"Strengthening Agri-Food Supply Chain Resilience: A Multi-Dimensional Analysis of the Impact of Contract Farming on Smallholder Integration."

Dr. Reshma Balu Shinde
College of Agri-Business Management, Baramati, Pune (MH)

Dr. Anika Khatke
Aditya Institute of Management, Narhe, Pune(MH)

Prof. Prasad Salunke
Sharadchandraji Pawar College of Agriculture, Kharavate,Chiplun, (MH)

Abstract:
This study evaluates the impact of contract farming on the supply chain efficiency and income levels of fruit and vegetable farmers in the Pune and Satara districts of Maharashtra. A comparative research design was employed, collecting primary data from a representative sample of 400 farmers (200 contract and 200 non-contract), alongside 200 wholesalers and 400 retailers. Analytical tools included Principal Component Analysis (PCA) to identify key input variations and Paired t-tests to measure socio-economic changes "before" and "after" the adoption of contract farming. PCA results indicate that contract farming significantly reduces burdens related to packaging, finance, and technical know-how. The supply chain analysis reveals that contract farming simplifies the process into a direct producer-to-consumer model, eliminating multiple intermediaries. Statistical testing confirms a highly significant increase ($p < 0.05$) across all measured indicators: average crop area increased from 0.66 to 0.78 ha, machinery investment rose by approximately 15%, and total family income grew from Rs.1,694,051 to Rs1,885,051. The study concludes that contract farming effectively mitigates market risks and price volatility, providing a robust framework for transforming subsistence agriculture into a profitable, market-led enterprise.

1. Introduction:

Agriculture is a backbone of Indian Economy. The scenario of Indian agriculture is changing. Farming is a main means of livelihood for Indians. Farmers are very keen in transforming from traditional approach of farming to market-led approach means subsistence farming to profitable farming system. Farmers are now looking for the means and ways to shift from subsistence agriculture to market-oriented production. (Anonymous, 2004) 'Marketing is the most important function in determining the success of any farming enterprise.

An effective marketing system is crucial for economic growth because it encourages production, stabilizes output and prices, lowers production costs, and ensures a fair share of the consumer's price. For the full benefits of economic development to be realized, the marketing landscape encompassing both its strategic approaches and technological tools must evolve dynamically to match advancements in production and the country's broader socioeconomic shifts.

The experience of many countries suggests that in the absence of an efficient marketing system strategy, agricultural development cannot go very far to stimulate production and contribute to price stability (Khalon A S, 1985). Price instability is a significant issue stemming from various interconnected factors. When these factors align, they lead to severe consequences for the most vulnerable populations. While elevated prices might seem beneficial to farmers, their volatility

poses considerable risks. Farmers and other participants in the food supply chain could face substantial financial losses if prices decline. Consumers are also negatively impacted by fluctuating prices, as it ultimately harms producers too. A commonly cited cause for rising prices is 'market fundamentals,' suggesting that demand surpasses available supply, thereby driving prices upward. Often, **climate change**, the **exhaustion of soils and aquifers**, and the **diminishment of biodiversity** are recognized as contributing elements. Nevertheless, present-day food production stands at an all-time high, and **commodity markets** are increasingly attracting the attention of **financial speculators**. (Happiness H, 2014).

Generally, small farmers do not have enough capital for investment to sustain this price fluctuating situations which is tough to predict in agricultural produce. This situation can lead to **suboptimal investment choices**, potentially **compromising long-term agricultural production**. It's important to note that increased food prices haven't always resulted in improved returns for farmers in developing nations. This is because the cost of **non-food essentials** like cooking fuel, transportation, rent, fertilizers, kerosene, and other agricultural inputs has also risen significantly. Additionally, **intermediaries** are contending with higher transportation expenses, which they're subsequently passing on to farmers. (Happiness H, 2014). However, there are only few options in which farmers are assured of a getting a market for produce, Farmers have on occasion had to throw away their produce for want of buyers. This is one side of the coin; other side of coin is the availability of agri-based and food industry, which are ready to buy produce from farmers on timely and adequate quality agricultural produce. This underlying situation of the Indian agricultural scenario has given birth to the Contract Farming, which promises to provide a proper linkage between the 'farm and market (Charles R., 2009)

