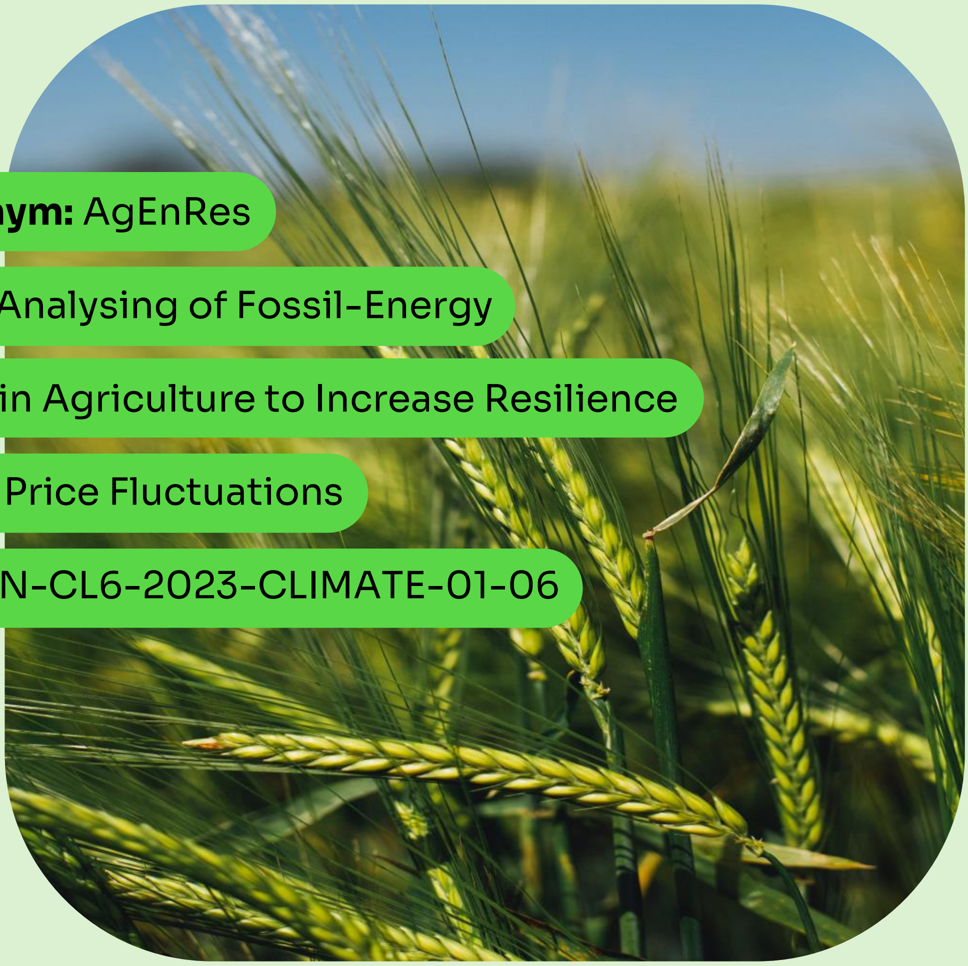
AgEnRes

D 5.2 Farmer’s adoption of price risk management tools



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Author list

Name	Organization
Riccardo Spada	Wageningen University & Research
Laura Moritz	University of Trento
Jens Rommel	Swedish University of Agricultural Sciences
Simone Cerroni	University of Trento
Miranda P.M. Meuwissen	Wageningen University & Research
Tobias Dalhaus	Wageningen University & Research

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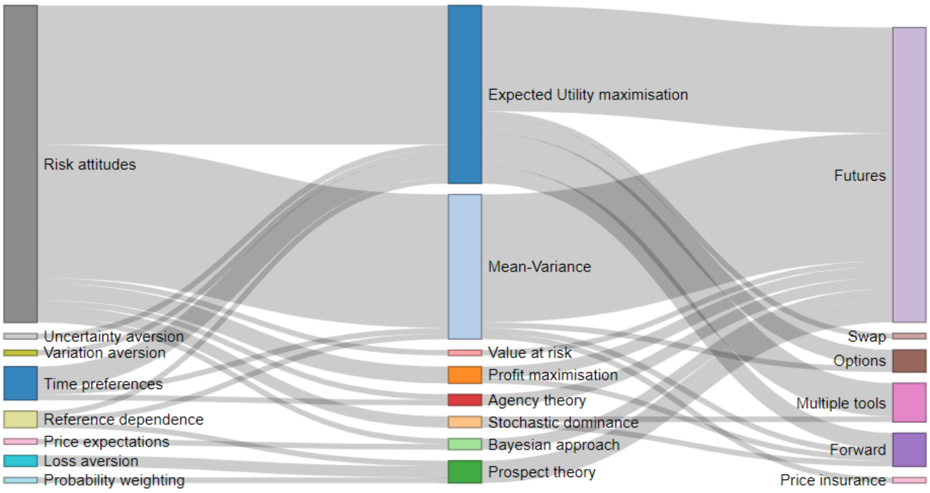
Executive Summary

Price volatility is an important risk in agricultural production. Financial tools like forward contracts, futures, options, and price insurance can be used by farmers to reduce price risk for both inputs and outputs. However, the uptake of financial tools to hedge price volatility is relatively low. Behavioral factors influence farmers' decisions, and are even more important for decisions made under risk and uncertainty like the ones regarding price risk management. Thus, insights from behavioral economics have been advocated to be incorporated in price risk studies.

In this report, we conduct a systematic literature review to identify behavioral factors that influence the adoption of financial tools for price risk mitigation in agriculture, limiting our analysis geographically to countries with highly intensive farming systems. We classify behavioral factors into behavioral preferences and psychological factors. Behavioral preferences can be incorporated in (mathematical) economic models (e.g. risk, ambiguity, time preferences, loss aversion, or probability weighting) while psychological factors are traits that influence behavior but that are often not formally incorporated in economic models (e.g. social interaction, culture, and personality traits).

Behavioral preferences in economic models

The majority of papers on behavioral preferences use an Expected Utility or Mean-Variance representation of farmers' risk preferences to find optimal hedging decision of futures. Surprisingly, only one paper focuses on Cumulative Prospect Theory's loss aversion and probability weighting relation to futures adoption in a simulation.



Psychological factors in experiments

Multiple empirical papers correlate farmers' psychological preferences with the adoption of price risk management tools. But findings regarding risk attitudes have been mixed, with many studies that elicit risk attitudes found no correlation with adoption decisions. Network influence can be a particularly promising avenue to formally be incorporated in economic models for price risk management. Additionally, tools knowledge was also found as an important factor in adoption decision. This suggests that extension services, financial tools providers, and policy makers can have a role in providing training and education to improve farmer' decision making ability regarding price risk.

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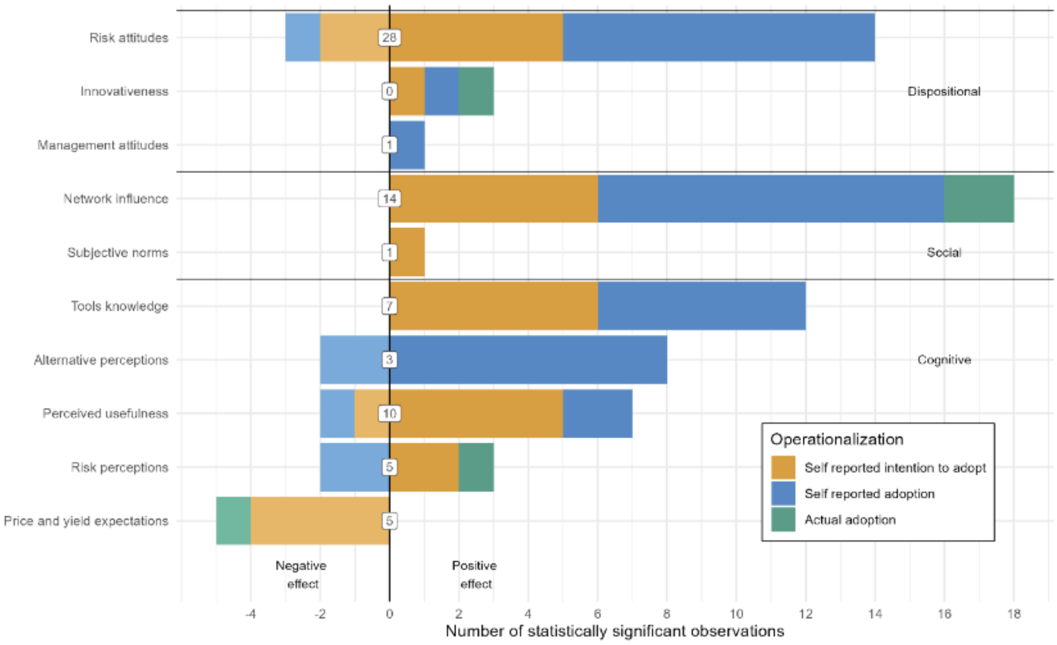

Notes: Numbers inside the boxes indicate the number of statistically insignificant observations.

Results show a substantial literature gap on empirical work that correlates elicited behavioral preferences with actual adoption of price risk management instruments. We thus conclude that currently there is a very limited understanding of farmers' price risk management adoption and related decision making processes. Additional experimental research on the relation between behavioral preferences and price risk management decisions would enable a more targeted design of instruments and policies to make these tools more attractive to farmers.

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List of Acronyms

CPT	Cumulative Prospect Theory
EUT	Expected Utility Theory
M-V	Mean-Variance
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
PRISMA-P	PRISMA for systematic review Protocols

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1. Introduction

Price volatility is an important risk in agricultural production. Risk-averse farmers are assumed to be willing to sacrifice part of their expected profits to mitigate price risk (Boyd & Bellemare, 2020) and, linked to financial insecurity, price risk can negatively impact farmers' wellbeing (Adam et al., 2024). Market-based risk management tools (henceforth financial tools) such as forward contracts, futures, or options (i.e. price insurance) can be used by farmers to reduce price risk for outputs not yet produced and inputs planned to be used in the future (Hardaker et al., 2004). The literature suggests that hedging benefits agricultural producers by offsetting their price risk (Garcia, 2004). However, the uptake of financial tools to hedge price volatility is relatively low (Assefa et al. 2017; Michels et al. 2019). Previous research argues that farmers' decisions are in general influenced by behavioral factors (Dessart et al., 2019; Palm-Forster et al., 2019; Wuepper, Bukchin‐Peles, et al., 2023), which can explain decision deviations from what standard economic theory suggests. Behavioral factors become even more important for decisions made under risk and uncertainty, like the ones regarding price risk management. Thus, insights from behavioral economics have been advocated to be incorporated in price risk studies (Bellemare & Lee, 2016). In a recent review, Wever et al. (2024) summarize how psychological factors affect futures and options contracts adoption. Yet an overview on how economic and behavioral economic preferences that can be incorporated mathematically in economic models affect such adoption decisions is lacking.

In this report, we conduct a systematic literature review using the PRISMA guidelines (Page et al., 2021) to identify behavioral factors that influence the adoption of financial tools for price risk mitigation in agriculture.

