A META-ANALYSIS OF AGRI-COMMODITY PRICE MANAGEMENT APPROACHES: TRENDS AND FUTURE PROSPECTS TOWARDS DIGITAL AGRI-MARKETING

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ABSTRACT

The study offers a comprehensive meta-review of price management models on agri- derivatives, which includes commonly studied attributes such as Price Discovery (PD), Price Volatility (PV), and Price Forecasting (PF). We investigated the best-fit model for each parameter mentioned above. The meta-analysis shows that 45% of the literature focused on PV and PD for commodities like chana, maize, and wheat. Whereas studies mostly on PF were performed on soybeans. We found that the Vector Error Correction Model and Bi-Variate Exponential General Autoregressive Conditional Heteroskedastic best fit the econometric model to determine PD and PV, respectively. Nevertheless, 43% of the studies followed other econometric models for price management modelling. The present investigation finds minimal intervention in PF. The present study addresses the research gap by providing a systematic review and suggesting trajectories for efficient agri-commodity derivatives price management using advanced econometric models and advocating active digital marketing participation by stakeholders.

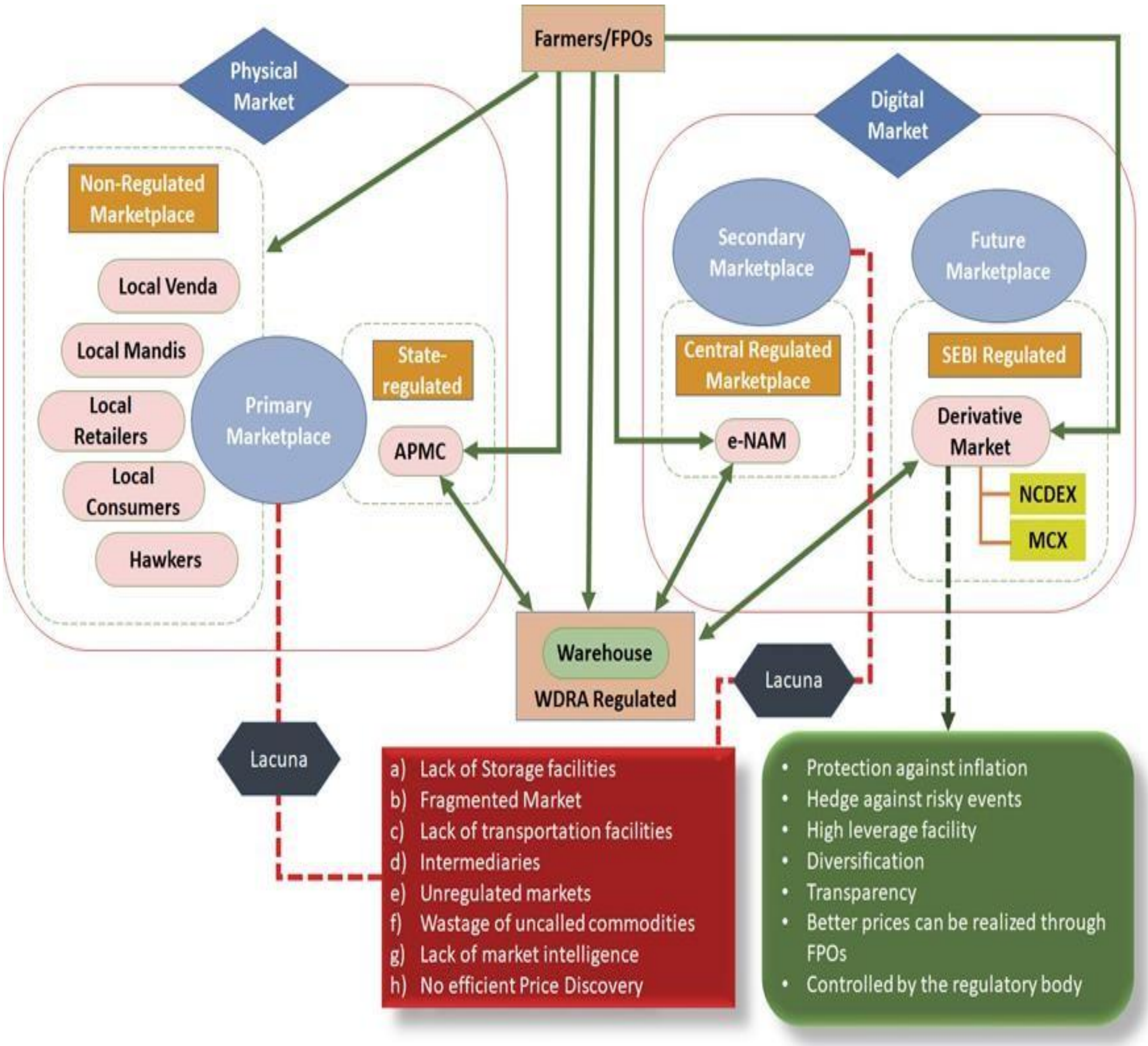
Keywords: Price management; meta-analysis; PRISMA; bibliographic analysis; agri-derivatives.

INTRODUCTION

The agricultural commodities derivatives market aims to stabilize the prices of agri- commodities. Future trading in agriculture makes it possible to ensure fair pricing to the farmers, prevent instability, provide appropriate price discovery, and manage price variations. However, the pricing of agricultural commodities is vulnerable to many factors, such as weather conditions, natural calamities, demand and supplies, production, availability of storage facilities, market information, governmental policies on procurement, and geopolitical activities. Hence, price management has become a significant concern for farmers, traders, and consumers (Broll et al. 2013). Price management incorporates all viewpoints and information to make the best pricing decisions. Agri-commodity prices are used to control by identifying the ideal price for each commodity, reducing its volatility, and making price projections for the future. Price management comprises three domains, namely price discovery (PD), price volatility (PV), and price forecasting (PF). PD mechanisms can help to achieve the best reasonable price. It allows sellers and buyers to set the market price of a tradable asset. Therefore, PD is related to finding the equilibrium price, facilitating the maximum liquidity for that asset (Raju and Karande 2003; Yang et al. 2021). PV shows the price fluctuations in any commodity due to several market inflations. Sellers and buyers try to balance prices by minimizing PV. PF projects commodity future prices so producers can realize their best price accordingly.

These three financial tools, PD, PV, and PF, are essential for efficient price management of agricultural commodities, especially in digital agri-marketplaces like commodity derivative exchanges shown in Figure 1. In the digital agri-market, transactions are done quickly, efficiently, and safely (Lee et al. 2021). Buyers or traders from different parts of the country can participate in commodity trading. Farmers also get more options for their commodities to sell with profit. Two kinds of regulated agri-digital marketing in India are the Electronic National Agriculture Market (e-NAM) and derivative markets. e-NAM is an electronic trading platform for agri-commodities that integrate the existing APMC mandis. Yet, some lacuna exists in terms of better profitability for the farmers. The lack of transport facilities, influential intermediaries, unregulated markets, standard quality inspections, and market intelligence prevent farmers from making a profit and bound them to sell their commodities at a lower price.

Figure 1. Agricultural Marketing Framework in India.



