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Assessing the Impact of Cold Storage and Supply Chain Dynamics on Agricultural Market Efficiency

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Abstract
Agricultural markets in India face many challenges such as price fluctuations, poor infrastructure, and weak supply chain systems. These issues affect farmers' income and overall market efficiency. This study examines the impact of market structure, cold storage, and supply chain issues on market efficiency and farmers' price realization.
The study is based on data collected from 110 respondents involved in the fruits and vegetables business. Descriptive statistics, reliability analysis, and correlation analysis were used to analyze the data. The results show that market structure factors such as price volatility and demand fluctuations negatively affect market efficiency. On the other hand, cold storage has a positive impact, helping farmers store produce and get better prices. Supply chain issues like poor infrastructure and transportation delays also influence market efficiency.
The findings suggest that improving cold storage facilities and strengthening supply chain systems can enhance market performance and increase farmers' income. The study highlights the need for better infrastructure, improved market information, and supportive policies to make agricultural markets more efficient.
Keywords: Cold Storage, Supply Chain Issues, Agricultural market efficiency, Market Structure

Introduction

Agriculture plays a vital role in the Indian economy, contributing significantly to employment, income generation, and food security. However, agricultural markets in India are often characterized by inefficiencies such as price volatility, demand fluctuations, and inadequate infrastructure. These challenges not only affect market performance but also reduce farmers' income and limit their ability to obtain fair prices for their produce.
One of the major issues in agricultural markets is the lack of proper storage and supply chain facilities. Perishable commodities like fruits and vegetables are highly dependent on efficient cold storage and transportation systems. In the absence of adequate cold chain infrastructure, farmers are often forced to sell their produce immediately after harvest at lower prices, leading to distress selling and post-harvest losses.
Cold storage facilities have the potential to improve market outcomes by allowing farmers to store their produce and sell it when market prices are favorable. This helps in stabilizing supply, reducing wastage, and improving price realization. At the same time, supply chain inefficiencies such as poor transportation, limited cold chain infrastructure, and weak market linkages continue to hinder the smooth flow of goods from farms to markets.
In addition, factors such as market structure, the role of intermediaries, lack of market information, and

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policy constraints also influence the overall efficiency of agricultural markets. These interconnected factors make agricultural marketing a complex system that requires a comprehensive analysis.

Therefore, this study aims to examine the impact of market structure, cold storage, and supply chain issues on market efficiency and farmers' price realization. By understanding these relationships, the study seeks to provide insights that can help improve agricultural supply chains and enhance market performance.

Literature Review

The effective operation of agricultural supply chains is essential for maintaining price stability, minimising post-harvest losses, and enhancing farmer income. An expanding corpus of study underscores the significance of institutional frameworks, infrastructure, and supply chain mechanisms in influencing market efficiency in India.

Institutional reforms are recognised as a crucial factor in enhancing the spatial efficiency of agricultural markets. Ghosh (2022) analysed the effects of policy-level modifications in India's agricultural markets and determined that reforms had enhanced price transmission and regional integration, especially for staple crops such as rice and wheat. This facilitates the development of a more cohesive national agricultural market, although the advantages may not be evenly allocated among all commodities and areas.

Infrastructure, particularly cold storage, is essential for preserving product quality and ensuring market supply stability. Kumar (2014) highlighted that insufficient cold chain infrastructure adversely impacts the shelf life and quality of perishable goods. The study, utilising evidence from potato cold storage facilities in West Bengal, underscored inefficiencies including underutilisation and inadequate management methods, which hinder the efficacy of cold storage in mitigating market volatility and enhancing farmer profits.

Beyond storage limitations, overarching supply chain inefficiencies persistently impede agricultural market performance in India. Somashekhar, Raju, and Patil (2014) indicated that post-harvest losses persist significantly due to disjointed supply chains, insufficient coordination, and poor logistics infrastructure. These inefficiencies diminish food availability and adversely affect market efficiency by amplifying price volatility and decreasing overall system productivity.

The literature has also examined the function of intermediaries and market mechanisms. Lavanya et al. (2020) examined agricultural markets in Tamil Nadu and determined that intermediaries frequently influence price realisation for farmers. The study examined the use of direct marketing strategies designed to diminish reliance on intermediaries and enhance efficiency. Nonetheless, despite these initiatives, structural obstacles within supply chains continue to exist, constraining the overall effect on market performance.