We classify behavioral factors into behavioral preferences and psychological factors. Behavioral preferences can be incorporated in (mathematical) economic models (e.g. risk, uncertainty, time preferences and hyperbolic discounting, loss aversion, or probability weighting) while psychological factors are traits that influence behavior but that are often not formally incorporated in economic models (e.g. social interaction, culture, and personality traits). To define search terms, we first build a theoretical framework of farmers' decision-making under price risk and introduce behavioral economic theories and psychological factors that qualify as driving forces in this decision process. We limit our analysis geographically to countries with highly intensive farming systems. In total, we identified 100 studies, yielding 234 distinct observations. The higher number of observations results from the fact that some studies examine multiple financial tools, consider more than one preference or factor, and may also focus on different farm types. The majority of papers on behavioral preferences use an expected utility representation of farmers' risk preferences to find optimal hedging decision of futures. Multiple empirical papers correlate farmers' psychological preferences with the adoption of price risk management tools. Surprisingly, only one paper focuses on Cumulative Prospect Theory's loss aversion and probability weighting relation to futures adoption in a simulation. Overall, our results show a substantial literature gap on empirical work that correlates elicited behavioral preferences with actual adoption of price risk management instruments. We thus conclude that we currently have a very limited understanding of farmers' price risk management adoption and related decision making processes. Additional experimental research on the relation between behavioral preferences and price risk management decisions would enable a more targeted design of instruments and policies to make these tools more attractive to farmers.

The remainder of the report is structured as follows. In the subsequent section 2, we build a theoretical foundation on decision-making under price risk to motivate how different farmer preferences (such as risk or loss aversion) might drive the decision to adopt financial tools. In section 3, we introduce our methodology to systematically collect peer-reviewed studies on behavioral preferences driving the adoption decision. We present our results in section 4 and discuss these in section 5. In our discussion, we put a particular emphasis on gaps in literature. That is, we identify those preferences that conceptually drive the price risk management decision (as motivated in section 2) but that have not yet been tested empirically. We end our paper with a general conclusion on future research and policy implications.

2. Conceptual framework

Including individual behavioral preference in theoretical choice models on farmer decision-making (e.g. by including risk attitudes in the Expected Utility framework) has a long history in agricultural economics. Since actual behavior of economic agents in general and farmers in particular often deviates from what Expected Utility maximization would suggest, behavioral economists developed new models that extend Expected Utility Theory and relax some of its assumption by incorporating new behavioral preferences (e.g. Kahneman and Tversky, 1979, Tversky & Kahneman, 1992). This lead to more and more preferences to be formally considered in theoretical specifications. Still, also psychological factors not yet considered formally in economic models, play an increasing role in applied agricultural economics research (e.g. Dessart et al., 2019; Palm-Forster et al., 2019; Wuepper et al., 2023; Schaub et al., 2023; Wever et al., 2024).

We therefore here generally classify farmer preferences in i) behavioral preferences, which we consider to be formally recognized in economic models (such as loss aversion or probability weighting), and ii) psychological factors, which describe farmer preferences but are not mathematically implemented into a theoretical economic model. We however acknowledge that overlaps can exist and past research does not always make this clear-cut distinction (Knapp et al., 2021).

2.1. Behavioral preferences

Decisions about the adoption of financial tools can be framed as decision-making under risk. These types of decisions in agriculture have been conceptualized based on different theoretical grounds. As a more normative model, Expected Utility Theory (EUT) can help to find optimal decisions given an expected return and riskiness of a production activity and the decision maker's preference for taking risks (Meyer, 2002). For positive modelling, that is predicting actual behavior, different theories from behavioral economics have been proven useful in an agricultural setting. Cumulative Prospect Theory (CPT) (Tversky & Kahneman, 1992) for instance, allows to include (biased) perceptions of probabilities and a particular aversion to losses with respect to a reference point (Finger et al., 2024). Additionally, in decision contexts where objective probabilities are simply not available, farmers make choices under uncertainty and ambiguity (Knight, 1921). Building on these theories[1], Subjective EUT (Savage, 1954), Smooth ambiguity model (Klibanoff et al., 2005), and Alpha EUT (Ghirardato et al., 2004) are adaptations that have been applied in the agricultural economics literature (see for example Bougherara et al., 2017; Cerroni, 2020; Cerroni et al., 2023; Couture et al., 2024).

Concluding from the above decision-making theories, the following preferences may explain farmers' price risk management decision: i) risk preferences as represented in the standard expected utility model (Garcia et al., 2024), i.e. how much risk a person is willing to take determining the expected utility of the outcome, ii) loss aversion (Sproul & Michaud, 2017), when losses, i.e. outcomes below a certain reference point, have a greater impact on decisions than

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[1] See also Hey & Pace (2014) and Conte & Hey (2013) for an overview of theories under uncertainty and ambiguity.

gains of the same size; iii) time preferences, these are assumed fixed and stable in the standard expected utility model but decision makers often over proportionally prefer “present goods” to those that will be available in the future (O’Donoghue & Rabin, 2015); and iv) probability weighting (Prelec, 1998), when individuals overweigh low probability events and/or underweight high probability outcomes; v) uncertainty aversion (or ambiguity aversion), preference for known-probability over ambiguous bets (Ellsberg, 1961); and vi) subjective probabilities, the personal degree of beliefs that an uncertain event will occur (e.g. de Finetti, 1931; Ramsey, 1931).

2.2. Psychological factors

In addition to the behavioral preferences integrated into economic models, psychological factors such as biases, social interaction, cultural, and personality aspects have been frequently used to explain farmers’ decision-making under risk (see Wuepper et al., 2023) for an overview of the current state of behavioral agricultural economics). We conceptually categorize these factors following the approach proposed by Dessart et al. (2019), which is commonly used in agricultural economics (Schaub et al., 2023; Wever et al., 2024). This classification is organized in i) dispositional, ii) social, and iii) cognitive factors. Dispositional factors are rather stable internal factors of a given individual, such as personality, attitudes, general preferences, and objectives. Social factors relate to the social environment (information, peers, networks, and interactions with other individuals). Cognitive factors are related to learning and reasoning and are more closely dependent on the specific decision-making process. In the context of risk management, they include personal knowledge about risk management in general, and in particular the knowledge and the perceived costs and benefits associated with a specific financial tool and its alternatives. Finally, some papers considering psychological factors include some measures of risk attitudes (such as self-reported risk aversion), which might conceptually overlap with risk preferences in economics models. Therefore, we indicate such cases in our literature review and classify those papers into either of the two categories.

3. Methods

A pre-registration plan for our methodological approach was developed based on the PRISMA-P guidelines (Moher et al., 2015; Shamseer et al., 2015) and uploaded to Open Science Framework before starting the formal search process of the literature review (Spada et al., 2024).

3.1. Literature search

The keywords used in the search process were developed based on the terms summarized in Table 1, which revolve around three key concepts: i) farmers: we are interested in studies that focus on decision of farmer at the farm level. Search terms in here should select such studies accordingly, ii) financial tools: we are interested in a broad range of financial tools for price risk management. Search terms describe different financial tools, and iii) behavioral factors: search terms in here should describe either behavioral preferences or psychological factors that potentially correlate with price risk management decisions. The literature search was conducted on Scopus and Web Of Science, filtering for English language and peer-reviewed literature (see Table S1 for full search strings).

Table 1. Key concepts and search terms.

Key concepts		Search terms
Farmers		agricultural entrepreneur, farmers, growers, producers
Financial tools		financial tools, forwards, futures, hedging, options, price insurance, risk management, swap
Behavioral factors	*Behavioral preferences*	alpha expected utility, ambiguity attitudes, ambiguity aversion, ambiguity preferences, attitudes consideration, discount, expected utility theory, loss aversion, probability weighting, prospect theory, rank-dependent utility, risk attitudes, risk aversion, risk considerations, risk preferences, smooth ambiguity model, subjective probability, subjective utility, temporal preferences, time preferences, uncertainty attitudes, uncertainty aversion, uncertainty consideration, uncertainty preferences
	Psychological factors	attitudes, attributes, behavioral, cognitive, factors, norms, perception, preferences, social

3.2. Eligibility

Studies were included according to the criteria summarized in Table 2. Only papers that target farmers as subjects were analyzed, while other actors in the food chain, integration, and collectives, were not considered. Although farmer collectives, like producer-owned cooperatives, are likely to hedge using futures contracts (Nienhaus et al., 2023), their decision-making process might be different from a single farmer and studies focusing on organizations rather than individuals are thus excluded from the analysis. Regarding the decision-making process, only articles that study the impact of behavioral preferences and psychological factors on the adoption of instruments targeting the mitigation of price risk were analyzed. Non-price focused risk management tools like revenue or yield insurance were excluded. We restrict our review geographically to only consider advanced economies (IMF, 2024) since we expect price risk management adoption decision to be substantially different in low-income countries[2]. Finally, only published peer-reviewed papers written in English were considered for the analysis, without applying any time restrictions.

Table 2. Eligibility criteria

	Included	Excluded
Study characteristic		
Subject	Farmers	Other actors in the food chain Integration Agricultural students
Decision making	• Adoption of financial price risk management tools: - Forwards - Futures - Options - Price insurances - Other price tools • Impact of behavioral preferences and psychological factors on adoption	• Adoption of non-price risk management tools, e.g.: - Collective risk management - Contract farming - Yield insurance - Revenue insurance • Focusing exclusively on farm- and farmer characteristics
Geography	Agricultural systems in countries classified as “advanced economies”*	Agricultural systems in countries outside the "advanced economies" classification
Report characteristics		
Type of report	Peer-review literature	Unpublished Grey literature
Year of publication	No limit	-
Language	English	Other languages

Notes: *Following the International Monetary Fund “advanced economies” classification. See (IMF, 2024) Statistical Appendix for more details.

3.3. Screening

The 1,469 entries obtained through the search process were scanned for duplicates on Zotero and Rayyan, leading to the exclusion of 435 duplicate records. Titles and abstracts were then screened against the inclusion criteria by two of the authors of this paper. Each of the two authors independently evaluated the studies without knowledge of the other’s decisions. The title and abstract screening resulted in the exclusion of 816 records, and, for the remaining 218 entries, the full text was sought and any conflicting paper between the two individual screening processes was discussed individually. During the retrieval process, 7 records could not be accessed. The number of included studies after full-text screening was 57. At this stage the snowballing method (Wohlin et al., 2022) was used to ensure literature saturation: the reference list of included studies (backward snowballing) and the list of papers citing the included studies (forward snowballing)

[2] The full list of advanced economies include: Andorra, Australia, Austria, Belgium, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong SAR, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Macao, Malta, The Netherlands, New Zealand, Norway, Portugal, Puerto Rico, San Marino, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States.

were scanned to identify additional relevant papers. The backward and forward snowballing process yielded 49 and 24 additional references respectively (Figure 1).