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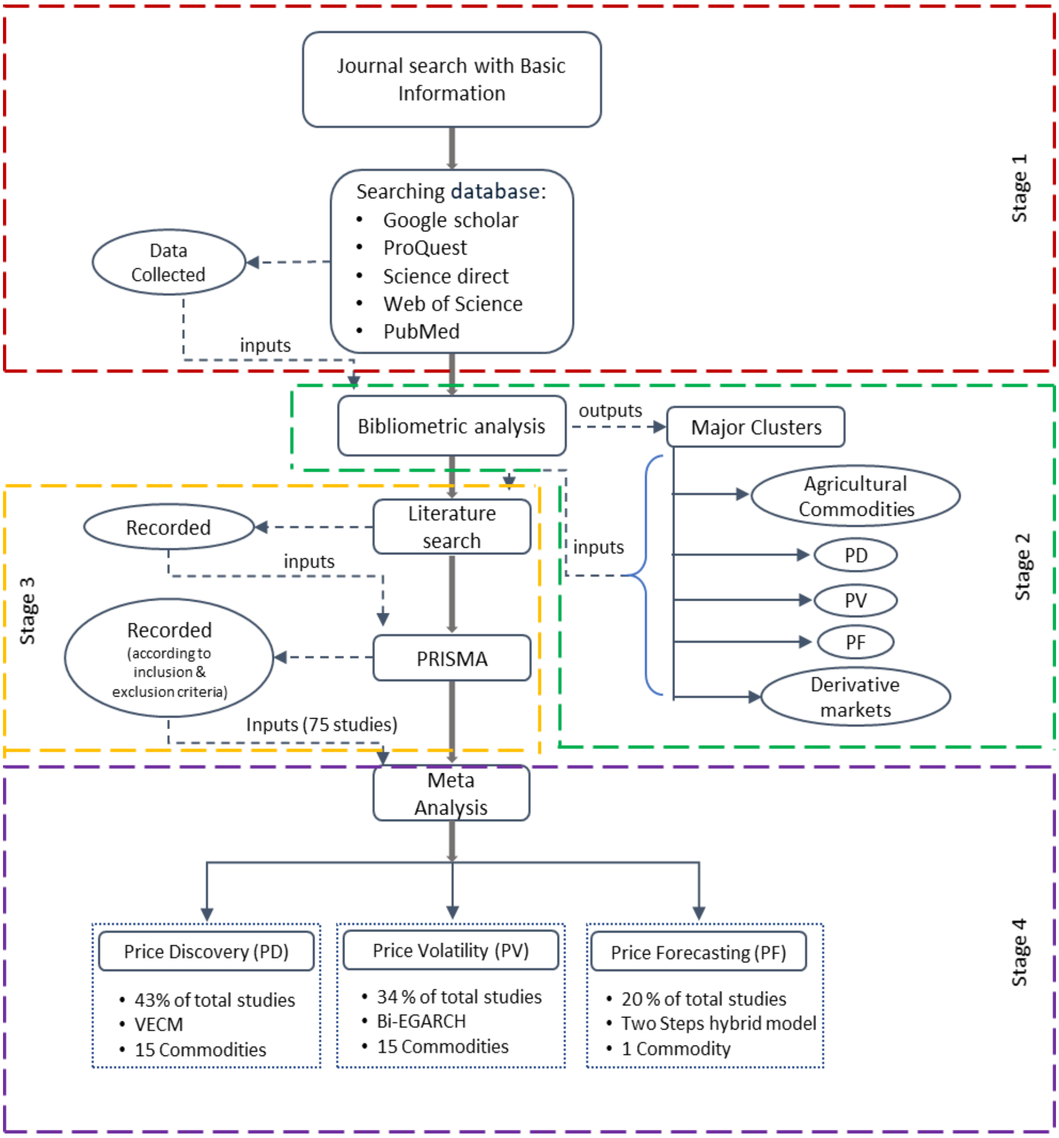
However, future marketplaces such as derivative markets can be a better alternative for digital agri-marketing, where farmers make their pre-contract to sell their commodities for a future prefixed amount on a pre-determined quantity. In the derivative market Farmer Producer Organisations (FPOs), i.e., a group of farmers who participate in the trade. The FPO work as an aggregator, and farmers are its shareholders. It helps them to get government benefits, farm inputs, marketing intelligence, and experts' advice for improvement. Based on their profit, the derivative market also answers several questions to the farmers, such as what to sow, when to sell, where to sell, to whom to sell. Digitization helps all the trade processes to be clear and transparent. In India, agricultural commodities are traded in derivative exchanges through the National Commodity & Derivatives Exchange Limited (NCDEX) platform and under the regulation of the Security Exchange Board of India (SEBI) (Raju and Karande 2003), which ensures the safety of fraudulent activities. Twenty-three agricultural commodities are traded through NCDEX by traders, individual farmers, and FPOs (NCDEX 2022).

Although numerous studies have explored aspects of PD, PV, and PF in the context of agricultural commodities within Indian derivative markets (Charlebois 2008; Gordon et al. 1999; Manogna and Mishra 2021; R L and Mishra 2020; Xu and Zhang 2022), there remains a lack of comprehensive synthesis of these works. This study addresses that gap by identifying the least-studied agri-commodities and the most suitable econometric models for price management.

To achieve this, the study begins with a bibliometric analysis to identify key terms used in existing literature related to price management in agri-derivative markets (Bhattacharyya 2023). Following this, a systematic review of the most relevant peer-reviewed research articles is conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Haque et al. 2021; Nikbin et al. 2022; Sahoo et al. 2022). The findings, illustrated in Figure 2, reveal that 43% of studies focused on PD, 34% on PV, and only 20% on PF. Additionally, while 23 agri-commodities are traded by FPOs in Indian derivatives markets, only 15 have been studied in the context of PD and PV. Notably, soybean is the only commodity that has been extensively studied across all three dimensions, including PF.

Figure 2. Flowchart of the presented study



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The study further evaluates the effectiveness of previous works by calculating the effect size for soybean-related research, which showed a significantly large effect—highlighting the robustness of existing studies for this commodity. These insights underscore the need for future research to address the underexplored areas of PF and to apply integrated models that simultaneously consider PD, PV, and PF across a wider range of commodities. The remainder of this paper is structured as follows: Section 2 presents a literature review; Section 3 details the data sources, methodology, and data collection procedures; Section 4 discusses the results and insights; and Section 5 concludes the study with key takeaways and suggestions for future research.

LITERATURE REVIEW

History of The Derivative Market in India

The origin of future trading can be traced to the seventeenth century. In 1710, Dojima Rice Exchange started the first structured futures exchange in Osaka, Japan. The Chicago Board of Trade (CBOT) was founded on April 3, 1848, by 83 merchants to promote the trading of spot produce and forward contracts. Standardized futures contracts were first implemented in 1865. The Chicago Produce Exchange (CPEX) and Chicago Butter and Egg Board were both founded in 1874 and 1898, respectively; and in 1919, it was changed the name to Chicago Mercantile Exchange (CMEX) to enable future trading. The Exchange's main goals are to bring a lot of buyers and sellers together on one stage for spot PD and to assure that commodities purchased and sold on the Exchange are delivered on time without exposing traders to counterparty risks (Kar 2021). Trading in commodity futures has a long history in India. Commodity futures trading has existed since prehistory; forward trading in commodities is mentioned in Kautilya's Artha Shastra (Mahajan and Singh 2015). The Bombay Cotton Trade Association (BCTA) is the first modern futures market for cotton contracts, established in 1875. With many ups and downs, forward trading doesn't fully realize its potential until 1952, thanks to the Forward Trading Regulation Act and the Forward Market Commission. However, the restriction on forward commodity trading was maintained until 2002 due to several legal and policy difficulties (Masood and Chary 2016; Shahwan and Odening 2007). After 2002, the derivative market became fully functional under the umbrella of SEBI.

Studies on Price Management of Derivative Market

The digital marketplace in India also gets a boost after the derivative market is implemented. Along with the derivative marketing systems' positive side, it also challenges farmers, traders, and customers. Price management is one of the major challenges to them. For example, Sendhil et al. (2013) has found that because of India's small-scale production system, farmers cannot participate in the futures market, and restrain themselves from the profit, However, farmers participations in futures market reduce their financial stress and improves their livelihood (Assa 2016). Dey et al. (2019) also emphasis on the factors which impressed the farmers to participation in derivative markets such as the efficiency of futures market price discovery, the spot and futures price relationship, price dissemination, understanding the socio-economic and exchange-related issues affecting farmer participation in futures markets, factors affecting demand and supply of participation, and the access to futures trading services. Ali and Gupta (2011) found Indian agricultural derivative markets are efficient and there is a long-term relationship between futures and spot prices for most of the studied commodities such as maize, chickpea, black lentil, pepper, castor, soyabean, and sugar. Several researchers have conducted on the topic research previously. Some relevant studies are discussed in the supplementary Table T1.