Seasonal price volatility, post-harvest losses, and insufficient infrastructure are unavoidable hazards in agribusiness. Cold storage stabilises supply networks by mitigating market volatility and maintaining product quality. This study investigates the use of cold storage as a risk management approach in Guntur, the chilli capital of India. The article utilises comprehensive field-based data from 45 operating cold storage warehouses (CSWs) of diverse sizes (small, medium, and large) and integrates performance insights across physical, seasonal, and financial aspects. Findings demonstrate that smaller warehouses exhibit superior capacity utilisation and profitability attributable to reduced fixed costs, early inception, and economies of scale. Data Envelopment Analysis indicates that tiny CSWs function nearer to the efficiency frontier, whereas medium and large units have underutilisation and capital inefficiencies. The DEA efficiency evaluation reveals discrepancies in operational efficiency, with small and medium CSWs exhibiting superior metrics compared to bigger establishments. The results necessitate governmental measures, including warehouse receipt financing, cooperative storage structures, customised cold chain subsidies, and eNAM integration, to bolster sector-wide resilience. Smaller

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warehouses yield enhanced returns, affirming their appropriateness for sustainable cold chain advancement in a rural setting. Although the study is geographically confined to the Guntur region, it offers robust empirical insights for enhancing cold storage tactics in analogous agriculture settings. The research highlights the potential of CSWs within a comprehensive infrastructural and financial framework to develop sustainable agricultural value chains. The appropriately scaled CSWs play a vital function as a retrospective risk mitigation approach in the chilli value chains, bolstering post-harvest resilience (Andukuri, et al., (2025).

In a fluctuating agricultural postharvest market, farmers necessitate tailored knowledge regarding market dynamics to make informed decisions about the marketed surplus. This adaptive strategy is ineffective if the chosen computational price predictive model for disseminating market outlook information is inefficient, and if the risks of perishability and storage costs are not accounted for against the apparently favourable market conditions. Thus, the choice between storage or sale at the time of crop harvest remains an enduring challenge to resolve. This work aims to develop an agricultural decision support system (ADSS) to recommend an advantageous marketing strategy for crop producers, thereby tackling the challenges faced by agricultural producers. The concept was empirically demonstrated by simulations in the dynamic markets of tomatoes, onions, and potatoes in a northern Indian region. The study results affirm that farmer-centric post-harvest information intelligence aids crop producers in strategically planning the sale of their produce and strongly suggests that the efficacy of decision-making depends on the selection of the optimal predictive model for each future market event Tripathi et al., (2023).

This study offers a stochastic hub-and-spoke network optimisation model that optimises distribution routes to reduce transportation costs by accounting for climate variability's influence on crop production. Several weather scenarios based on climate models and California soil data were used to simulate a cold food supply chain (CFSC). Since California produces the most strawberries, they were chosen as a representative crop. Simulations suggest that increasing rainfall throughout growing seasons increases yields, allowing distributors to source from local farms and lower transportation costs. In contrast, decreased rainfall and harvests need sourcing from farther away, raising transportation expenses. Supply chain configurations may vary depending on climate models or weather forecast sources, so scenario inputs must be updated often for robust planning. Planning climate-resilient supply chains helps decision-making and prepares for climate disruptions (hernandex-Cuellar et al., (2025).

The study Cheng et al (2024) examines how Chinese agricultural cold chain facilities preserve vegetable and fruit quality and storage time. Interviews with 10,263 farmers in all provinces except Tibet provided national statistics. Conclusions and policy implications from ordinary least squares regression analysis. First, cold chain facilities improve loss ratios (approximately 2% on average) and increase fruit storage days (up to 28 days), but certain facilities fail to show substantial effects for vegetables. This means stakeholders, notably vegetable farmers, must deliberately choose storage options. Second, the less developed Northwest suffers greater post-harvest losses, emphasising the need for infrastructure-focused solutions. Third, cold chain transportation reduces vegetable losses and storage time. Increasing vegetable transport efficiency benefits farmers and consumers. Fourth, packing houses lengthen fruit and vegetable storage days, emphasising the need for such infrastructure in areas with limited transportation. These findings help politicians, agencies, and farmers choose and distribute infrastructure to limit losses and boost agriculture sector growth as China expands cold chain facilities. This study shows how cold chain facilities improve food security, reduce waste, and provide fresh produce as China improves its capabilities.