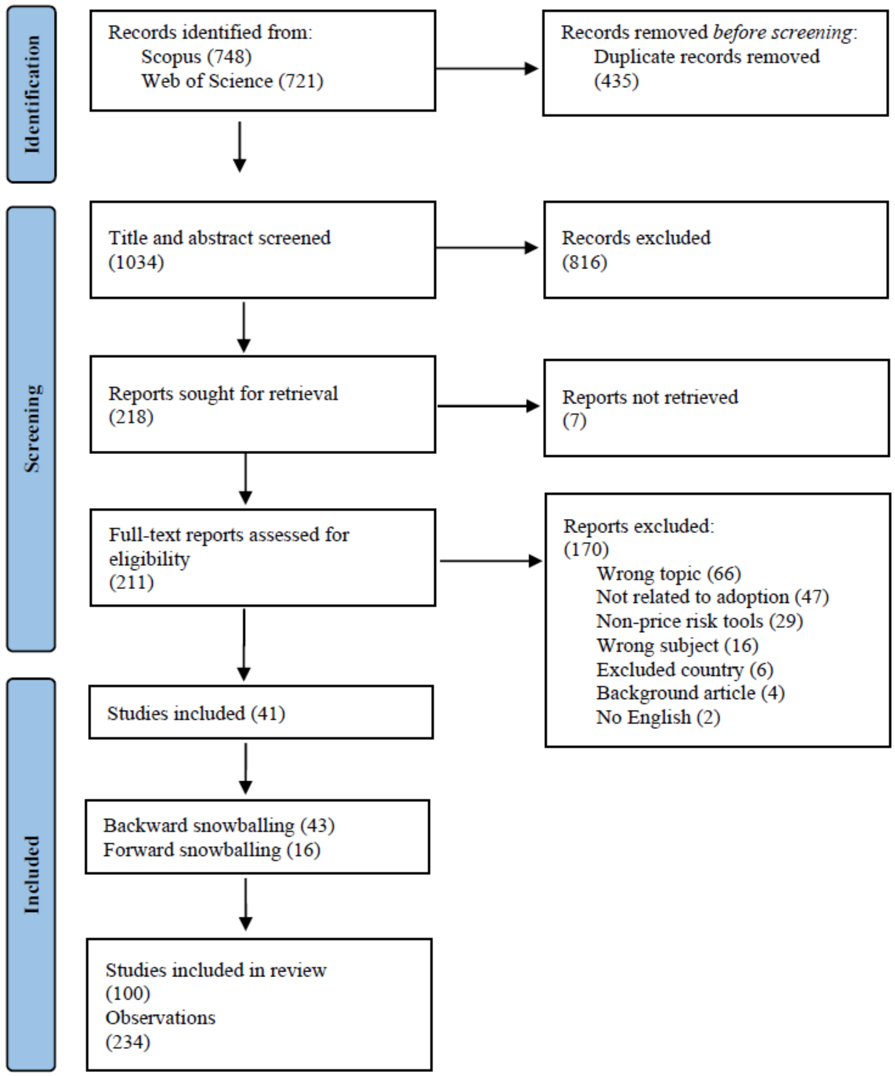

Figure 1. Flow diagram of article selection

Based on PRISMA guidelines (Page et al., 2021).

4. Results

4.1. Categorization and data description

Based on the categorization defined in the conceptual framework, Table 3 provides a general overview of the behavioral preferences and psychological factors that relate to the adoption of financial tools. Psychological factors are conceptually categorized into i) dispositional, ii) social, and iii) cognitive factors according to Dessart et al. (2019).

Table 3. Overview of behavioral preferences and psychological factors

Behavioral preferences	Psychological factors
- *Risk preferences*	Dispositional factors
- *Time preferences*	- *Risk attitudes*
- *Uncertainty and Variation aversion*	- *Innovativeness*
- *Probability weighting*	- *Management attitudes*
- *Loss aversion*	Social factors
- *Reference dependence*	- *Network influence*
- *Price expectations*	- *Social norms*
	Cognitive factors
	- *Tool knowledge and perceived ease of use*
	- *Alternative perceptions*
	- *Perceived usefulness*
	- *Risk perceptions*
	- *Price and yield expectations*

Note: A distinction exists for price expectations, where in behavioral preferences they are mathematically incorporated in economic models, while in the psychological factors category they are simply elicited or derived in experiments.

In total, we identified 100 studies, yielding 234 distinct observations. The higher number of observations results from the fact that some studies examine multiple financial tools, consider more than one preference or factor, and may also focus on different farm types. Table 4 presents a methodological categorization of the studies based on their approach of dealing with either behavioral preferences or psychological factors. Of the 100 papers, 57 implement behavioral preferences in mathematical notations. Of these, 15 are purely theoretical. They propose a theoretical model that includes a behavioral preference in mathematical terms, without a numerical application. Studies that implement optimizations (42 papers) apply numerical applications to a theoretical framework to optimize an objective function (typically a utility function). The studies that investigate psychological factors are in total 43, of these, 39 analyze farmers' behavior by conducting experiments to collect primary data, while 3 papers employ econometric techniques to explore secondary data.

Table 4. Methodological categorization of the studies

Behavioral preferences	Number of papers	Psychological factors	Number of papers
Theoretical models	15	Experiments	40
Optimizations	42	Econometric methods	3
Stochastic dominance	2		
Total	**57**		**43**

Geographically, the countries most represented are the United States, the Netherlands, and Australia (Table S2). The majority of studies focus on tools for managing output price risk (92 papers). Approximately half of the observations relate to farms engaged in crop production (Table S3). Among the 234 observations, 72 pertain to behavioral preferences and 162 to psychological factors (Figure 2). Risk attitudes emerge as the most extensively studied concept. Within the domain of behavioral preferences, risk preferences, is predominant. Similarly, in the domain of psychological factors, risk attitudes, categorized under “dispositional factors” receive significant attention. Risk attitudes are different from how farmers might perceive risk and these are classified as different factors. The difference between the two domains is that in behavioral economics, risk preferences refer to a property/parameter of a utility function, while this mathematical implementation is not necessary in a psychological setting.

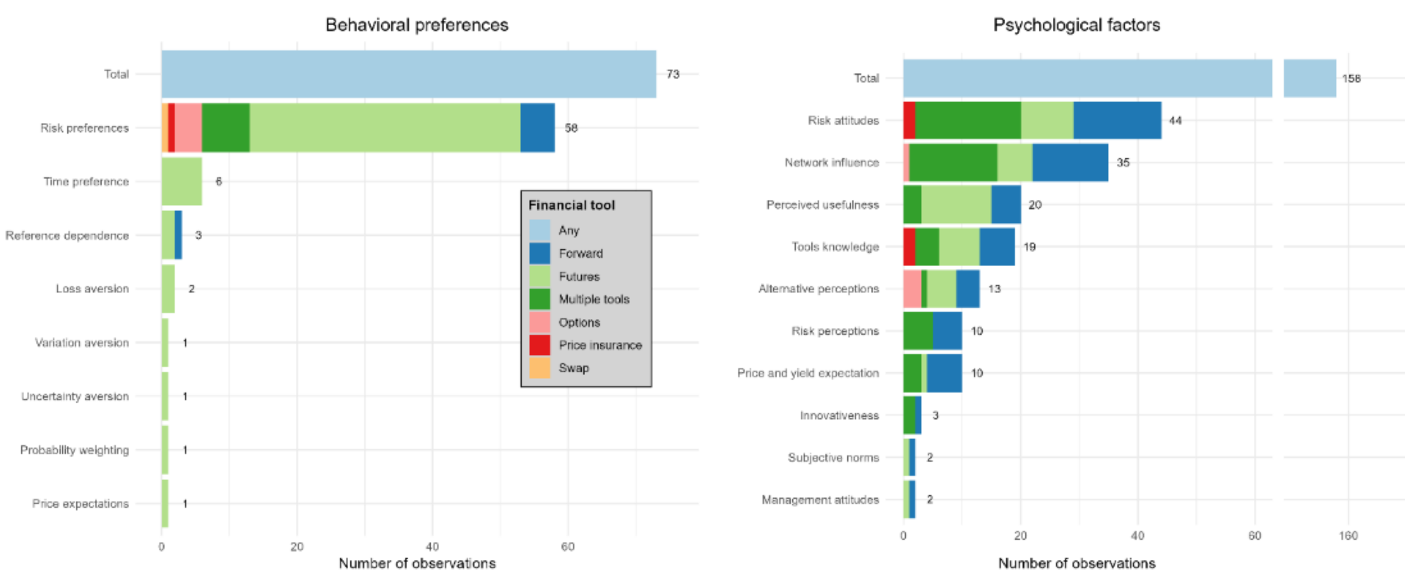

Figure 2. Overview of behavioral preferences and psychological factors

4.2. Behavioral preferences

Since the adoption of financial price risk management tools is a decision under risk, it is not surprising that the majority of papers focus on risk attitude, amounting to 77% of the total observations relating to behavioral preferences. Risk preferences and other preferences are mainly incorporated mathematically in Expected Utility maximization or Mean-Variance (M-V) methodologies (Figure 3) and mostly used to investigate adoption decisions regarding futures contracts, while other risk management tools receive less attention (see Table S4 for a comprehensive overview).

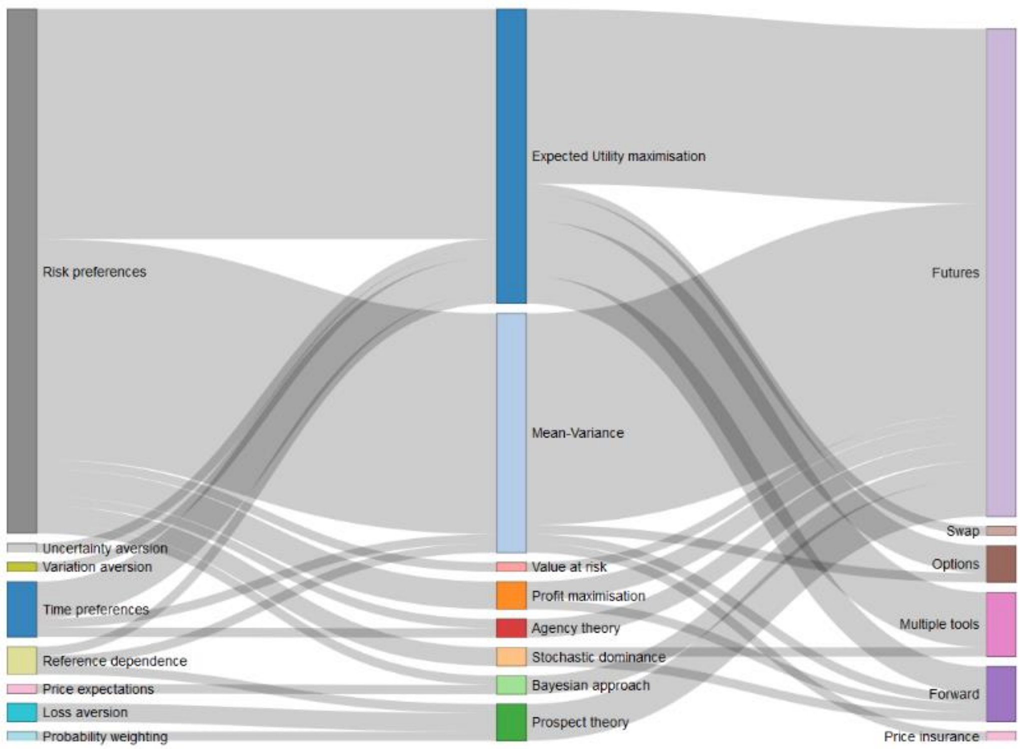

Figure 3. Mathematical models incorporation of behavioral preferences and usage relative to different financial tools.

Figure 4 provides a concise overview of how various behavioral preferences affect the optimal adoption decision for price risk management tools in theoretical models. The evidence on the impact of farmers' risk preferences, mainly risk aversion, is mixed. Although other behavioral preferences appear to have a consistent directional effect, the limited number of studies on these factors weakens the support for this claim. Moreover, uncertainty and loss aversion seem to have no impact based on the reviewed studies.