Methodology and Data Collections

Bibliographic Analysis for Identifying and Interlinking the Keywords

To review the previous studies published by the researchers, identifying co-occurrence keywords helps to get a path for searching the articles. Bibliographic analysis can check the concentration of co-occurrence keywords in graphical visualization based on the total link strength using the VOSviewer tool (Bhattacharyya 2023; Khan and Khan 2022). The Larger circles of the same color convey one cluster, and the size correlates to the subject's significance. Based on the bibliometric analysis, the output helped to grasp the familiarity and significance of the keywords and identified the potential gap. The size of the circles shows the frequency with which terms are presented. The distance between the circles represents the strength of their relationship. The keywords are selected after examining the clusters, circle size, and link strength created from the bibliographic analysis (Cortés-Pérez et al. 2023).

PRISMA

A systematic review is a crucial method to summarize evidence accurately and reliably and is considered a guide for researchers (Yildiz Çankaya et al. 2022). There are different methodologies for conducting a systematic review of past literature, including integrative review (Elsbach and van Knippenberg 2020; Whittemore and Knafl 2005), steps and process organizing existing literature review (Palmatier et al. 2018). However, to evaluate the previous work, PRISMA was done as a preliminary study to review the existing studies that the earlier researchers did. This will help to identify the research gaps present to map the proposed research and the study's novelty (Acevedo et al. 2020). PRISMA is a minimal set of criteria based on evidence intended to assist scientific researchers in reporting various systematic reviews and meta-analyses from randomized trials. It enhances the systematic review reporting quality and significantly increases transparency in selecting papers for the study (Henriksson et al. 2021; Page et al. 2021). The typical processes involved in PRISMA start by identifying the research questions, followed by the critical keywords and variables related to the proposed objectives. Then, the existing publications are searched from the available peer database and other grey literature, and all the data must be recorded. The duplicate articles are excluded by screening with the titles. The screening will start from the abstract, and the non-required articles will be removed. Further screenings need to be done through the introduction, followed by the literature reviews and methodologies. In all the steps, the validations of research questions and variables must be satisfied, disconnected articles are excluded, and others are recorded. After that, the screening is done by checking the results and discussing the selected articles, and the data is recorded. This analysis may narrow future research scopes on the proposed topics and direct further research with some valuable novelties. The keywords were first finalized from bibliographic analysis for the systematic review, such as agricultural commodity, price discovery, price volatility, and price forecasting. Then, the studies will search from the database with peer-reviewed journals such as Scopus, Web of Science, and other literature found in grey journals such as Press Bureau of India, NCDEX report, NABARD, and Agmarknet. All the articles written in English are included, and duplicate studies are checked and removed after the first search with screening with the title and abstracts. Then, finally, after going through the complete text, the studies that do not fulfill the research objectives are eliminated. The established inclusion measures for the presented study are:

- The studies rely on price management of agricultural commodities in the Indian derivative market.
- All the published theoretical studies explain any PD, PV, and PF in agri-commodities for the Indian derivative market.
- The studies explain the different empirical methods for finding PD, PV, and PF.
- The published studies consider the price data of agri-commodities after 2002 from the Indian derivative market.

The article uses exclusion measures to discard the studies that are unfitting with research aims are:

- The studies focus on the market efficiency of the Indian derivative market.
- The studies that are not considering the agri-commodities of the Indian derivative market.
- The studies that are considering the post-2021 price data of agri-commodity.

The steps through which the review was conducted is shown in supplementary Figure F1. Then the selected studies were analyzed and sorted using PRISMA. Crop and market data are also required for further assessment using effect size.

All the studies are sorted and categorized according to different methods, such as data taken, period, and commodity selection, and they are grouped into PD, PV, and PF. Further divisions were made according to the methodology used in the above subdomain (PD/PV/PF). In PD, the division was made by synthesizing the commodity selection, period of data taken, and steps followed for finding the PD, such as stationarity check, cointegration check, causality check, log run check, and lead-lag approach in each study. For PV, synthesis is done based on the spillover movement of spots and futures, information biases, and the number of studies. For PF, the previous studies are synthesized according to the methodology used, the period considered, and the commodity taken for forecasting. All the required data were synthesized and recorded.

Effect Size

Effect size is one of the important findings for empirical studies. It is the magnitude of association of the previous studies (Al Wali et al. 2022; Tehseen et al. 2019). Researchers are frequently encouraged to disclose them because it allows researchers to convey the size of the documented effects in a standardized way regardless of the scale employed to measure the dependent variable. Rather than simply presenting the statistical significance, these normalized effect sizes enable researchers to explain the actual relevance of their findings (Lakens 2013; Mohammad et al. 2021). The effect sizes also allow researchers to compare standardized effect sizes across investigations and derive meta-analytic conclusions. The effect size also helps design a new study based on earlier studies (Lakens 2013; Tam and Trang 2023).

Researchers frequently use the null hypothesis significance tests to draw inferences about observed differences between observational groups. The power of a statistical test is the likelihood of successfully rejecting the null hypothesis (Cohen 1988). The study's sample size, the magnitude of the effect, and the significance level affect statistical power. The sample size required to observe an effect of a particular size, along with the necessary statistical power, is calculated in a standard power analysis (Ng 2016).

Although there are various kinds of effect sizes, the ones covered here provide details on the amount and direction of the difference between two groups or the connection between two variables. An effect size might be a correlation, a percentage difference between means, or both (Vacha-Haase and Thompson 2004). Typically, researchers attempt to demonstrate that the groups they are investigating differ or that the factors they are examining are associated. Effect sizes analyses this information by measuring the degree of difference between groups or the strength of the association between variables. In other words, effect sizes evaluate the size or significance of the results that appear in research investigations. It cannot be attained by concentrating on a specific p-value (Vacha-Haase and Thompson 2004). A p-value with an effect's size cannot be determined directly. There is no direct correlation between an effect's size and its usefulness. A modest p-value can indicate a moderate, medium, or high impact. Depending on the situation, an effect with a minor impact on one outcome may be more significant than one with a considerable impact on another.

Effect sizes can be divided into two families: the r family, which assesses the degree of connection, and the d family, which consists of standardized mean differences. The difference between data, divided by the standard deviation of these observations, serves as the conceptual foundation for the d family effect sizes. The r family effect sizes express the percentage of variance that can be explained by group membership (Lakens 2013).

Cohen’s d describes the standardized mean difference of an effect. Even when the dependent variables are measured differently between studies, this value can be used to compare effects. It ranges from 0 to infinity. Cohen’s d refers to the standardized mean difference between two groups of the independent outcome, and it is given by:

$$d = \frac{(X_1 - X_2)}{Pooled\ SD} \qquad \dots (1)$$

$$Pooled\ SD = \sqrt{\left(\frac{(n_1 - 1)SD_1^2 + (n_1 - 1)SD_2^2}{n_1 + n_2 - 2}\right)} \qquad \dots (2)$$

There is also some correction α required to be multiplied with d if the sample size is very small.

$$\alpha = \sqrt{\frac{n_1 + n_2}{n_1 \times n_2} + \frac{d^2}{2(n_1 + n_2)}} \qquad \dots (3)$$

$$95\%\ CI = d \pm 1.96\alpha(d) \qquad \dots (4)$$

In Equation 1, the difference in mean between the two observational given groups in the numerator, and the pooled standard deviation is in the denominator. The difference between each observation and the group mean is employed to compute the standard deviation. Bessel's correction for bias in estimating the population variance is applied to this value by dividing it by the number of observations less than one. The square root is then calculated. Based on the least square estimator, this adjustment for bias in the sample estimate of the population variance (McGrath and Meyer 2006). Note that Cohen’s d is also sometimes referred to as Cohen’s g.