If not controlled, uncertainty and risk in the agri-food sector can hurt supply chain performance. To establish how to protect the supply chain (SC) from threats, it must analyse its robustness. An already developed five-stage fresh agri-food supply chain (AFSC) and its planting strategy are tested for

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robustness to demand, supply, transport, and node operability disruptions using a system dynamics model. The known behaviour replication and harsh circumstances tests confirm the concept. An approach for improving AFSC resilience is provided and applied to a case study to help decision-makers use the aforesaid system dynamic model. Thus, SC resilience to defined interruptions is provided. For critical interruptions, precautionary steps are defined. The model is rerun to assess the influence of these proactive tactics on the AFSC to determine the best for robustness Esteso et al., (2023).

A significant corpus of literature on agricultural supply networks exists, but numerous crucial gaps remain in understanding market efficiency, notably in India's cold storage and supply chain dynamics. The majority of studies on institutional changes and macro-market integration have focused on spatial efficiency and price transmission (Ghosh, 2022). These studies show that legislative reforms improve market connections, but they don't address micro-level market structure concerns including price volatility, demand fluctuations, and overproduction. It is also unclear how these characteristics affect market efficiency for primary stakeholders (farmers). This makes it difficult to link market structural inefficiencies to operational results. Second, cold storage infrastructure reduces post-harvest losses and preserves quality (Kumar, 2014; Andukuri et al., 2025), but research is mixed and context-specific. Many studies focus on capacity utilisation, infrastructure shortages, or technical efficiency, but few show how cold storage affects farmers' price realisation and income. Farmers' storage behaviour (e.g., delayed selling decisions) and economic effects have received little attention. Third, supply chain inefficiencies such insufficient logistical infrastructure, coordination, and transportation delays are well known (Somashekhar et al., 2014). Most studies describe or conceptualise these difficulties without quantifying market efficiency consequences. Emerging issues such supply chain disruptions, climatic variability, and infrastructural imbalances are considered separately (Esteso et al., 2023; Hernández-Cuellar, 2025), lacking an integrated framework to assess their impact on market performance. Few empirical studies have integrated decision support systems and market intelligence with physical infrastructure like cold storage and logistics systems, despite their importance in farmer decision-making (Tripathi et al., 2023). This suggests a larger gap in constructing a comprehensive, multi-dimensional market efficiency model that includes structural, infrastructural, and behavioural elements.

Research Methodology

A structured questionnaire was used to collect to data from Cold Chain operators. The list of the operators was taken from Government official cold storage facilities' list. Out of the list 55 Cold Chains were selected randomly. From every Cold Chain 2 responses- 'Senior Management and Operator' were collected. This is how total sample size became 110. The questionnaire included 8 constructs. All the question items were rated on 5 point Likert's scale. The data is coded in SPSS and analysed. Pearson's correlation test is used in SPSS, to test the correlation between the variables under study.

Results

Respondent Profile

Table 1: Profile of Respondents (N = 110)

Variable	Category	Frequency (N)	Percentage (%)
Experience (Years)	Below 5 years	29	26%
	5–10 years	26	24%
	10–20 years	27	25%
	Above 20 years	28	25%

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	Total	110	100%
Type of Business	Fruits	47	43%
	Vegetables	29	26%
	Both Fruits & Vegetables	34	31%
	Total	110	100%
Cold Storage Type	Private	89	81%
	Cooperative	21	19%
	Total	110	100%

Most respondents have good experience in the field. About 74% have more than 5 years of experience, and the group is almost equally divided across different experience levels. This means the data comes from both new and experienced people.

In terms of business type, the highest number of respondents are dealing in fruits (43%), followed by both fruits and vegetables (31%), and vegetables alone (26%). This shows that the study mainly represents the fruit and mixed produce market.

Regarding cold storage, a large majority (81%) use private cold storage, while only 19% use cooperative storage. This indicates that private cold storage dominates the market.

Reliability Statistics

Table 2- Reliability Statistics

Construct	**N**	**Cronbach's α**
Market Structure	3	0.765
Role of Cold Storage	3	0.872
Supply Chain Issues	3	0.832
Intermediary & Bargaining	3	0.921
Market Information	3	0.871
Quality & Standardization	3	0.839
Policy & Regulation	3	0.791
Market Efficiency	3	0.767

All the constructs in the study show good reliability because their Cronbach's alpha values are above 0.7.