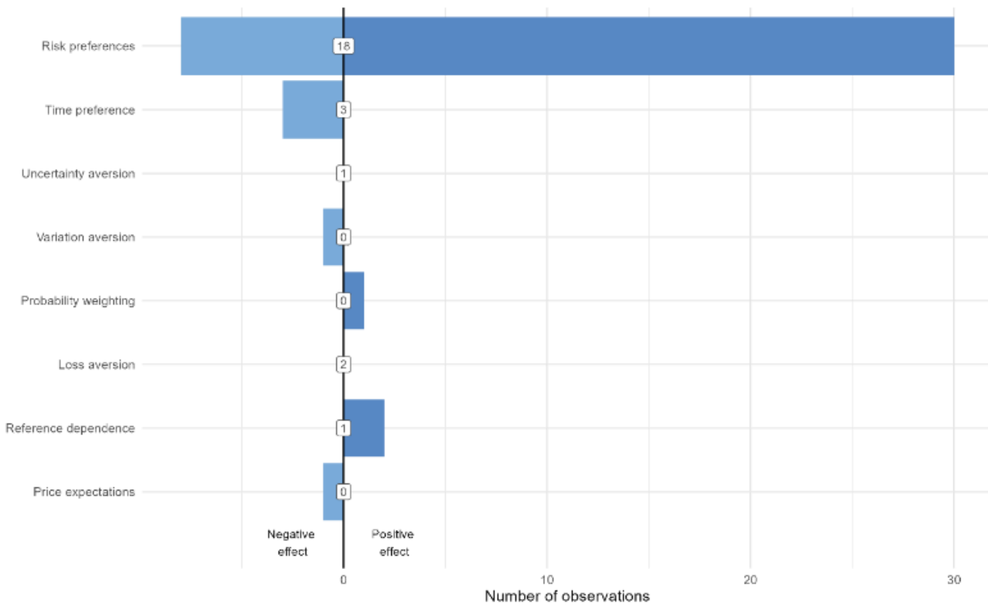

Figure 4. Direction of effect on the price risk management decision for each behavioral preference

(Numbers inside the boxes indicate the number of statistically insignificant observations)

Risk preferences are the most studied concepts relating to behavioral preferences (77.8% of observations) and refer to the way farmers behave when making decisions under risk. Decision-makers can be risk-averse, risk-neutral, or risk-seeking. Risk aversion is extensively covered in the traditional decision-making models based on the M-V and EU approaches. These types of investigations derive the optimal hedge ratio, i.e. the proportion of a cash position that should be hedged to minimize risk. Following the insight that farmers are risk-averse on average (Iyer et al., 2020), the majority of studies on risk management tools assume farmers to be risk-averse. This concept is extended to include the degree of risk aversion, introduced mathematically by a coefficient. Nonetheless, studies that consider risk neutrality are also preferent (Brorsen, 1995; Loy & Pieniadz, 2009).

Early investigations incorporated risk preferences mathematically in the standard M-V hedging model (e.g. Heifner, 1972; Rutledge, 1972). This approach, based on Modern Portfolio Theory (Markowitz, 1959), derives the optimal level of the hedging position, and has been the preferred theoretical model of normative hedging behavior due to its intuitive trade-off of expected return and risk, and ease of implementation. It has the general form:

$$Max\ W = E(R) + \lambda Var(R)$$

where the final wealth (W) depends on expected return (R) and its variance. In this framework, the optimal hedging position was assumed to be independent of the risk aversion coefficient (λ), thus being the same for all risk-averse decision-makers. Kahl (1983) demonstrated that this happens when cash and futures positions are treated as endogenous, making the optimal hedge ratio independent of the risk parameter[3]. Later Bond & Thompson (1985) showed that λ is a relevant determinant. The M-V approach was extended by maximizing its EU (e.g. Alexander et al., 1986; Bielza et al., 2007; Frechette, 2000; Liu & Pietola, 2005; Simmons & Rambaldi, 1997), thus mathematically incorporating risk preferences through the curvature of the utility function. Models that employ an EU maximization framework without considering the variance have also been explored (e.g. Arshanapalli & Gupta, 1996; Benninga et al., 1983; Grant, 1985; Ke & Wang, 2002; Lapan & Moschini, 1994; Lei et al., 1995; Moschini & Lapan, 1995; Wolf, 1987). In particular, (Lence, 1996) found that when production is stochastic, there is a negative correlation between risk aversion and the optimal hedge position, while most of the paper assume that as risk aversion increase, the optimal hedge position increases.

Time preferences, i.e. standard (non-behavioral) time preferences are typically incorporated in models that consider multi-period risk management and often involve the discounting of future benefits or costs, captured mathematically through a discount function (Wuepper, Henzmann, et al., 2023). Given that most studies focus on single-period decisions (e.g. a decision made at planting time t0 to mitigate the price risk at the selling time, t1), time preferences were found in only 6 papers. These papers incorporate discounting alongside risk preferences. Ho (1984) found that each farmer's hedge ratio, ceteris paribus, would increase as harvest time approaches. (i.e. the optimal position falls with the longer the time to harvest). On a similar note, Myers & Hanson (1996) found that the optimal hedge increases at the inverse of time to maturity (and interest rate). Basically, the more the time distance between the decision and the selling time, the lower the optimal hedging position.

Uncertainty aversion and *Variation aversion* are investigated only by Frechette (2005) who uses a Recursive Utility approach (Epstein and Zin 1989, 1991) in a multi-period decision model. Uncertainty aversion is the tendency to prefer a guaranteed value over one that is unknown[4], and variation aversion is the tendency to prefer a steady stream over a lump sum. They found that uncertainty aversion explains little observed behavior. On the other hand, as aversion to intertemporal variation increases, the optimal hedge position declines to zero, concluding that moderately risk-averse and even highly risk-averse hedgers may not hedge at all if they are averse to intertemporal variation. The argument is that a farmer paying transaction costs to manage risk incurs a utility loss to secure that in the future a utility loss will be minimized. To smoothen the utility stream, the farmer can reduce the larger loss (transaction costs) by hedging less, resulting in a more balanced utility stream.

Probability weighting is a bias that occurs as people tend to overweight small probabilities and underweight large probabilities. This distortion is captured by a probability weighting function and is usually incorporated in Prospect Theory frameworks. Only one paper was found that studied this concept in relation to price risk management tool adoption decisions (Mattos, Garcia, &

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[3] The optimal hedging ratio is dependent on risk aversion based on the assumption relating to the cash position. If the cash market position and the hedging position are determined simultaneously or if the cash market position is stochastic, the optimal hedging ratio is independent of the risk aversion coefficient, while assuming that the cash market position is given the optimal hedging ratio is dependent on the degree of risk aversion.

[4] The definition given by Frechette (2005) of uncertainty aversion is equivalent to ambiguity aversion (Ellsberg, 1961).

Pennings, 2008). The authors of the simulation paper concluded that changes in probability weighting affect hedge ratios relatively more than changes in loss and risk aversion. A complementary concept that is commonly implemented alongside probability weighting in prospect theory frameworks is loss aversion, and it has been applied in the price risk context.

Loss aversion refers to the phenomenon that losses are perceived as disproportionately worse than gains of equal size, and loss aversion is usually incorporated into a CPT framework (Tversky & Kahneman, 1992). This behavioral preference has received relatively little attention regarding price risk management decisions, with only 2 simulation papers considering it. Lien (2001) and Mattos, Garcia, & Pennings (2008) introduce loss aversion for futures contracts hedging decisions and arrive at the same conclusion that loss aversion has relatively small or no impact on hedging decisions. The functional form of loss aversion is strongly dependent on another fundamental behavioral concept of prospect theory: reference dependence.

Reference dependence occurs when people evaluate outcomes and express preferences relative to an existing reference point, which often is the status quo. It has been applied not only to CPT but also to other frameworks (Koszegi & Rabin, 2006). This is confirmed by studies found in the literature. Turvey & Nayak (2003) extended the traditional M-V model by considering only the (downside) semi-variance. This is done by applying the Mean-semi-variance model of portfolio selection (Hogan & Warren, 1972) to the hedging problem. This approach minimizes the semi-variance for a given expected value or that maximize expected value for a given semi-variance, where the semi-variance is measured in relation to a reference point that can be either the expected value or a fixed target value. Turvey & Nayak (2003) conclude that the choice of the reference point influences the optimal hedge position, with the higher the target value, the higher the hedge ratio. Reference dependence is also implemented by Mattos, Garcia, & Pennings (2008) in a Prospect Theory framework by considering the status quo as the reference point, this allows risk-averse behavior in the domain of gains, and risk-seeking behavior in the domain of losses. Nonetheless, their investigation focuses on the impact of loss aversion, so no conclusion can be derived regarding the effect of reference dependence on the hedging decision other than the mediated effect through the horizontal translation of the loss aversion function. Lastly, Jacobs et al. (2018) develop a model of optimal hedging by integrating static and dynamic reference dependence into an EU framework. They find that the optimal hedge ratio appears to respond positively to futures price changes above the static reference prices, but is not statistically different when futures prices are below the reference price. Similar results are found by using a dynamic reference price (the thirty-day moving average) of the futures contract. Jacobs et al. (2018) find an increase in hedging activity when the futures price increase and is above the moving average. On the other hand, when the futures price is below the moving average price, producers do not increase their hedge position in response to price changes. Nonetheless, they find no significant difference in hedging activity between a standard EU producer and a reference-dependent producer. Closely related to the concept of reference dependency, is the subjective expectation that farmers might have about the spot price.

Price expectations reflect farmers' subjective views on the spot price outcome distribution. Expectations have been shown to influence decisions (Manski, 2004) and the role of expectations has been applied in agricultural economics settings (Cerroni & Rippo, 2023; Hardaker & Lien, 2010). Price expectations can affect the farmers behavior if the risk management tool provides a higher price (in the case of output prices) or lower price (in the case of inputs) than the expected spot outcome. Results show that Shi & Irwin (2005) apply a Bayesian approach to incorporate subjective price expectations in a M-V framework. They present an investigation of farmers' expected futures contract price movement and found that if a farmer has a bullish view regarding the futures market direction, the hedger should decrease his/her short position in futures, on the contrary, if the farmer has a bearish view regarding the futures market direction, the hedger will increase his/her position. They showed that the optimal position could be substantially modified based on subjective views and that the magnitude of the adjustment depends on the magnitude and relative confidence level of the view with respect to the prior belief.

4.3. Psychological factors

Following the overall trend observed for behavioral preferences, risk attitudes are again the most investigated psychological factor (45 observations). Network influence is also highly studied (35 observations) and has more statistically significant ($p < 0.1$) observations compared to risk attitudes (Figure 5).

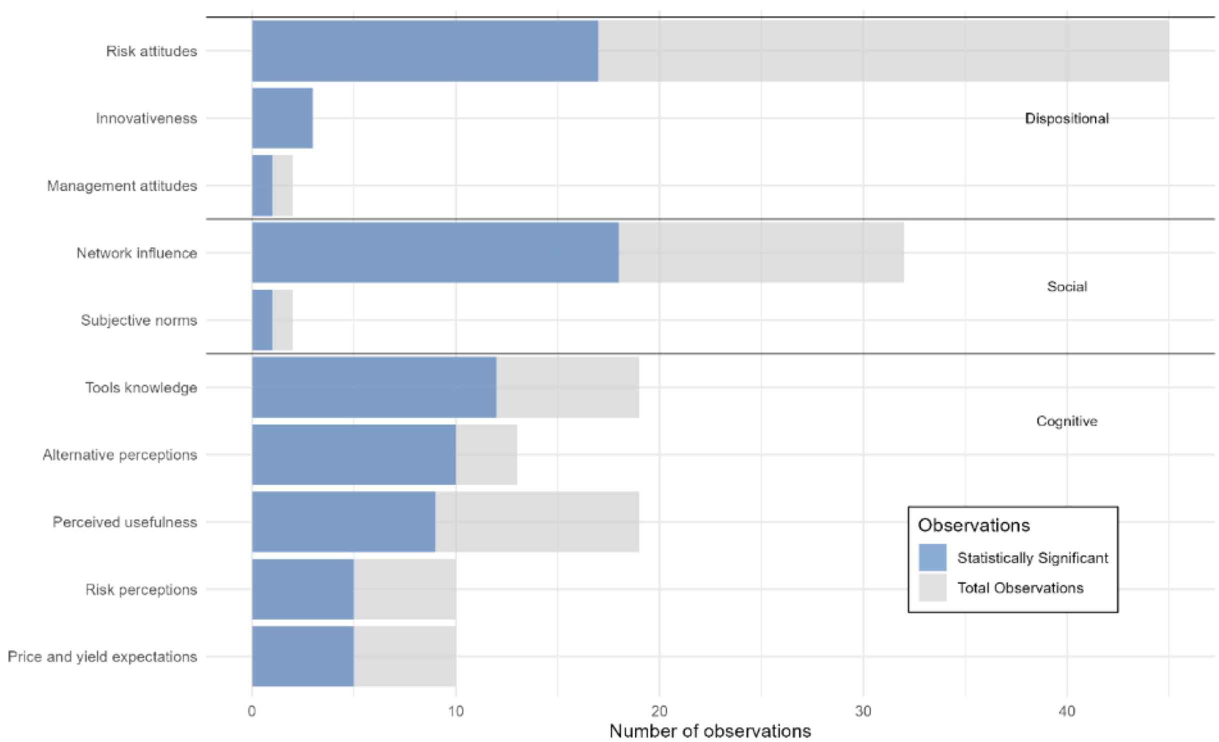

Figure 5. Statistically significant results for each psychological factor relative to total observations.

