decision-making, particularly within the domain of inventory management. The findings highlight the practical importance of considering newsvendors' implicit attitudes toward risk when designing effective decision support systems and strategies for improving inventory management outcomes.

While this study brings important insights to the forefront, it also opens several avenues for future research. One promising direction is to investigate the dynamics of the relationship between implicit attitudes toward risk and other cognitive factors that might influence inventory ordering decisions. Investigating the role of cognitive biases, decision heuristics, and individual cognitive styles combined with implicit attitudes toward risk could provide a more comprehensive understanding of decision-making in the newsvendor context. Furthermore, extending this research to explore the effects of implicit attitudes toward risk on diverse types of businesses or industries would broaden the applicability of our findings. Examining how implicit attitudes toward risk varies across industries and the potential nuances in its impact on decision-making within various contexts would offer valuable insights with practical implications.

In conclusion, this study indicates the role of implicit attitudes toward risk in shaping inventory ordering behaviour in the NVP. This research contributes not only to the theoretical understanding of decision-making under uncertainty but also offers practical implications for optimising inventory management practices. The future research directions outlined above hold the potential to deepen our insights and drive further advancements in this domain.

VI. ACKNOWLEDGEMENTS

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