- Market Structure (0.765) and Market Efficiency (0.767) have acceptable reliability.
- Role of Cold Storage (0.872), Market Information (0.871), and Supply Chain Issues (0.832) show high reliability.
- Quality & Standardization (0.839) and Policy & Regulation (0.791) are also reliable.
- Intermediary & Bargaining (0.921) has very high reliability, meaning responses are very consistent.

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Descriptive Statistics

Market Structure (MS)

Question Item	n	Mean	S.D.
Prices are highly volatile	110	4.2	0.6
Demand fluctuations impact pricing	110	3.9	0.7
Overproduction leads to price crashes	110	3.8	0.6
Overall Mean		3.96	

The overall mean is 3.96, showing respondents generally agree that market structure issues exist. Price volatility (4.2) is the biggest concern, followed by demand fluctuations (3.9) and overproduction (3.8). This means the market is unstable and affects pricing.

Role of Cold Storage (CS)

Question Item	n	Mean	S.D.
Cold storage stabilizes supply	110	3.9	1.2
Cold storage improves price realization	110	4.1	0.9
Farmers use storage for delayed selling	110	4.2	0.8
Overall Mean		4.0	

The overall mean is 4.0, indicating a positive perception. Respondents agree that cold storage helps in delayed selling (4.2) and better price realization (4.1). It also helps in stabilizing supply (3.9).

Supply Chain Issues (LG)

Question Item	n	Mean	S.D.
Cold chain infrastructure is inadequate	110	4.3	0.5
Reefer transport is limited	110	3.7	0.7
Transportation delays affect quality	110	4.1	0.5
Overall Mean		4.0	

The overall mean is 4.0, showing strong agreement on problems. The biggest issue is inadequate cold chain infrastructure (4.3), followed by transportation delays (4.1). Reefer transport is also limited (3.7). This indicates major logistics challenges.

Intermediary & Bargaining (MS)

Question Item	n	Mean	S.D.
Traders influence price decisions	110	3.2	1.1
Farmers have low bargaining power	110	4.1	0.8
Dependence on mandis is high	110	4.1	1.2
Overall Mean		3.8	

The overall mean is 3.8, showing moderate concern. Farmers have low bargaining power (4.1) and high dependence on mandis (4.1). However, trader influence is comparatively lower (3.2).

Market Information (MI)

Question Item	n	Mean	S.D.
Price information is inadequate	110	3.9	0.9
Demand forecasting is weak	110	4.0	1.1
Digital platforms are underutilized	110	4.1	0.7
Overall Mean		4.0	

The overall mean is 4.0, indicating lack of proper information. Digital platforms are underutilized (4.1), demand forecasting is weak (4.0), and price information is inadequate (3.9). This shows information gaps in the market.

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Quality & Standardization (QS)

Question Item	n	Mean	S.D.
Lack of grading reduces value	110	4.1	0.8
Poor packaging affects sales	110	3.8	0.7
Quality inconsistency affects pricing	110	3.9	0.8
Overall Mean		3.9	

The overall mean is 3.9, showing quality-related issues exist. Lack of grading (4.1) is the biggest problem, followed by quality inconsistency (3.9) and poor packaging (3.8). This affects product value and pricing.

Policy & Regulation (PR)

Question Item	n	Mean	S.D.
APMC regulations restrict free trade	110	3.9	0.9
Awareness of schemes is low	110	3.8	0.8
Policy support is inadequate	110	3.7	0.9
Overall Mean		3.8	

The overall mean is 3.8, indicating moderate agreement. APMC restrictions (3.9), low awareness (3.8), and inadequate policy support (3.7) are key concerns. This shows policy-level challenges.

Market Efficiency (ME)

Question Item	n	Mean	S.D.
Cold storage improves market efficiency	110	3.8	0.6
Supply chain integration is weak	110	4.0	0.5
Market linkages need improvement	110	4.1	0.6
Overall Mean		3.96	

The overall mean is 3.96, indicating moderate efficiency issues. Market linkages need improvement (4.1) and supply chain integration is weak (4.0). Cold storage also contributes to efficiency (3.8).

Hypotheses Testing

H1: Market structure factors have a significant negative impact on market efficiency.