Figure 6 summarizes the direction of statistically significant observation for each psychological factor, highlighting the operationalization of the outcome variable: self-reported intention to adopt, self-reported adoption, and actual adoption. It shows that network influence, tools knowledge, and innovativeness have a clear positive trend on adoption decisions, while higher price expectations have a negative impact on adoption. Other factors present mixed results such as risk attitudes, risk perceptions, and perceived usefulness, while social norms and management attitudes have not been investigated enough to derive appropriate conclusions.

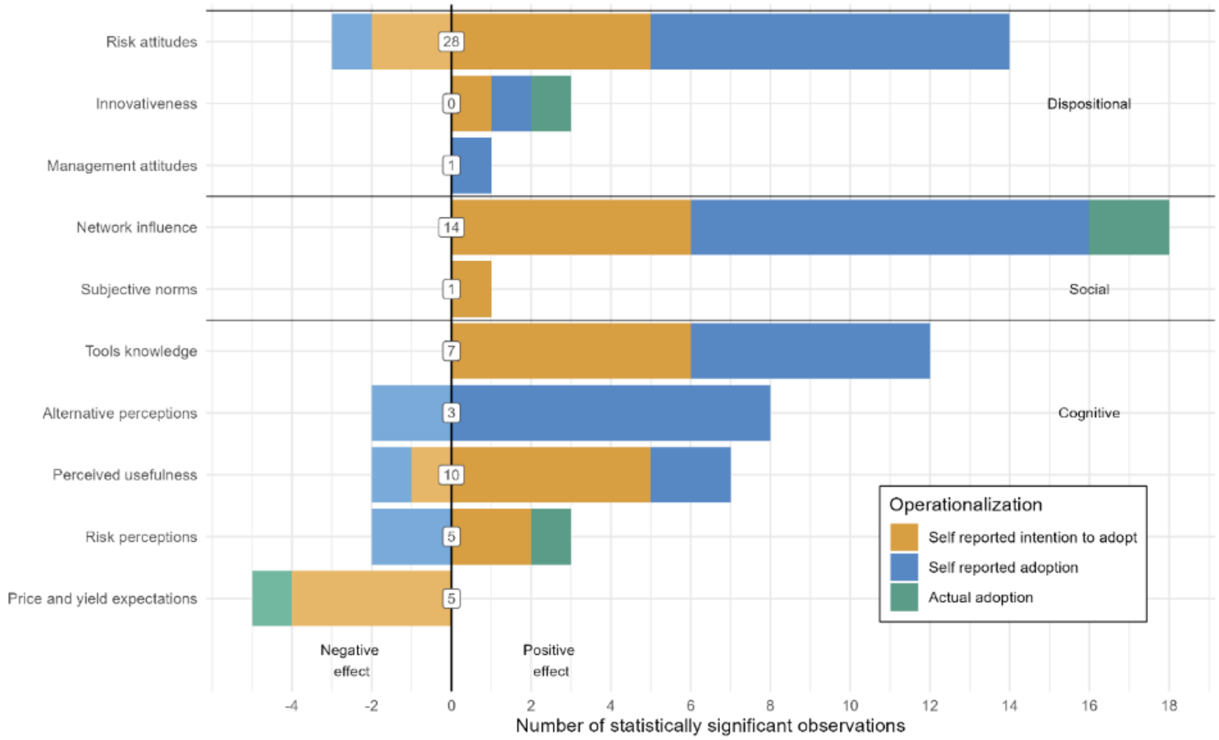

Figure 6. Effect and direction of statistically significant results for each psychological factor

(Numbers inside the boxes indicate the number of statistically insignificant observations)

4.3.1. Dispositional factors

Dispositional factors include farmers' general internal beliefs that drive behavior in a certain way. They include risk attitudes, management attitudes, and innovativeness (see Table S5 in the appendix for an overview).

Risk attitudes is the most studied factor, however, the majority of observations indicate that risk aversion has no statistically significant effect on risk management tools adoption. When the results are statistically significant, there is a general trend (14 observations) that the more producers are risk-averse, the more they adopt price risk management tools, but some papers provide the opposite evidence (3 observations). In particular, Goodwin & Schroeder (1994) found that risk-seeking producers are more likely to adopt forward pricing than risk-averse ones, Van Winsen et al. (2016) conclude that farmers who are more willing to accept risk are more likely to use risk management tools (i.e. forwards, futures, and insurances), and Boyer et al. (2024) find that farmers with higher risk tolerance (i.e. lower risk aversion) for their beef cattle operation are more likely to buy price insurance. The fact that many papers derive non-significant results and some even counter the general trend, may be due to the fact that risk attitudes is a concept extremely difficult to measure. The studies found in the literature display a lot of heterogeneity in their elicitation methods[5]. This may contribute to the mixed results. Some derive elaborated risk constructs, where multiple questions are used to obtain a global risk measure (e.g. Franken et al., 2014; Pennings & Garcia, 2001; Pennings & Leuthold, 2000; Pennings & Smidts, 2000). Other studies focus on diverse self-assessment scales: Likert-type (Anastassiadis et al., 2014; Isengildina & Hudson, 2001), simple dummy (Goodwin & Kastens, 1996; Vergara et al., 2004), and finally some papers use a different risk attitude definition. Examples are Musser et al. (1996) that use a safety-first approach, eliciting risk preferences more related to the concept of loss aversion, or Fields & Gillespie (2008) that use preference regarding investments as a proxy for preferences over income variability.

Innovativeness is the farmer's attitude toward innovation such as the adoption of new technologies or practices. This was found to have a positive statistically significant effect in all the studies in the review: for forward pricing tools. i.e. forwards, futures, and options (Coffey & Schroeder, 2019), for forwards contracts (Ricome & Reynaud, 2022), and for digital risk management tools in general (Block et al., 2023).

Management attitudes reflect the preferences of farmers towards free entrepreneurship, but limited evidence was found in the literature. Farmers that state a preference for more freedom of action regarding their operation[6] are more likely to adopt futures contracts (Pennings & Leuthold, 2000). Ricome & Reynaud (2022) found that farmers who prefer free market prices (as opposed to administrated minimum prices) are more likely to adopt forward pricing, but the results were not statistically significant.

4.3.2. Social factors

The social environment and the interpersonal relationship affect farmers' decisions to adopt price risk management tools. Social factors include social norms and network influence (see Table S6 for an overview). Given the relevance of peers and other actors in the social sphere in the context of decision-making, network influence was found to be highly investigated and the factor with the highest number of positive and significant effects on adoption decisions.

Network influence refers to the direct impact exerted by peers, institutions, and other actors in the chain on the adoption of financial tools. It includes recommendations and encouragement, typically provided by lenders, buyers, or extension services, and information exchange among peers who can share (positive or negative) experiences with these tools. Although 14 observations reported no significant impact of network influence on adoption (Figure 6), a significant amount found a positive relationship between the influence of different actors and adoption decisions (18 observations). For example, producer organizations play a role in the

[5] For the sake of comparison, all the results were collected and recorded by considering what is the effect of increasing risk aversion on adoption decisions. This standardization allowed us to normalize different scales direction in different studies (some studies measure risk attitudes from risk-averse to risk-seeking, while other measure it in the opposite direction).

[6] Based on the argument made by Working (1953) that futures contracts gives the farmer a greater freedom such as making a sale or purchase that would otherwise not be possible.

decision: farmers that view producer organizations as important source of marketing information (Fu et al., 1988), attend organizations meeting (Asplund et al., 1989), or are simply organization member (Makus et al., 1990), are more likely to adopt forward contracting. Another example relates to market advisory and extension services that have been found to have a positive effect on the adoption of forwards, futures, and options (B. K. Coffey & Schroeder, 2019; Davis et al., 2005; Isengildina et al., 2006; Katchova & Miranda, 2004; Perry, 1999). Moreover, upstream and downstream actors, also play a role in the decision process. Penone et al. (2024) demonstrated that when buyers recommend forward contracts, farmers state that will adopt them more frequently. Finally, a positive effect on forwards frequency of use was found for farmers who participated in education programs or seek information in general from magazines or digital sources (Goodwin & Schroeder, 1994; Vergara et al., 2004).

Social norms reflect the producer's perception of how other people think he/she should behave, also called subjective norms in the Theory of Planned Behavior (Ajzen, 1991). Unlike network influence, which is more specific, social norms dictate what people ought to do. A positive effect of social norms was found in futures adoption (Michels et al., 2019). On the same line Penone et al. (2024) found a positive effect on forwards but the results in not statistically significant. Given the low number of observation, no clear conclusion can be derived regarding the effect of social norms on price risk management tools adoption.

4.3.3. Cognitive factors

Cognitive factors are more specific and closely related to risk management and financial tools adoption decisions. They include risk perceptions, price and yield expectations, perceived usefulness, tools knowledge, and perception of alternative tools (see Table S7 for an overview). Among these, the tools knowledge is the one with the most significant positive effects on adoption decisions (Figure 6).

Tools knowledge refers to the level of understanding and the perceived ease of use of financial tools. As expected, farmers with a high (low) level of understanding, are more (less) likely to adopt financial tools (Ennew et al., 1992; Patrick et al., 1998; Pennings & Leuthold, 2000; Vergara et al., 2004). The perceived ease of use (or the perceived complexity) also impacts adoption decisions: a higher perceived ease of use, or lower perceived complexity, leads to higher adoption levels (Davis et al., 2005; Michels et al., 2019). Further, farmers who put higher effort into seeking information specifically about markets (market orientation), such as prices or volume traded are more likely to hedge using futures (Meulenberg & Pennings, 2002; Pennings & Leuthold, 2000).

Alternatives perceptions relate to how other financial tools are perceived. Most of the positive observations derive from the study by Edelman et al. (1990), where investigating different farm-type use of forwards, futures, and options, found that the use of one tool is correlated with the use of other financial tools. Similarly, Makus et al. (1990) found that farms that use forward contracting are more likely to use futures and options. In contrast, (Ennew et al., 1992; Isengildina & Hudson, 2001) found that the more other means of risk management are preferred, the less the adoption of futures.

Perceived usefulness is the perception of farmers regarding the perceived benefits and drawbacks of financial tools adoption. Most of the studies focus on the price enhancement capacity of financial tools, which is closely related to price expectations. Farmers that believe risk management tools will provide a higher price than the spot one (Meulenberg & Pennings, 2002; Michels et al., 2019; Pennings, 2002), have higher adoption levels. Another capacity is the risk reduction that these tools provide. A positive relationship was found in the literature between the perceived risk reduction performance of the tool and adoption levels (Meulenberg & Pennings, 2002; Pennings & Leuthold, 2000; Penone et al., 2024). On the other hand, several perceptions about the drawbacks of using these tools hinder adoption. For example, the more the belief that futures markets are risky, the less the adoption of futures contracts (Ennew et al., 1992), or the more farmers are concerned about the other party not complying with the contract, the less the adoption of forwards (Penone et al., 2024).