In particular, for small samples (n=20), the formula for Cohen's d, which is based on sample averages, provides a distorted estimate of the population effect size. So, the uncorrected effect size is another name for Cohen's d (Borenstein et al. 2009). Formula 3 shows the corrected effect size or Hedges’s g.

$$g = d \times \left(1 - \frac{3}{4(n_1 + n_2) - 9}\right) \qquad \dots (5)$$

$$g = \frac{(X_1 - X_2)}{Pooled\ SD} \times \left(\frac{N-3}{N-2.25}\right) \times \sqrt{\frac{N-2}{N}} \quad \ldots (6)$$

$$Pooled\ SD = \sqrt{\frac{[(SD_1^2)(n_1-1)+(SD_2^2)(n_2-1)]}{(n_1+n_2)-2}} \quad \ldots (7)$$

When the given data are nf researchers provide the number of participants in each condition for a between-subjects comparison.

For group design, if there are mean, standard deviations, and populations involved, then the hedges's g will be Where,

$X_1 \,\&\, X_2 = Sample\ mean\ of\ sample\ 1\ and\ 2$

$SD_1 \,\&\, SD_2 = Standered\ deviation\ of\ sample\ 1\ and\ 2$

$n_1 \,\&\, n_2 = Sample\ size\ of\ 1\ and\ 2$

Interpreting Cohen's d

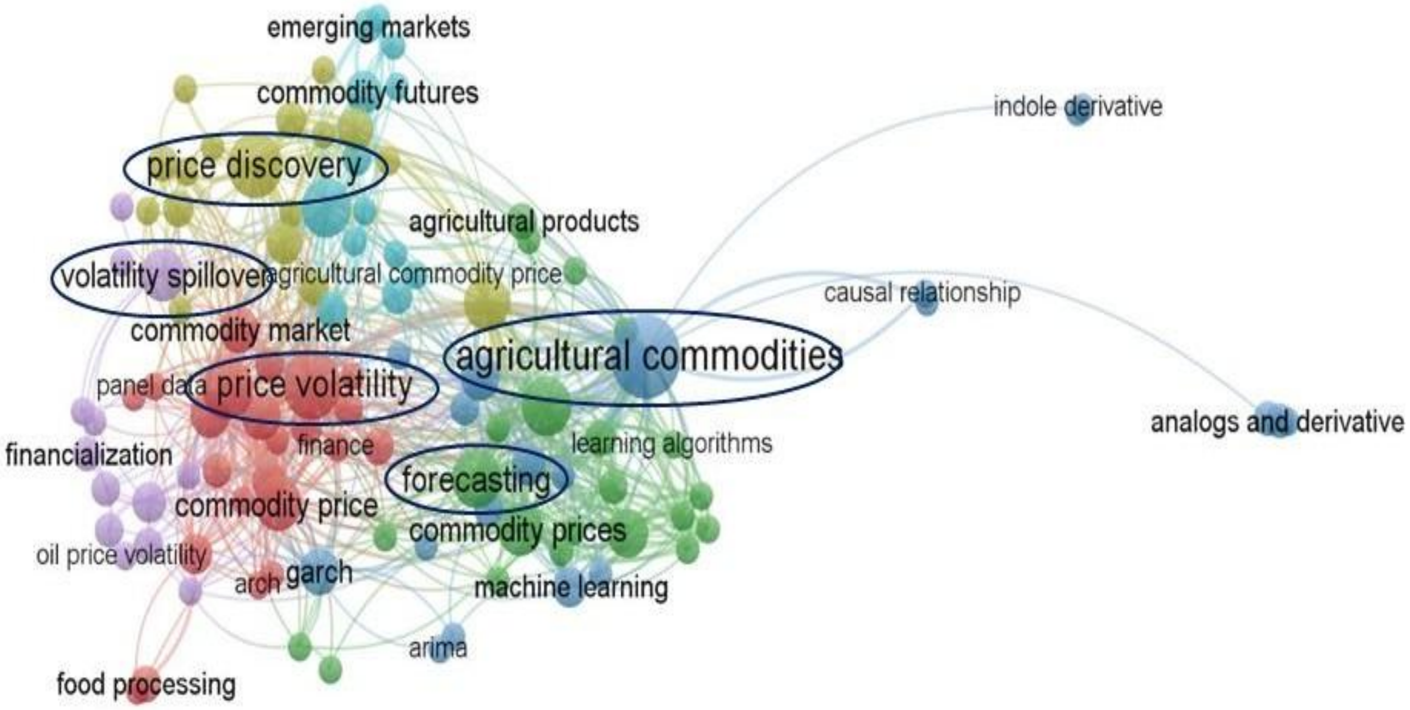
Effect sizes are frequently described as modest (d=0.2), medium (d=0.5), and large (d=0.8) based on benchmarks recommended by (Cohen 1988). However, as these values are arbitrary, they shouldn't be rigidly interpreted. Small effect sizes can have significant effects, as in the case of an intervention that reliably lowers suicide rates with a d=0.1 effect size. These criteria are only used since the findings are so new that they cannot be compared to similar conclusions from the literature. A Cohen's d of 0.5 indicates that the difference equals half a standard deviation, which is an easy way to understand Cohen's d between subject designs. The best way to analyze Cohen's d is to compare it to other effects from the literature and, if possible, explain the effect's real-world implications. Unfortunately, there are no specific instructions on how to achieve this (Fidler 2002). The values through which the study's effect size is interpreted are shown in supplementary Table T2, along with their magnitude.

The effect size calculation will be done using the STATA software, and the meta-analysis will be performed. Equations are used to calculate effect size (d) using the Cohen's d measure and the corresponding Confidence Interval (CI), and the overall effect was determined. All the sample sizes and standard deviations were tabulated before to find the effect size of the studies. Soybean is considered to find the effect size from the studies, as it is the most traded agricultural commodity in the Indian derivative market. Only nine studies were considered out of the total study because they provided the complete data information for finding the effect size of the studies. The effect size of the studies was plotted into a forest plot, and the overall effect of the study is determined.

RESULTS AND DISCUSSIONS

Six clusters are identified as having 681 links and a total link strength of 925 out of 108 items. It shows that 'agricultural commodities' is the most used term with 34 occurrences, followed by 'price volatility' (with 21 occurrences), 'price discovery' (with 18 occurrences), 'volatility' (with 13 occurrences), 'forecasting' (with 13 occurrences), and 'volatility spill over' (with ten occurrences). The top five items are selected from the graphical visualization (see Figure 3) of bibliographic analysis for article search keywords and PRISMA review, i.e., agricultural commodity, price discovery, price volatility, and price forecasting.

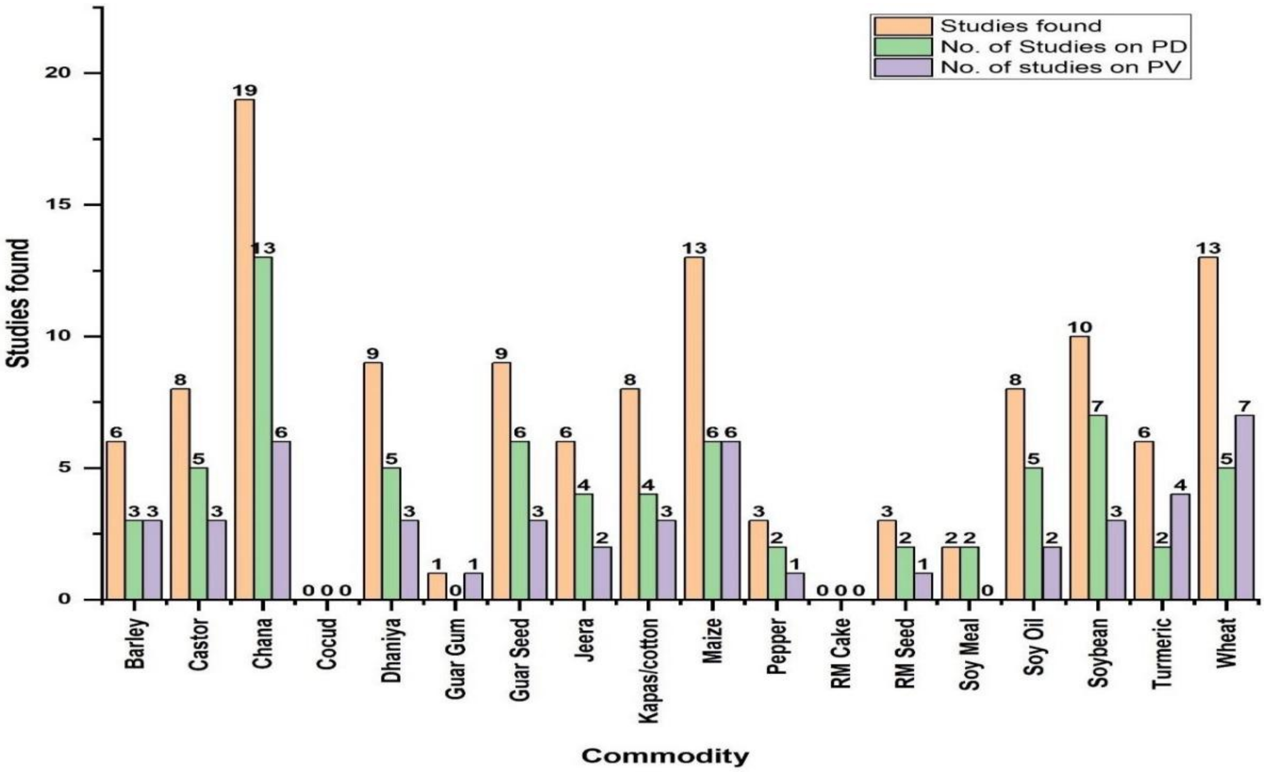
Figure 3. Graphical visualization of keyword co-occurrence