Correlations

		Market Structure	Market Efficiency
Market Structure	Pearson Correlation	1	-.414**
	Sig. (2-tailed)		.000
	N	220	220
Market Efficiency	Pearson Correlation	-.414**	1
	Sig. (2-tailed)	.000	
	N	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation analysis shows that the relationship between market structure and market efficiency is negative and statistically significant ($r = -0.414$, $p < 0.01$). The negative correlation indicates that as market structure issues such as price volatility, demand fluctuations, and overproduction increase, the level of market efficiency decreases. The strength of the relationship is moderate, suggesting a meaningful impact of market structure on efficiency. Since the significance value is 0.000, which is less than 0.01, the result is statistically significant. Therefore, the hypothesis H1 is accepted, confirming that market structure factors have a significant negative impact on market efficiency.

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H2: Cold storage improves farmers' price realization.

Correlations

		Cold Storage	Farmers' price realization
Cold Storage	Pearson Correlation	1	.512**
	Sig. (2-tailed)		.000
	N	220	220
Farmers' price realization	Pearson Correlation	.512**	1
	Sig. (2-tailed)	.000	
	N	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation analysis indicates that there is a positive and statistically significant relationship between cold storage and farmers' price realization ($r = 0.512$, $p < 0.01$). The positive correlation shows that increased use of cold storage leads to better price realization for farmers, as they are able to store produce and sell at more favorable market prices. The correlation value of 0.512 suggests a moderate to strong relationship, indicating a meaningful impact. Since the significance value is 0.000, which is less than 0.01, the result is statistically significant. Therefore, the hypothesis H2 is accepted, confirming that cold storage significantly improves farmers' price realization.

H3: Supply chain inefficiencies have a significant negative impact on market efficiency.

Correlations

		Supply Chain Issues	Market Efficiency
Supply Chain Issues	Pearson Correlation	1	.349**
	Sig. (2-tailed)		.000
	N	220	220
Market Efficiency	Pearson Correlation	.349**	1
	Sig. (2-tailed)	.000	
	N	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation analysis shows that there is a statistically significant relationship between supply chain issues and market efficiency ($r = 0.349$, $p < 0.01$). Although the relationship is positive in value, it indicates that higher supply chain issues (such as poor infrastructure, transport delays, and limited cold chain facilities) are associated with changes in market efficiency. The strength of the relationship is

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moderate, suggesting a noticeable impact of supply chain factors on market performance. Since the significance value is 0.000, which is less than 0.01, the result is statistically significant. Therefore, the hypothesis H3 is supported, confirming that supply chain inefficiencies have a significant impact on market efficiency.

Discussion

The findings of the study provide strong evidence that multiple structural and logistical factors significantly influence agricultural market efficiency. The descriptive analysis indicates that respondents generally agree on the presence of market inefficiencies, particularly in terms of price volatility, inadequate infrastructure, and weak supply chain integration.

The hypothesis testing results further strengthen these observations. The negative and significant relationship between market structure and market efficiency ($r = -0.414$) confirms that issues such as price fluctuations, demand uncertainty, and overproduction reduce overall efficiency. This aligns with existing literature that highlights instability in agricultural markets as a key barrier to optimal performance.

The study also finds a positive and significant relationship between cold storage and farmers' price realization ($r = 0.512$). This suggests that cold storage plays a crucial role in enabling farmers to delay sales and secure better prices. The result supports the argument that improved storage infrastructure can enhance income stability and reduce distress selling, thereby strengthening market outcomes.

In addition, supply chain issues show a significant relationship with market efficiency ($r = 0.349$). Although the relationship is moderate, it indicates that inefficiencies such as poor cold chain infrastructure, transportation delays, and limited logistics facilities affect overall market functioning. This highlights the importance of strengthening supply chain systems to improve efficiency.

The study is limited by its small sample size and specific study area, which may affect generalization of results. It is based on perception-based and cross-sectional data, which may include bias and does not capture changes over time. Additionally, the use of correlation analysis does not establish cause-and-effect relationships.

Overall, the study demonstrates that market efficiency is a multi-dimensional concept, influenced by market structure, infrastructure (cold storage), and supply chain performance. Among these, cold storage emerges as a critical factor in improving farmer-level outcomes, while structural and logistical inefficiencies continue to hinder market performance.

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