Risk perceptions relate to the subjective assessment of price risk. The intuition would be that farmers that perceive higher price risk, would adopt more risk management tools, but the evidence is mixed and there is no clear direction on the effect that higher perceived risk has on adoption decision. For instance, farmers that perceive high price risk were found to have higher adoption levels for futures and options (Davis et al., 2005; Pennings & Garcia, 2004) and forwards (Davis et al., 2005). On the other end, the effect was found negative for futures, options, and forwards (Vergara et al., 2004). This might be due to the fact that risk perception might affect actual behavior through t(Pennings & Garcia, 2004)tudes (Pennings & Garcia, 2004). Producers who perceive high price risk but are risk-neutral, will not use financial tools and when no risk is perceived, a manager's risk attitude does not influence their behavior.

Price and yield expectations, reflect farmer beliefs about future prices and output levels. A clear trend was found in the literature that when farmers believe that prices at harvest would be higher (lower) than current prices, they state that they are less (more) willing to adopt risk management tools (Anastassiadis et al., 2014; Davis et al., 2005; Ricome & Reynaud, 2022). Nonetheless, almost all of the observation relates to a self-reported intention to adopt financial tools (Figure 6) providing less validity to support the claim. Interestingly, these expectations are often based on the current spot price being the reference point. Yield expectation can influence the adoption of forward contracts because they directly affect farmer's ability to meet contractual obligations. Producers determine whether the benefits of hedging price risk outweigh the potential costs and risks associated with committing to fixed production volume. This was studied in only one paper (Roussy et al., 2018), but no significant effect was found.

5. Discussion

This literature review systematically summarizes the role of behavioral preferences used in theoretical economic models and psychological factors in the adoption of price risk management tools. We find that a large share of the literature is theoretical and focuses on optimal hedging decisions which are driven by producers' risk preferences (i.e. risk-averse, risk-neutral, and risk-seeking attitudes). However, findings regarding risk attitudes inside the psychological factors have been mixed (Figure 6, with many studies that elicit risk attitudes found no correlation with adoption decisions.

The neoclassical models for risk management decisions have been extended by considering factors beyond risk preferences. Working (1953) recognized early that hedging couldn't be explained solely in terms of risk reduction but also as a source of potential profits, giving rise to speculative behavior. Anderson & Danthine (1980), included this possibility in their hedging model, viewing the optimal hedge as a sum of a risk-minimizing and a speculative position. Several other papers extended these traditional models by investigating different non-behavioral factors that have a negative impact on the optimal hedging position, among which: production uncertainty (e.g. Ho, 1984; Karp, 1987; Lence, 1996; McKinnon, 1967), diversification (e.g. Berck, 1981), financial leverage (e.g. Turvey & Baker, 1989), transaction costs (e.g. Pannell et al., 2008), and use of subsidized non-price insurances (e.g. Coble et al., 2003; Makus et al., 2007). These models have also been expanded by considering different definitions of risk: while the traditional M-V model assumes that farmers are willing to renounce upside potential opportunities to reduce variance, a downside risk approach has been considered (Mattos et al., 2008; Turvey & Nayak, 2003), or considering skewness in the price distribution (Gilbert et al., 2006; Vercammen, 1995). Other decision rules that consider behavioral preferences have also been employed such as stochastic dominance (Gloy & Baker, 2002; Parcel & Langemeijer, 1997) and Value at Risk (Schütz & Westgaard, 2018). Besides Shapiro & Brorsen (1988), that elicited an Arrow-Pratt risk aversion and related to futures adoption, no other behavioral economic studies exist that empirically relate elicited behavioral economic preferences (e.g. based on the approach suggested by Tanaka et al., 2010) to the adoption of price risk management tools.

Moving away from the normative approach of EU and M-V frameworks towards behavioral economics insights seems to be a promising path for future research to better explain and predict farmers' price risk management decisions, which has however been little explored so far. Only a handful of studies explore behavioral preferences that shed light on the relation between price risk management and reference dependence, loss aversion, uncertainty preferences, and time preferences. Regarding this matter, reference dependence has been applied both to the traditional M-V model (Turvey & Nayak, 2003) and to the prospect theory model (Mattos, Garcia, & Pennings, 2008), which are however both simulational in nature and lack an experimental confirmation. , Those simulational findings are confirmed in studies on psychological factors (e.g. Anastassiadis et al., 2014; Davis et al., 2005; Ricome & Reynaud, 2022), where price expectations depend on a reference level (often the status quo).

A related concept to reference dependence is loss aversion, but conceptually it seems to have little explanatory power regarding farmers' price risk management decisions, at least in a classical risk management framing of the decision (Figure 4). Insights from psychological factors investigations, suggest that some papers elicit risk attitudes framing the question as loss aversion, for example Musser et al. (1996) ask farmers if they are more concerned about a large loss in their farm operation than missing a substantial gain. Nonetheless, no experimental studies exist that implement tasks to reveal farmers sensitivity to losses relative to gains and relate them to actual price risk management decisions.

CPT incorporates not only reference dependence and loss aversion, but also a biased perception of probability distributions. (Mattos, Garcia, & Pennings (, 2008) concluded that changes in probability weighting affect hedge ratios relatively more than changes in loss and risk aversion, but again the shape of the weighting function or any other form of probability distortion has not been related to price risk management decision in any experimental work.

Another promising avenue from behavioral economics that received little attention in the context of price risk management is decision making under uncertainty and ambiguity. Only one study investigated uncertainty aversion (Frechette, 2005) but this has no impact on the decision (Figure 4). Uncertainty preferences have been investigated in relation to farmers' decisions to enter contract farming to mitigate uncertainty related to future market prices of agricultural commodities (e.g. Cerroni, 2020; Cerroni, 2023). Other theories might offer better behavior explanations such as Subjective EUT (Savage, 1954), Smooth ambiguity model (Klibanoff et al., 2005), Alpha EUT (Ghirardato et al., 2004), or muti-reference theories (Wang & Johnson, 2012). These theories were developed to find better explanations than EUT models given the fact that people often do not behave in accordance with EUT predictions, and it also remains an open question as to how far behaviors, with growing experience, converge towards a rational benchmark (List, 2003).

Given that price risk management tools are designed to hedge against future price risk price risk management decisions are an intertemporal choice. In this context, few studies have considered time preferences and price risk management tools in simulations (Frechette, 2005; Ho, 1984; Karp, 1987; Kuwornu et al., 2005; Lence et al., 1993; Myers & Hanson, 1996). In this context, recent evidence shows that farmers elicited time preferences in the US and Europe seem to be unrealistically high (Wuepper, Henzmann, et al., 2023). Therefore, behavioral discounting models (such as quasi hyperbolic discounting) might allow for a more flexible representation of farmers' time preferences including a present bias (Liebenehm & Waibel, 2014).

We did not find a single study that formally models a heuristic, for instance through a decision tree, rather than utility maximization. The vast literature in psychology on heuristics (Gigerenzer & Gaissmaier, 2011) has yet to find its way into the general Agricultural Economics literature and the literature on adoption and use of financial tools in particular.

Hedging decisions are shaped not only by risk consideration and behavioral preference but also by other psychological factors that have not yet been considered in theoretical specifications regarding financial tools for price risk management. Based on the insights derived from the psychological factors investigations, the network influences are a particularly promising avenue (Figure 6). Much empirical work on technology adoption in agriculture uses simple measures of network influence, such as the numbers of peer adopting a tool, or behaviorally informed interventions that state average adoption numbers of a relevant peer group. A new approach is to open this black box of social norms by investigating mechanisms in farmer samples (Raineau et al., 2025) and to consider the distribution rather than averages in relevant peer networks (Dimant et al., 2024).

Tools knowledge was also found as an important factor in adoption decision. This suggests that extension services, financial tools providers, and policy makers can have a role in providing training and education to improve farmer' decision making ability regarding price risk.

Finally, several of the latest developments in the behavioral economics literature in Agricultural Economics could also be relevant for a better understanding of the adoption of financial risk management tools. For instance, the role of culturally shaped experiences and beliefs plays an important way in financial decisions in general (Malmendier, 2021). Likewise, farmers' cultural differences can lead to differences in conservation practices (Wang et al., 2023). A small literature is also concerned with the role of identity in the adoption of (Faccioli et al., 2020; Z., 2020; Zemo & Termansen, 2022), and this literature could be relevant for the adoption of financial tools as well.

6. Conclusion

This study systematically reviewed the literature on how behavioral factors impact financial tools adoption for price risk management. These behavioral factors were divided into behavioral preferences and psychological factors based on their incorporation into economic choice models. Our results show that the neoclassical models, based on the notion that optimal hedging decisions are primarily driven by producers' risk preferences, are still the central frameworks of price risk management. Empirical findings on risk attitudes remain mixed, with many studies finding little correlation between elicited risk measures and hedging adoption. This suggests that factors such as reference dependence, loss aversion, probability weighting, and decision making under uncertainty may better explain financial tools adoption decisions. Some instances were found that tried to shift the focus from normative models toward a behavioral economics approach but more effort in this direction is required.

Moreover, the literature indicates that non-risk factors, in the domain of social and cognitive factors also play a role in farmers' hedging decisions. These insights underscore the importance of incorporating more psychological factors in economic choice models. Despite promising but timid theoretical advances, the lack of empirical studies that employ experimental tasks to elicit farmers' behavioral preferences (e.g. loss aversion, reference dependence, and probability weighting) highlights an important avenue for future research.

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Supplementary material

Table S1. Search strings

	Search string
Scopus	TITLE-ABS-KEY ((farm* OR producer OR grower OR "agricultural entrepreneur") AND ("price risk*" OR "price volatility" OR "financial tools" OR {futures} OR {hedge} OR {hedging} OR "forward contract" OR swap) AND (attitude* OR attribute* OR behavio* OR norms OR preference* OR cognitive OR perception OR factors OR "uncertainty preference" OR "uncertainty attitude" OR "uncertainty consideration" OR "uncertainty avers*" OR "risk preference" OR "risk attitude" OR "risk consideration" OR "risk avers*" OR "ambiguity preference" OR "ambiguity attitude" OR "attitude consideration" OR "ambiguity avers*" OR "probability weighting" OR "loss avers*" OR "subjective probability" OR "time preference" OR "temporal preferences" OR "discount*" OR eut OR "expected utility theory" OR "prospect theory" OR "alpha expected utility" OR "subjective utility" OR "rank-dependent utility" OR "smooth ambiguity model")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ch")) AND (LIMIT-TO (LANGUAGE , "English")) AND (EXCLUDE (SUBJAREA , "ENER") OR EXCLUDE (SUBJAREA , "ENGI") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "CENG"))
Web of Science Core Collection	#1: TS=(farm* OR producer$ OR grower$ OR "agricultural entrepreneur") #2: TS=("price risk" OR "price volatility" OR "financial tools" OR “futures” OR “hedge” OR “hedging” OR "forward contract" OR “swap”) #3: TS=(attitude$ OR attribute$ OR behavio* OR “norms” OR preference$ OR “cognitive” OR perception$ OR factor$ OR "uncertainty preference" OR "uncertainty attitude" OR "uncertainty consideration" OR "uncertainty avers*" OR "risk preference" OR "risk attitude" OR "risk consideration" OR "risk avers*" OR "ambiguity preference" OR "ambiguity attitude" OR "attitude consideration" OR "ambiguity avers*" OR "probability weighting" OR "loss avers*" OR "subjective probability" OR "time preference" OR "temporal preferences" OR "discount*" OR "eut" OR "expected utility theory" OR "prospect theory" OR "alpha expected utility" OR "subjective utility" OR "rank-dependent utility" OR "smooth ambiguity model") Combined search: #1 AND #2 AND #3

Table S2. Geographical distribution of studies found in the review.