Source(s): Compiled by the authors.

Figure 4. Commodities studied by the previous researchers in terms of PD and PV

Source(s): Compiled by the authors.



Around 5187 studies are found after the first search from 1998 to 2022. For PD (1255), PV (2520), and PF (1412). Around 4487 papers were excluded due to delicacy, and 635 studies did not fulfil the inclusion measures. Furthermore, 75 studies were included per the inclusion criteria.

All 75 studies were synthesized, with 34 studies based on PD and 26 studies on PV. For PF, only 15 studies were found. It shows that forecasting and volatility measurement of price for agricultural commodities were not covered extensively, as only 35% and 20% of studies are based on PV and PF, respectively. Also, 23 commodities are traded in various markets all over the country. Barley, chana, castor, dhaniya, guar seed, jeera, cotton, maize, pepper, turmeric, soybean, and wheat; these 16 commodities were considered in studies, but based on FPO traded were not specified, as well other two commodities were not considered at all. Chana, maize, soybean, and wheat were found in more than 10 number papers, and no study was found for RM cake and cocud (see Figure 4). Hence, there is a scope for study on that aspect to better realize prices with these three price management tools.

Price Discovery (PD)

In PD, the commodities traded by the FPOs, only chana, maize, and soybean were studied more than five times. No studies were found for gaur gum, cocud, and RM cake; the remaining 12 commodities have less than five studies (see Figure 4). So, there is a scope for further research regarding the PD of the FPO-traded agricultural commodities in derivative markets.

The Augmented Dickey-Fuller (ADF) Test can be employed to determine stationarity between price time series data to detect PD of the commodity between spot and future data (Madziwa et al. 2022). For long-run associations between the spots and future price data, Johansen's Cointegration test may employ (Bohmann et al. 2019; Kumar and Pandey 2013; Singh and Singh 2017). The Granger causality (GC) test investigates the causal relationship between proposed commodity futures and spot prices. The lead-lag approaches between spot and futures price data were checked using the Vector Error Correction Model (VECM), which was then utilized to understand the existence of both long- and short-run causation among the identified determinants of market efficiency (Gupta et al. 2018; Kumar Mahalik et al. 2014). A systematic review of the previous study shows the gaps and scopes of future studies on the price management of agri-commodities using PD methods. It was found that none of the studies followed all the PD processes, and none of the studies analyzed the PD of the FPO-traded agricultural commodities. Hence, there is ample scope for study in that gap so that FPOs also can trade in the derivative market effectively (see supplementary Table T3). In Table 1, we discussed all the steps that are followed during PD and the models which follow them.

Price Volatility (PV)

The volatility hypothesis examines the lead-lag relationship between spot and future price movements. The Bivariate Exponential Generalized Autoregressive Conditional Heteroskedastic (Bi-EGARCH) will determine these price trends. It can detect positive and error terms that have asymmetric effects on volatility and informational bias. Market up (Positive News) and market downfalls (Negative News) are equal impacts on the PV of a commodity. EGARCH can check whether traders react more to negative or positive information (Kumar Mahalik et al. 2014; Rout et al. 2021).

The study synthesized 26 studies on PV. Wheat, maize, and chana are studied for PV checking (see Figure 4). None of the commodities were reviewed more than ten times in PV, and in PF, only 13 crops were covered by each study individually; two studies were found using machine learning techniques to predict the prices. Wheat, chana, and maize were considered in more than five studies out of 18 commodities that the authors considered for PV. Five commodities were covered in three studies, eight commodities in two studies, and 12 commodities were studied at single times (see Figure 4). Hence, the previous researchers obviously did not cover all the remaining three objectives. Studying that area requires better and more efficient price management of FPO-traded agricultural commodities traded in the Indian derivative market.

To find the PV of any commodity, it's vital to check inter-linkage between markets, lead-lag between spot and future, spillover or movement detection, and information biases in the price of a commodity at a time. Some models are used by the previous researcher, such as the Generalized Supremum Augmented Dickey-Fuller (GSADF) test, Extrema Value Theory, and Generalized Autoregressive Conditional Heteroscedasticity (GARCH) (Siddiqui and Roy 2020). These models do not fulfil all the required procedures of the PV shown in Table 1 except Bivariate Exponential Generalized Autoregressive Conditional Heteroscedasticity (Bi-EGARCH). It is found that none of the studies found on analyzing the PV in commodities that the FPOs trade, and none of the models covers the external factors which affect the PV such as new market information, speculation, hazardous, etc.

Table 1. Methods for finding PD and PV, and steps involved.

	Models	Stationarity Check	Long & short run	Direction of inflation	Market Information's	Lead-lag Approach
	CC	✓	-	✓	-	-
Price Discovery	TVAR	-	-	✓	✓	-
Price Discovery	GISM and CSM	-	-	✓	✓	✓
Price Discovery	Co and GC test	✓	-	✓	-	-
Price Discovery	UC Test	✓	-	✓	-	-
	VECM	✓	✓	✓	✓	✓
	Models		**Inter-linkage between Markets**	**Lead-lag approach**	**Spill over**	**Information biases**
	GSADF test		✓	✓	-	-
Price Volatility	Extreme Value Theory		-	✓	-	✓
Price Volatility	GARCH		✓	✓	✓	-
Price Volatility	Bi-EGARCH		✓	✓	✓	✓

Note: (✓) Steps considered; (-) Steps not considered.

Source(s): Compiled by the authors.

Table 2. Methods used by the previous researchers for PF of agricultural product

Authors	Study area	Sample interval	Crops	Model used	FPO Consideration
Bayona-Oré et al. (2021)	Global	2011-2020	Aggregate commodities	Statistical and Graphical	✗
D. Zhang et al. (2020)	Global	2004-2016	Piglet, Pork, wheat bran, layer chick, corn, pig grain, mutton, broiler feed, broiler, wool, hog, beef, pig feed, egg, bean, fish, live chicken, plain chicken, layer feed	ANN, SVM, RF, MRMR	✗
Ouyang et al. (2019)	Global	2005-2019	Lagged Raisin	LSTNet	✗
Akın and Dizbay (2018)	World	2015	Raisins	ANN, SVM	✗
Wu et al. (2017)	China	January 2014-March 2015	cowpea	Mixed model with PLS regression	✗
Mahto et al. (2021)	India	January 2011-December 2016	sunflower seed and soybean seed	ANN, LSTM	✗
Y. Zhang and Na (2018)	FAO	July 2017-December 2017	Aggregate Food, Meat, Dairy, Cereal, Oils, Sugars	SVM	✗

Note: (✗) Not included or not considered.

Source(s): Compiled by the authors.