Country		Studies
US		52
EU		20
-	*Netherlands*	*7*
-	*Germany*	*4*
-	*France*	*3*
-	*Belgium*	*1*
-	*Finland*	*1*
-	*Italy*	*1*
-	*Norway*	*1*
-	*Spain*	*1*
-	*Multi-country*	*1*
Australia		4
Canada		1
UK		1
Not specified		22

Table S3. Different farm types as a share of total observations.

Farm type	% of observation
Crop	55.6
Livestock	18.8
FV	0.8
Fish	0.4
Not specified	24.4

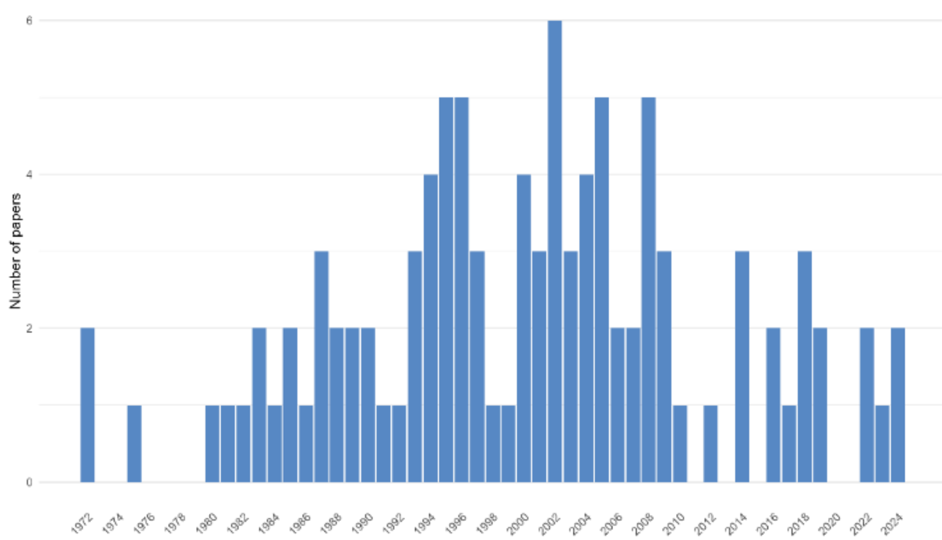

Figure S1. Distribution of publication over time

Table S4. Behavioral preferences

Preference	Tool	Study	Country	Farm type	Product	Model	Direction
Loss aversion	*Futures*	Lien, Donald (2001)	not specified	other	not specified	Prospect theory	0
		Mattos; Garcia; Pennings (2008)	US	crop	soybean	Prospect theory	0
Price expectation	*Futures*	Shi, Wei; Irwin, Scott H. (2005)	not specified	other	not specified	Bayesian approach	-
Probability weighting	*Futures*	Mattos; Garcia; Pennings (2008)	US	crop	soybean	Prospect theory	+
Reference dependence	*Forward*	Jacobs, K.L.; Li, Z.; Hayes, D.J. (2018)	US	crop	not specified	EU max	+
	Futures	Turvey, CG; Nayak G (2003)	US	crop	wheat	Mean-Variance	+
		Mattos; Garcia; Pennings (2008)	US	crop	soybean	Prospect theory	0
Risk preferences	*Forward*	Grant, Dwight (1985)	not specified	other	not specified	EU max	+
		Gilbert, S; Jones, SK; Morris, GH (2006)	not specified	crop	Cotton	EU max	0
		Bielza, M.; Garrido, A.; Sumpsi, J.M. (2007)	Spain	crop	potato	Mean-Variance	+
		Loy, Jens-Peter; Pieniadz, Agata (2009)	Germany and Poland	crop	wheat	Profit max	0
		Parcel & Langemeijer (1997)	Canada	livestock	hog	Stochastic Dominance	+
	Futures	Kuwornu et al. (2005)	Netherlands	crop	potato	Agency Theory	0
		Shi, Wei; Irwin, Scott H. (2005)	not specified	other	not specified	Bayesian approach	+
		Benninga, S; Eldor, R; Zilcha, I (1983)	not specified	other	not specified	EU max	0
		Ho, T.S.Y. (1984)	US	crop	wheat	EU max	-
		Karp, LS (1987)	US	crop	wheat	EU max	0
		Lapan, Harvey; Moschini, Giancarlo (1994)	US	crop	soybean	EU max	-
		Lei, L.-F.; Liu, D.; Hallam, A. (1995)	US	crop	corn	EU max	-
		Arshanapalli, B.G.; Gupta, O.K. (1996)	US	livestock	cattle	EU max	0
		Lence, Sergio H (1996)	not specified	crop	grain	EU max	+
		Myers, R.J.; Hanson, S.D. (1996)	not specified	other	not specified	EU max	0
		Ke, B.; Wang, H.H. (2002)	US	other	not specified	EU max	+
		Coble et al. (2004)	US	crop	soybean	EU max	+
		Frechette, D.L. (2005)	not specified	livestock	not specified	EU max	+
		Makus, L.D.; Wang, H.H.; Chen, X. (2007)	US	crop	wheat	EU max	0
		Gaston Clément et al. (2022)	not specified	other	not specified	EU max	0
		Heifner, Richard G (1972)	US	livestock	cattle	Mean-Variance	+

Risk preferences	*Futures*	Rutledge, David J.S. (1972)	US	crop	soybean	Mean-Variance	+
		Peck, A. E. (1975)	US	livestock	egg	Mean-Variance	+
		Anderson, RW; Danthine, JP (1980)	US	crop	grain	Mean-Variance	0
		Berck, Peter (1981)	US	crop	cotton	Mean-Variance	0
		Chavas, Jean-Paul; Pope, Rulon (1982)	not specified	other	not specified	Mean-Variance	+
		Kahl, KH (1983)	not specified	other	not specified	Mean-Variance	0
		Bond, Gary E.; Thompson, Stanley R. (1985)	not specified	other	not specified	Mean-Variance	+
		Alexander et al. (1986)	US	crop	corn and soybean	Mean-Variance	+
		Witt et al. (1987)	US	crop	barley and sorghum	Mean-Variance	+
		Turvey, Calum G.; Baker, Timothy G. (1989)	not specified	other	not specified	Mean-Variance	+
		Fackler, Paul L.; McNew, Kevin P. (1993)	US	crop	soybean	Mean-Variance	+
		Lence, Sergio H (1996)	not specified	crop	grain	Mean-Variance	-
		Simmons, P.; Rambaldi, A. (1997)	Australia	crop	wheat	Mean-Variance	+
		Frechette, Darren L. (2000)	US	livestock	dairy	Mean-Variance	0
		Simmons, P. (2002)	Australia	other	not specified	Mean-Variance	0
		Coble, KH; Zuniga, M; Heifner, R (2003)	US	crop	soybean and cotton	Mean-Variance	+
		Liu, X.; Pietola, K. (2005)	Finland	crop	wheat	Mean-Variance	+
		Bielza, M.; Garrido, A.; Sumpsi, J.M. (2007)	Spain	crop	potato	Mean-Variance	+
		Mattos, F.; Garcia, P.; Nelson, C. (2008)	US	crop	soybean	Mean-Variance	0
		Pannell et al. (2008)	Australia	livestock	wool production	Mean-Variance	+
		Collins, R.A. (1997)	not specified	other	not specified	Profit max	0
		Schütz, P.; Westgaard, S. (2018)	Norway	fish	salmon	Value at Risk	+
	Multiple tools	Lapan et al. (1991)	not specified	other	not specified	EU max	+
		Lence, S.H.; Sakong, Y.; Hayes, D.J. (1994)	not specified	other	not specified	EU max	+
		Lei, L.-F.; Liu, D.; Hallam, A. (1995)	US	crop	corn	EU max	-
		Moschini & Lapan (1995)	US	crop	soybean	EU max	-
		Vercammen, J. (1995)	not specified	other	not specified	EU max	0
		Mahul, O. (2003)	France	other	not specified	EU max	0
		Gloy, BA; Baker, TG (2002)	not specified	other	not specified	Stochastic Dominance	-
	Options	Wolf, Avner (1987)	not specified	other	not specified	EU max	+

Risk preferences	*Options*	Sakong, Y.; Hayes, D.J.; Hallam, A. (1993)	US	crop	corn	EU max	+
		Lei, L.-F.; Liu, D.; Hallam, A. (1995)	US	crop	corn	EU max	-
		Garcia, P; Adam, Bd; Hauser, Rj (1994)	not specified	livestock	hog	Mean-Variance	+
	Price insurance	Bielza, M.; Garrido, A.; Sumpsi, J.M. (2007)	Spain	crop	potato	Mean-Variance	+
	Swap	Bowden (1995)	not specified	other	not specified	EU max	+
Time preferences	*Futures*	Kuwornu et al. (2005)	Netherlands	crop	potato	Agency Theory	0
		Ho, T.S.Y. (1984)	US	crop	wheat	EU max	-
		Karp, LS (1987)	US	crop	wheat	EU max	0
		Myers, R.J.; Hanson, S.D. (1996)	not specified	other	not specified	EU max	-
		Frechette, D.L. (2005)	not specified	livestock	not specified	EU max	0
		Lence, S., K. Kimle, and M. Hayenga (1993)	US	crop	corn	Mean-Variance	-
Uncertainty aversion	*Futures*	Frechette, D.L. (2005)	not specified	livestock	not specified	EU max	0
Variation aversion	*Futures*	Frechette, D.L. (2005)	not specified	livestock	not specified	EU max	-

Notes: (1) positive effect, (-1) negative effect, (0) no direction

Table S5. Dispositional factors

Factor	Tool	Study	Country	Farm type	Product	Operationalization	Direction
Risk attitudes	*Forwards*	Sartwelle et al. (2000)	US	crop	grain	Self reported adoption	0
		Isengildina, O.; Hudson, M.D. (2001)	US	crop	cotton	Self reported adoption	0
		Vergara et al. (2004)	US	crop	cotton	Self reported adoption	0
		Davis et al. (2005)	US	crop	corn	Self reported intention	0
			US	crop	soybean	Self reported intention	0
		Pennings et al. (2008)	US	crop	not specified	Self reported adoption	0
	Forwards	Franken et al. (2009)	US	livestock	hog	Self reported adoption	+
		Franken et al. (2012)	US	crop	corn	Self reported adoption	+
			US	crop	soybean	Self reported adoption	+
		Anastassiadis et al. (2014)	Germany	other	not specified	Self reported intention	+
		Franken et al. (2014)	US	other	not specified	Self reported adoption	+
		Mußhoff et al. (2014)	Germany	crop	sugar beet	Self reported intention	+
		Vassalos, M.; Li, Y. (2016)	US	FV	tomato	Self reported intention	0
		Franken et al. (2017)	US	livestock	hog	Self reported adoption	+
		Ricome, A.; Reynaud, A. (2022)	France	other	not specified	Actual adoption	0
	Futures	Shapiro & Brorsen (1988)	US	crop	corn and soybean	Self reported adoption	0
		Pennings & Leuthold (2000)	Netherlands	livestock	hog	Self reported adoption	0
		Pennings, JME; Smidts, A (2000)	Netherlands	livestock	hog	Self reported adoption	0
			Netherlands	livestock	hog	Self reported adoption	+
			Netherlands	livestock	hog	Self reported adoption	+
		Isengildina, O.; Hudson, M.D. (2001)	US	crop	cotton	Self reported adoption	0
		Pennings, J.M.E.; Garcia, P. (2001)	Netherlands	livestock	hogs	Self reported intention	+
		Meulenberg & Pennings (2002)	Netherlands	livestock	hogs	Self reported intention	0
		Pennings, J.M.E. (2002)	Netherlands	livestock	hogs	Self reported intention	+
		Anastassiadis et al. (2014)	Germany	other	not specified	Self reported intention	0
	Multiple tools	Goodwin & Schroeder (1994)	US	other	multiple products	Self reported adoption	-
			US	crop	wheat	Self reported adoption	0
			US	crop	corn	Self reported adoption	0

Risk attitudes	*Multiple tools*	Goodwin & Schroeder (1994)	US	crop	sorghum	Self reported adoption	0
			US	crop	soybean	Self reported adoption	0
		Musser et al. (1996)	US	crop	corn	Self reported adoption	+
			US	crop	soybean	Self reported adoption	+
		Sartwelle et al. (2000)	US	crop	grain	Self reported adoption	0
		Pennings & Garcia (2004)	Netherlands	livestock	hogs	Actual adoption	0
		Vergara et al. (2004)	US	crop	cotton	Self reported adoption	0
		Davis et al. (2005)	US	crop	corn	Self reported intention	0
			US	crop	soybean	Self reported intention	0
	Multiple tools	Franken et al. (2012)	US	crop	corn	Self reported adoption	0
			US	crop	soybean	Self reported adoption	0
		Anastassiadis et al. (2014)	Germany	other	not specified	Self reported intention	0
		Franken et al. (2014)	US	other	not specified	Self reported adoption	0
		Van Winsen et al. (2016)	Belgium	other	not specified	Self reported intention	-
		Coffey, B.K.; Schroeder, T.C. (2019)	US	crop	grain and soybeans	Self reported adoption	0
	Price insurance	Fields & Gillespie (2008)	US	livestock	beef	Self reported intention	+
	price_insurance	Boyer et al. (2024)	US	livestock	cattle	Self reported intention	-
Management attitudes	forward	Ricome, A.; Reynaud, A. (2022)	France	other	not specified	Actual adoption	0
	futures	Pennings &Leuthold (2000)	Netherlands	livestock	hog	Self reported adoption	+
Innovativeness	forward	Ricome, A.; Reynaud, A. (2022)	France	other	not specified	Actual adoption	+
	multiple_tools	Coffey, B.K.; Schroeder, T.C. (2019)	US	crop	grain and soybeans	Self reported adoption	+
	multiple_tools	Block et al. (2023)	Germany	other	not specified	Self reported intention	+

Notes: FV: Fruit and Vegetables; (+) positive and significant effect, (-) negative and significant effect, 0 not significant

Table S6. Social factors

Factor	Tool	Study	Country	Farm type	Product	Operationalization	Direction
Network influence	*Forwards*	Fu et al. (1988)	US	crop	peanuts	Self reported intention	+
		Asplund et al. (1989)	US	crop	grain and soybeans	Self reported adoption	+
			US	crop	grain and soybeans	Self reported adoption	+
		Mishra, Ashok K; Perry, Janet E (1999)	US	other	not specified	Self reported adoption	+
		Vergara et al. (2004)	US	crop	cotton	Self reported adoption	+
		Katchova, AL; Miranda, MJ (2004)	US	crop	corn	Actual adoption	+
			US	crop	soybean	Actual adoption	+
			US	crop	wheat	Actual adoption	0
		Davis et al. (2005)	US	crop	corn	Self reported intention	+
			US	crop	soybean	Self reported intention	+
		Ricome, A.; Reynaud, A. (2022)	France	other	not specified	Actual adoption	0
		Penone, C.; Giampietri, E.; Trestini, S. (2024)	Italy	other	not specified	Self reported intention	+
	Futures	Fu et al. (1988)	US	crop	peanuts	Self reported intention	0
		Shapiro, B. I.; Brorsen, B. Wade (1988)	US	crop	corn and soybean	Self reported adoption	0
		Asplund et al. (1989)	US	crop	grain and soybeans	Self reported adoption	0
			US	crop	grain and soybeans	Self reported adoption	+
		Mishra, A.K.; El-Osta, H.S. (2002)	US	other	not specified	Self reported adoption	0
	Multiple tools	Makus et al. (1990)	US	other	not specified	Self reported adoption	+
		Goodwin & Schroeder (1994)	US	other	multiple products	Self reported adoption	+
		Goodwin & Kastens (1996)	US	crop	wheat	Self reported adoption	+
			US	crop	corn	Self reported adoption	0
			US	crop	sorghum	Self reported adoption	+
			US	crop	soybean	Self reported adoption	0
			US	crop	wheat	Self reported adoption	0
			US	crop	corn	Self reported adoption	0
			US	crop	sorghum	Self reported adoption	0
			US	crop	soybean	Self reported adoption	0
		Patrick et al. (1998)	US	crop	corn and soybean	Self reported adoption	0

Network influence	*Multiple tools*	Vergara et al. (2004)	US	crop	cotton	Self reported adoption	+
		Davis et al. (2005)	US	crop	corn	Self reported intention	+
			US	crop	soybean	Self reported intention	+
		Coffey, B.K.; Schroeder, T.C. (2019)	US	crop	grain and soybeans	Self reported adoption	0
Subjective norms	*Forward*	Penone, C.; Giampietri, E.; Trestini, S. (2024)	Italy	other	not specified	Self reported intention	0
	Futures	Michels et al. (2019)	Germany	other	not specified	Self reported intention	+

Notes: (+) positive and significant effect, (-) negative and significant effect, 0 not significant

Table S7. Cognitive factors

Factor	Tool	Study	Country	Farm type	Product	Operationalization	Direction
Risk perceptions	*Forward*	Vergara et al. (2004)	US	crop	cotton	Self reported adoption	-
		Davis et al. (2005)	US	crop	corn	Self reported intention	+
			US	crop	soybean	Self reported intention	0
		Pennings et al. (2008)	US	crop	not specified	Self reported adoption	0
		Vassalos, M.; Li, Y. (2016)	US	FV	tomato	Self reported intention	0
	Multiple tools	Pennings, Joost M.E.; Garcia, Philip (2004)	Netherlands	livestock	hogs	Actual adoption	+
		Vergara et al. (2004)	US	crop	cotton	Self reported adoption	-
		Davis et al. (2005)	US	crop	corn	Self reported intention	+
			US	crop	soybean	Self reported intention	0
		Van Winsen et al. (2016)	Belgium	other	not specified	Self reported intention	0
Price and yield expectations	*Forward*	Davis et al. (2005)	US	crop	corn	Self reported intention	0
			US	crop	soybean	Self reported intention	-
		Anastassiadis,= et al. (2014)	Germany	other	not specified	Self reported intention	-
		Roussy, C.; Ridier, A.; Chaib, K.; Boyet, M. (2018)	France	crop	wheat	Self reported adoption	0
			France	crop	wheat	Self reported adoption	0
		Ricome, A.; Reynaud, A. (2022)	France	other	not specified	Actual adoption	-
	Futures	Anastassiadis et al. (2014)	Germany	other	not specified	Self reported intention	-
	Multiple Tools	Davis et al. (2005)	US	crop	corn	Self reported intention	0
			US	crop	soybean	Self reported intention	0
		Anastassiadis et al.(2014)	Germany	other	not specified	Self reported intention	-
Alternative perceptions	*Forward*	Edelman et al. (1990)	US	crop	grain	Self reported adoption	+
			US	livestock	hog	Self reported adoption	0
			US	livestock	fed cattle	Self reported adoption	0
		Isengildina, O.; Hudson, M.D. (2001)	US	crop	cotton	Self reported adoption	0
	Futures	Edelman et al. (1990)	US	crop	grain	Self reported adoption	+
			US	livestock	hog	Self reported adoption	+
			US	livestock	fed cattle	Self reported adoption	+

Alternative perceptions	*Futures*	Ennew, C.; Morgan, W.; Rayner, T. (1992)	UK	crop	potato	Self reported adoption	-
		Isengildina, O.; Hudson, M.D. (2001)	US	crop	cotton	Self reported adoption	-
	Multiple_Tools	Makus et al. (1990)	US	other	not specified	Self reported adoption	+
	Options	Edelman et al. (1990)	US	crop	grain	Self reported adoption	+
			US	livestock	hog	Self reported adoption	+
			US	livestock	fed cattle	Self reported adoption	+
Perceived usefulness	*Forward*	Vergara et al. (2004)	US	crop	cotton	Self reported adoption	0
		Jackson et al. (2009)	Australia	livestock	wool production	Self reported intention	-
		Penone, C.; Giampietri, E.; Trestini, S. (2024)	Italy	other	not specified	Self reported intention	+
			Italy	other	not specified	Self reported intention	0
	Futures	Shapiro, B. I.; Brorsen, B. Wade (1988)	US	crop	corn and soybean	Self reported adoption	+
		Ennew, C.; Morgan, W.; Rayner, T. (1992)	UK	crop	potato	Self reported adoption	0
			UK	crop	potato	Self reported adoption	0
			UK	crop	potato	Self reported adoption	0
			UK	crop	potato	Self reported adoption	-
			UK	crop	potato	Self reported adoption	0
		Pennings, J.M.E.; Leuthold, R.M. (2000)	Netherlands	livestock	hogs	Self reported adoption	+
		Meulenberg, M.T.G.; Pennings, J.M.E. (2002)	Netherlands	livestock	hogs	Self reported intention	+
			Netherlands	livestock	hogs	Self reported intention	+
		Pennings, J.M.E. (2002)	Netherlands	livestock	hogs	Self reported intention	+
		Michels, M.; Möllmann, J.; Musshoff, O. (2019)	Germany	other	not specified	Self reported intention	+
			Germany	other	not specified	Self reported intention	0
	Multiple Tools	Patrick et al. (1998)	US	crop	corn and soybean	Self reported adoption	0
			US	crop	corn and soybean	Self reported adoption	0
		Vergara et al. (2004)	US	crop	cotton	Self reported adoption	0
Tools knowledge	*Forward*	Vergara et al. (2004)	US	crop	cotton	Self reported adoption	+
		Davis et al. (2005)	US	crop	corn	Self reported intention	+
			US	crop	soybean	Self reported intention	+

		Pennings et al. (2008)	US	crop	not specified	Self reported adoption	0
Tools knowledge	*Forward*	Jackson et al. (2009)	Australia	livestock	wool production	Self reported intention	0
		Penone, C.; Giampietri, E.; Trestini, S. (2024)	Italy	other	not specified	Self reported intention	0
	Futures	Ennew, C.; Morgan, W.; Rayner, T. (1992)	UK	crop	potato	Self reported adoption	+
			UK	crop	potato	Self reported adoption	0
		Pennings, J.M.E.; Leuthold, R.M. (2000)	Netherlands	livestock	hog	Self reported adoption	+
			Netherlands	livestock	hog	Self reported adoption	+
		Meulenberg, M.T.G.; Pennings, J.M.E. (2002)	Netherlands	livestock	hogs	Self reported intention	+
			Netherlands	livestock	hogs	Self reported intention	+
		Michels, M.; Möllmann, J.; Musshoff, O. (2019)	Germany	other	not specified	Self reported intention	+
	Multiple tools	Patrick et al. (1998)	US	crop	corn and soybean	Self reported adoption	+
		Vergara et al. (2004)	US	crop	cotton	Self reported adoption	+
		Davis et al. (2005)	US	crop	corn	Self reported intention	0
			US	crop	soybean	Self reported intention	0
	Price Insurance	Fields, Deacue; Gillespie, Jeffrey (2008)	US	livestock	beef	Self reported intention	+
		Boyer et al. (2024)	US	livestock	cattle	Self reported intention	0

Notes: (+) positive and significant effect, (-) negative and significant effect, 0 not significant

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