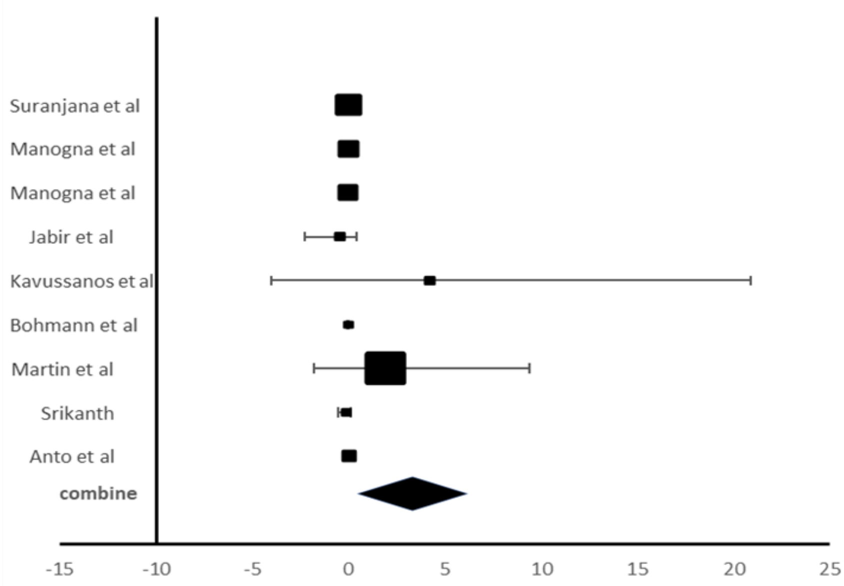
Piece Forecasting (PF)

From the overall studies, only 13 found forecasting agricultural commodities' prices in the derivative market using various models to achieve better prediction. Some of the prominent and minimum error models with their studies are shown in Table 2. Artificial Neural Network (ANN), Long short-term memory (LSTM) method, Support vector machine (SVM), and Maximum Relevance Minimum Redundancy (MRMR) are the common algorithms used by previous researchers for forecasting the prices of the agri-commodities traded in the derivative markets. Only a single study found, where researchers are trying to predict the prices of the agri-commodities traded in the Indian derivative markets using ANN and Long short-term memory (LSTM). No study has been found that considers the external factor to be an influencer of commodity prices. The discussed models cannot take external factors such as new market information, global stocks, pandemics, recession, hazards, etc., into consideration for forecasting the prices of the commodity. There is a requirement for such a model which can automatically train and employ the modal according to the price requirement and predict the prices. Forecasting of prices of agricultural commodities is important for producers and tradersin the price management of their commodities. Through the PF, the future discovery of the prices and the volatility can be predicted, and they can also develop strategies for better price management and profit.

Effectiveness of the Studies

To find effect sizes of the previous studies, soybean price data of future and spot markets were considered because soybean is the most traded commodity in the agricultural derivative market in India. But, only nine studies have been found from the previous studies where all the required data for effect size calculation on soybeans. The overall effect size was calculated using a forest plot in Figure 5. The interpretation of the effect size of the results can be traced from supplementary Table T2. It concludes that the individual studies have small and small to medium effect sizes on their studies. However, the combined results show that the overall effect size of the previous study on soybeans is large. So, there is a possibility that if the numbers of studies increase, the magnitude of the effect of studies will increase. This allows for revaluating the other commodities included in previous studies to check their effectiveness. It may also give more robust results if all other studies on every commodity are checked simultaneously.

Figure 5. Effect size of soybean from the previous study.



Source(s): Compiled by the authors.

CONCLUSION

Price management of the agricultural commodity stands on three main pillars: price discovery, price volatility, and price forecasting in the digital derivative trading space. This study systematically identified the keywords using bibliographic analysis and reviewed the most relevant past literature in the above-sited pillars using PRISMA. The research shows that most of the studies were published on PD (around 43%), while relatively fewer studies are available on the other two sub-domains, i.e., PV and PF. Moreover, there were very limited studies deriving price management using all three above sub-domains. So, further research is required to integrate PD, PV, and PF for better price management and regulation.

In India, 23 commodities are currently being traded in the derivative market, out of which chana, maize, and soybean are mostly studied for PD, wheat, chana, and maize for PV, and only soybean was studied for PF. However, other commodities are also essential to consider as they occupy 34.5% of the total traded volume in the National Commodity Derivative Exchange (NCDEX) by FPO. FPO is a group of farmers working as aggregators with scale economics and negotiation power in trade to achieve better price realization. In India, 82% of farmers are small and marginal and cannot bargain with large traders and buyers. They hardly participate in the derivative market due to limited production and capital strength. GoI is promoting FPOs in a big way, and NCDEX is facilitating the FPO-based trade in the agri-derivative segment to harness the potential of digital marketing and provide better prices to the farmers through advanced price management techniques. Till now, they have connected around 439 FPOs.

Furthermore, the government emphasizes creating and promoting 10000 new FPOs, and till now, 6000 FPOs have been successfully created across the country. However, only a small fraction (439/6000) of FPOs is connected with NCDEX for agri-derivative trading till now. Hence, there is a big opportunity to connect the significant number of FPOs to the digital trade in the derivative market and help the farming community nationwide. We have not come across any research exploring the lacuna of FPO-based trading using advanced price management techniques. The outcome of this review work supports the active digital market participation of farmers/FPOs and other producer-centric organizations through well-regulated derivative platforms, i.e., NCDEX, for better price realization. Further, under the methodological evolution analysis, the present study concluded that the VEC model is one of the latest and most popular PD models. This model uses most PD steps, such as stationarity in the price data, long-run between the spot and future prices, positive and negative inflations, the effect of new information, and a lead-lag approach between the prices. The model can be used for the PD of other commodities traded by the FPOs. We found that the Bi-EGARCH model is robust and allows market information biases for decoding volatility. Very few researchers have used these models for volatility. Hence, Bi-EGARCH can be used for other agri-commodities and for encountering PV for future volatility estimations of prices.

Moreover, only a single study was found on PF in the Indian agricultural commodity derivative markets. However, the model used in that study did not consider how external factors such as weather data, oil and gas price data, and geopolitical activities would impact the PF of an agri- commodity. Two-Step Hybrid Models are a few examples of advanced computational econometric techniques that allow external factors during PF. This model is a machine-learning technique that will enhance the prediction's robustness; as it has a self-learning mechanism, it can quickly adapt and develop itself to show a better prognosis. The perspective has significant potential, especially in these three dimensions of price management. The conclusion of this review will help institutions and other shareholders access the scope of advanced methods in the price forecasting of agricultural commodities.

The study performed the effect size analysis to check the mutual association of the past studies in different price management domains, i.e., PD, PV, and PF, for various agri-commodities. The amount of available past literature in the specific area is essential for effect size analysis. We found that only PD studies for soybean are moderately associated with each other. We could not perform the effect size analysis for the other agri-commodities because of the availability of the required number of studies for the effect size analysis. There is a scope that if more studies are performed capturing all the domains of price management for major traded agricultural commodities, the effectiveness of conducting substantial review work in exploring the mutual association of the studies can be increased. This work empirically established (effect size) that there is a need to conduct price management work for the other agri-commodities to get more associated literature support for future PD, PV, and PF. The present work would have given more robust results if we could have performed an effect size analysis in every price management domain for all digitally traded agricultural commodities.

This study supports that digital agri-marketing participation by the farmers/FPOs, producer collectives, traders, and consumers need to increase using derivative platforms. This is one of the most effective ways to achieve better price management and income realization at the farmer level. There is plenty of scope for enabling high-end price management approaches for effective price realization and better profitability.

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Kripamay Baishnab: Writing – original draft, review & editing, Methodology, Software, Formal analysis, Visualization, Formal analysis, Conceptualization. **Piyush Kumar Singh:** Review & editing, Validation, Supervision, Methodology, Investigation, Conceptualization. **Alok Kumar Singh:** Review & editing, Validation, Supervision, Conceptualization

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APPENDIX - 1

Table T1. Findings of the related studies related Indian agri-commodity derivative market

Authors	Sample size	Methods used	Name of methodology	Commodity Selected	Major Finding
Iyer and Pillai (2010)	Up to 2008		Two-regime, TVAR	Cu, Au, Ag, Ni, Ru, CkP	Five of six commodities have evidence that the PD process occurs in the futures market. The pace of convergence during the futures contract expiry week was instantaneous for copper, gold, and silver, confirming the usefulness of futures contracts as an efficient hedging tool. However, this wasn't the case for chickpeas, nickel, and rubber.
Pavabutr and Chaihetphon (2010)	2003 - 2007		VECM	Au	Even though they only make up 2 percent of the trading value on the MCX, mini contracts are responsible for nearly 30 per cent of PD in the gold futures market.
Joarder and Mukherjee (2021)	2005 - 2014	LL	GC, F-statistic	S_1, ReSO, Sm, CaSe, CoSeOC, MuSe	The assessment of spot market volatility and improved PD is greatly aided by information about futures market volatility. Government interference and speculative activity could harm the derivative market's risk control.
R L and Mishra (2020b)	2010 - 2019	SC, CC, SR, LL	ADF, PP, GC, VECM, EGARCH	CoSe, CaSe, S_1Se, RMuSe, Tu, J, Cor, GuSe and Ch	Nine commodities show the futures market leading the spot in the case of six commodities, including turmeric, soybean seed, coriander, guar seed, castor seed, and chana, while the spot market uses VECM to determine the price of three commodities, including rapeseed, mustard seed, and jeera. The futures markets have robust ability to predict spot prices, indicated by the Granger causality test.
Inani (2018)	2009 - 2015	CSM, ISM, MISM, SC, Co	VECM, ADF, PP, JTME, EGC	CaSe, Cor, CoSeOC, SO, Su-M, Tu, Ch, GuSe, J, MuSe	Given that the results reveal that the futures market outperforms the spot market in the case of six commodities, it was concluded that it is more effective in determining the price of agricultural commodities. At the same time, PD occurs in the spot market for four commodities: chana (chickpea), guar seed, jeera, and mustard seed.
Pani et al. (2022)	2005 - 2019	CC	GC, JJC, VECM	Ag, Al, Cu, Pb, Ni, Zn, CudO	The spot market is ahead of the futures market regarding copper and zinc PD. However, in terms of PD for silver, aluminium, and lead, the futures market outperforms the spot market. The study concludes that market players should employ hedging and arbitrage tactics.
Minakshi (2018)	2009 - 2013		VECM	Ch, Co	Investigate the connection between spot and futures prices. The cointegration results do not support a long-term link between spot and futures prices. The implication is that futures prices are unlikely to act as market expectations of upcoming spot prices of certain agricultural commodities in India and do not aid in PD.
Vijayakumar (2022)	2017 - 2020	SC, LL, Ca test	JC, VECM, GC, RDV	Crd	According to the statistical findings, PD in the e-auction market results in spot and futures pricing. Cardamom futures and spot prices negatively correlate with cardamom e-auction prices. Additionally, it discovers that India's high-value cardamom e-auction system does not have a day-of-the-week effect.

Kumar Mahalik et al. (2014)	2005 - 2008	SA	VECM, Bi-EGARCH	S_1Se, Cor, Tu, CaSe, GuSe and Ch	A flow of data from future to spot commodity markets is implied by the effectiveness with which the agriculture future price index, energy future price index, and aggregate commodity index serve the PD function in the spot market, but the reverse causality is not present. The metal future price index and the metal spot price index do not cointegrate.
Sendhil et al. (2013)	Up to 2009	MIPT	JMVrA, GS	Ckp, Wh, Mz, Bar	According to the study, wheat and maise futures are more effective at determining price. The study has found that because of India's small-scale production system, farmers cannot participate in the futures market.
Mallikarjunappa and Afsal (2010)	2006 - 2006	URT, Co, DE	VECM EGARCH	CT, IC, Inf, IVR Infra, RC, SBI, Sterlite, Tata Steel, Wp, Hdl, PLyd, and RIL	There is a short-lived feedback loop between the two markets. Both marketplaces experience PD simultaneously. Short-term disequilibrium exists, but it can be fixed in the following time frame. The spot and futures markets have a simultaneous and bidirectional lead-lag relationship.
Ali and Bardhan Gupta (2011)	2003 - 2007	EM	JC, GC, ADF, PP	Wh, R, Mz, Ckp, BkL, RdL, GuSe, Pep, Csw, CaSe, S_1, Su	Cointegration is present in futures and spot prices for all the agricultural commodities chosen except for wheat and rice. This suggests that there is a long-term association between futures and spot prices for most agricultural commodities, including maise, chickpeas, black lentils, pepper, castor seed, soybeans, and sugar. For chickpea, castor seed, soybean, and sugar, the analysis of short-term correlations by causality test show that futures markets have higher ability to anticipate subsequent spot prices than for maise, black lentil, and pepper, where short-term bi-directional links exist.
Salvadi Easwaran and Ramasundaram (2008)	2007	EM	B Test, ET	Ca, Co, Pep, S	PD does not occur in the agricultural commodity futures market, according to a statistical examination of data from a sample of four agricultural commodities traded on futures markets. The econometric assessment of the relationship between price return, volume, market depth, and volatility has demonstrated that the return and volatility of futures and spot markets do not significantly affect the market volume and depth.
Garg et al. (2023)	2004 - 2015		Stat	Bar, CaSe, Ch, Cl, Cor, CoSeOC, Co, CudPol, Gu Gum, GuSe, Gu, Je, Kp, Mz, MentaO, MuO, P, Pep, Pot, Ru, S_1, SO, Su, Tu and Wh	In most agricultural commodities, the PD between futures and spot prices indicates substantial information transmission from futures markets to spot markets. Additionally, there is one-way causal connectivity between spot and futures market prices and a feedback relationship between futures and spot market prices. According to the study, the agri-futures market's volatility spillover effects are relatively significant.
Irfan and Hooda (2017)	2005 - 2015		DStat, ADF, PP, JC, GC	Wh, Su, Ch, MuSe, Ch, Pep, Tu, S_1, Bar, and Mz	Ten commodities have a long-term equilibrium relationship established. When there were two cointegrations and causality, the Granger causality test revealed unidirectional Granger lead-lag correlations between spot and futures markets for all agricultural commodities.

Narsimhulu and Satyanarayana (2016)	2004 - 2013	JC, VECM, WchS, GC	Ch, Cl, and Tu	The findings of the Granger causality test showed that there is only a unidirectional connection between the spot returns of the commodities, chili and turmeric, and futures returns. However, there is a two-way causal relationship between spot returns and futures in the case of chana.

Source(s): Compiled by the authors.

Commodities**:** CkP-Chickpea, Wh-Wheat; S1-Soybean; ReSO-Refined_Soyoil; Sm-Soymeal; CaSe-Castor_Seed, CoSeOC-Cotton_Seed_Oilcake; MuSe-Muster Seed; CoSe-Cotton Seed; CaSe-Castor Seed; S1Se-Soybean Seed; RpMuSe-Rape_Muster_Seed; Tu-Turmeric; J-Jeera; Cor-Coriander; GuSe-Guar Seed; Ch-Chana; SO-Soy Oil; SuM-SugarM; Co-Cotton; Crd-Cardomom; Mz-Maize; Bar-Barley; BkL-Black Lentil; RdL-Red lentil; Pep-Pepper; Csw-Cashew; Su-Sugar; S-Soya; Cl-Chilli; CudPol-Crude Plam Olein; Cn-Corn; SSe-Soy Seed; Kp-Kapas; O-Oil; P-Peas; Pot-Potato; Pol-Palm Olein; G-Gram; Cu-Copper; Au-Gold; Ag-Silver; Ni-Nickel; Ru-Rubber; Al-Aluminium; Pb-Lead; Zn-Zinc; CudO-Crude Oil; NG- Natural Gas.

Company: CT - Century Textiles; IC - India Cements; Inf - Infosys; RC - Reliance Capital; SBI – State Bank of India; Wp – Wipro; Hdl - Hindalco; PlyD - Pun Lloyd; RIL - Reliance Industries Limited.

Methodology: JTME-Johansen Trace and Maximum Eigenvalue; EGC-Engle-Granger Cointegration; JGHC-Johansen and Gregory-Hansen Cointegration; TYC-Toda-Yamamoto Causality; JJCA-Johansen and Juselius Cointegration Analysis; JT-Johansen's Trace; LR-Likelihood-ratio Test ; JMVrA-Johansen's Multivariate Approach; GS-Garbade and Silber's Approch; Bi-RW-Bivariate Random Walk; WchS-Wald chi-square test; Stat-Statistical; SC-Stationarity Check; LR-Long Run between spot and Future; DI-Direction of inflation; MI-Market Information's ; LL-Lead-lag Approach; DStat-Descriptive statistics; LLR-Linear long-run relationship; IsSMI-Inter-state Spatial Market Integration; CC-Cointegration Causality test; SR-Short-run Check; CSM-Component share method; ISM-Information share method; MISM-Modified information share method; Ca-Causality test; SA-Spillover analysis; Pa-Parametric; UR-Unit root tests; Co-Cointegration tests; UPH-Unbiasedness and prediction hypotheses; CFP-Comparison with futures prices; MIPT-Market Integration and Price Transmission; DE-Dynamic Effect; EM-Econometric methods; RDV-regression with dummy variables; ET-Expectations Theory; GISM-Generalised Information Share Measure; CSM-Component Share Measure.

Table T2. Interpretations for reporting effect size in quantitative research

Reference	Effect size statistic	Values	Interpretation of effect size
		0.10	Small effect size
Cohen (1988)		0.30	Medium effect size
		0.50	Large effect size
	Cramer's Phi or Cramer's V for nominal data	0.00 and under 0.10	Negligible association
		0.10 and under 0.20	Weak association
Rea and Parker (1992)		0.20 and under 0.40	Moderate association
		0.40 and under 0.60	Relatively strong association
		0.60 and under 0.80	Strong association
		0.80 and under 1.00	Very strong association
		0.20	Small effect size
	Cohen's d for independent t-tests	0.50	Medium effect size
		0.80	Large effect size
Cohen (1988)			
	Cohen's f for ANOVA and ANCOVA	0.10	Small effect size
		0.25	Medium effect size
		0.40	Large effect size
		0.196	Small effect size
Cohen (1988)	R2 for multiple regression	0.1300	Medium effect size
		0.2600	Large effect size

Source(s): Statistical Power Analysis for the Behavioral Sciences Second Edition (2nd ed.). LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS. https://www.utstat.toronto.edu/~brunner/oldclass/378f16/readings/CohenPower.pdf

Table T3. Relevant studies on PD in Indian agri-derivative with their methods

Authors	Sample Size	Commodity selected	Methods SC	LR	DI	MI	LL	O	FPO
Iyer and Pillai (2010)		Cu, Au, Ag, Ckp, Ni, Ru						TVAR	✗
Joarder and Mukherjee (2021)	2005-2014	S_1, ReSO, Sm, MuSe, CaSe, CoSeO Cake	✓						✗
R L and Mishra (2020)	2010-2020	S_1Se, Cor, Tu, CaSe, GuSe, Ch		✓	✓		✓		✗
Inani (2018)	2009-2015	CaSe, Cor, CoSeO Cake, SO, Su-M, Tu, Ch, GuSe, Je, MuSe			✓	✓	✓	CS, IS, MS	✗
Irfan and Hooda (2017)	2005-2015	Wh, Su, Cl, MuSe, Ch, Pep, Tu, S_1, Bar, Mz	✓	✓	✓			St, PP test	✗
Brahmaiah and Palamalai (2016)	2004-2015	Bar, CaSe, Ch, Cl, Cor, CoSeO Cake, Co, Crude PO, Gu Gum, GuSe, Gu, J, Kp, Mz, Menta O, MuO, P, Pepper, Pot, Ru, S_1, SO, Su, Tu, Wh						S	✗
Anupama and Malik (2010)	2004 - 2009	GuSe and Ch	✓					GS, BRW	✗
Narsimhulu and Satyanarayana (2016)	2004 - 2013	Ch, Cl, and Tu		✓			✓	S	✗
Vijayakumar (2022)	2017-2020	Crd		✓	✓		✓	RDV	✗
Kumar Mahalik et al. (2014)	2005-2008	S_1Se, Cor, Tu, CaSe, GuSe, Ch					✓		✗
Sendhil et al. (2013)	2009-2010	Ckp, Wh, Mz, Bar	✓		✓		✓		✗
R L and Mishra (2020)	2010-2019	CoSe, CaSe, S_1Se, RpMuSe, Tu, J, Cor, GuSe, Ch			✓		✓		✗
Salvadi Easwaran and Ramasundaram (2008)	2007	Ca, Co, Pep, S						B Test, S	

Source(s): Compiled by the authors.

Notations: '✓'=Methods included in the study; '✗'=FPO not considered;

Methods: SC-Stationarity Check; LR-Long Run between spot and Future; DI-Direction of inflation; MI-Market Information's; LL-Lead-lag Approach.

Commodities: CkP-Chickpea, Wh-Wheat; S1-Soybean; ReSO-Refined Soy Oil; Sm-Soymeal; CaSe-Castor Seed, CoSe-Cotton Seed; MuSe-Muster Seed; RpMuSe-Rape_Muster_Seed; Tu-Turmeric; J-Jeera; Cor-Coriander; GuSe-Guar Seed; Ch-Chana; Su-Sugar; Cn-Corn; Cl-Chilli; Crd-Cardomom; SSe-Soy Seed; BkL-Black Lentil; RdL-Red lentil; Pep-Pepper; Csw-Cashew; Kp-Kapas; Mz-Maise; Bar-Barley; Mz-Maise; R-Rice; O-Oil; P-Peas; Pot-Potato; S-Soya; Pol-Palm Olein; G-Gram; Cu-Copper; Au-Gold; Ag-Silver; Ni-Nickel; Ru-Rubber.

APPENDIX – 2

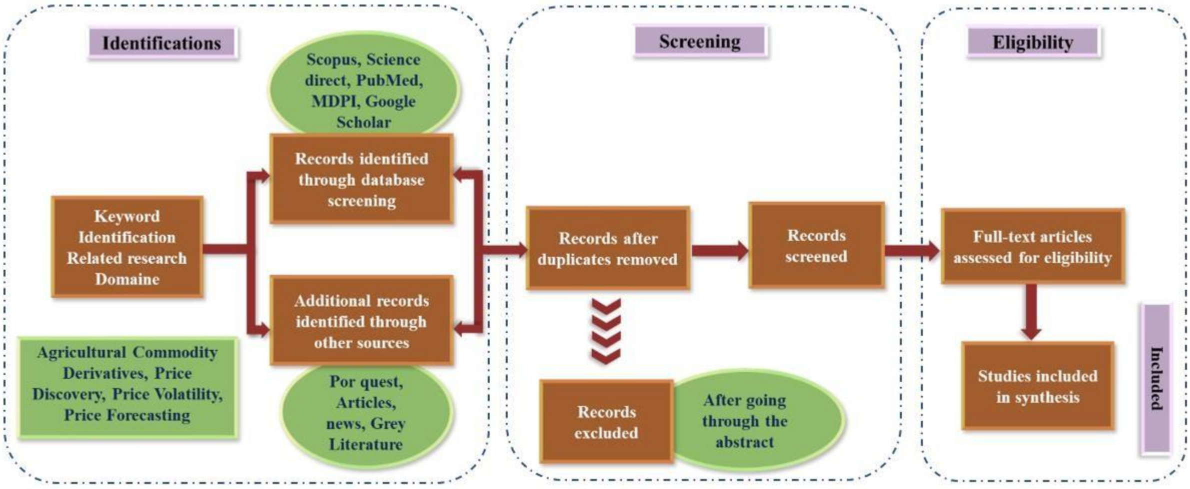

Figure F1. Steps of PRISMA review were made for the study

Source(s): Compiled by the author.