In developed countries contract farming is used, where it accounts for about 15% of agricultural output and also has been rapidly expanding in developing countries. Although contracting needs government involvement in all countries, it must be underlined that the role of government is highly important in all contracting schemes in developing and less-developed countries. Improving the rural infrastructure, issuing direct and indirect regulations in favor of small-poor farmers under the fair trade practices, aiming at the securing of food sovereignty and safety, encouraging the development of domestic markets and farmers' organizations etc., could be addressed as major responsibilities (Rehber, 2007). Farmers in developing countries are commonly vulnerable to the vagaries of **climate**, **price fluctuations**, and **disease outbreaks**. The intense uncertainty from these factors often pushes many to the very edge of their endurance, sometimes just barely surviving. They cannot foresee favorable or unfavorable rainfall during a growing season, predict future market prices for their harvested goods, or know if their crops will be afflicted by disease. Although these risks are beyond the farmers' direct influence, certain individuals have devised coping and management mechanisms. Among these is the **future price contract**, which provides farmers with a guaranteed income.(Kahan, 2013)

1.1.Research Objectives

2. To study the supply chain of contract and non-contract farming of fruits and vegetables.

3. To study the impact of contract farming on income level of farmers.

1.2.Hypothesis:

- **Null Hypothesis (H_0):** There is no significant difference in the income levels of farmers participating in contract farming compared to those practicing traditional farming.
- **Alternative Hypothesis (H_1):** There is significant difference in the income levels of farmers participating in contract farming compared to those practicing traditional farming.

2. Methodology:

For the research on contract and non-contract farming, a systematic selection of tehsils was undertaken to ensure a diverse and representative sample area. The study focuses on regions that exhibit significant agricultural activities, specifically within Pune and Satara districts of Western Maharashtra. The research was conducted in five tehsils selected from Pune and Satara districts of Maharashtra. A sample of 400 farmers was chosen in order to estimate production costs in both contract and non-contract farming. 200 of these samples came from farmers who had contracts to grow fruits (pomegranates and grapes) and vegetables (okra and chilli). The remaining 200 samples came from same geography that did not have contracts. For the purpose of gathering marketing data on aspects, the intermediaries—one wholesaler and two retailers per farmer were chosen. A total of 200 wholesalers and 400 retailers provided the marketing data.

2.1. Sample Sizes

The list collected from companies for contract farmers of chilli, okra, pomegranate and grapes. The total population was 380 for selected fruits and vegetables. As per Krejcie and Morgan Sample Size Table the sample estimated as 192 for contract farmers. The actual sample size was set 200 for more accuracy. As this research is comparative in nature so same number of samples collected from non-contract farming. The total 400 sample farmers, 200 wholesalers and 400 retailers were selected for this research.

3. Results & Discussions:

The Supply Chain of Fruits and Vegetables:

3.1 Backward Supply Chain (Input Procurement):

In backward supply chain farmers procure inputs from contractor (company) & in non-contract procurement done by retailers cause higher price than contract farmer. In Contract packaging material is bought by contractor.

Table: 3.1 Supply Chain (Input Procurement) of Vegetable Crops:s

Input	Contract chilli	Non-Contract chilli	Contract okra	Non- Contract okra
Seeds	1	1	1	1
Fertilizers & Chemicals	3	4	4	5
Machineries	1	2	1	1

Packaging Materials	0	4	0	4
Finance	1	2	1	2
Technical Know-how	3	0	4	0

In the case of vegetable crops such as chilli and okra, the backward supply chain shows distinct advantages for contract farmers over their non-contract counterparts. While seed procurement remains uniform across both systems, significant differences emerge in other inputs. Contract farmers benefit from reduced costs and better access to fertilizers and chemicals, with lower input intensity ratings (e.g., 3 for contract chilli vs. 4 for non-contract chilli). Similarly, machinery availability is more streamlined under contract farming, particularly for chilli, where contract farmers face fewer procurement issues. A major differentiating factor is packaging materials: contractors provide packaging support in contract farming (rating 0), while non-contract farmers must arrange it themselves, incurring extra costs (rating 4).

Finance is more accessible to contract farmers, thanks to direct company support or facilitated loans (rating 1), compared to the higher financial burden on non-contract farmers (rating 2). Lastly, technical know-how is a key area where contract farmers have a clear edge. They receive expert guidance and training from the contracting agency (rating 3–4), whereas non-contract farmers often operate without any formal support or advisory services (rating 0). Overall, contract vegetable farming offers a more supportive and cost-effective input procurement system.

Table: 3.2 Supply Chain (Input Procurement) of Fruit crops

Input Name	Contract Pomegranate farming	Non-Contract Pomegranate farming	Contract Grapes farming	Non-Contract Grapes farming
Seeds	1	1	1	1
Fertilizers & Chemicals	8	12	6	7
Machineries	2	1	2	1
Packaging Materials	0	2	0	8
Finance	1	4	1	3
Technical Know-how	8	5	7	4

Principal Component Analysis (PCA): Principal Component Analysis has been used for identification of which inputs (e.g., Fertilizers, Packaging, Technical Know-how) **contributed most** to the difference between Contract and Non-Contract farming.

Table: 3.3 Data Table for PCA:

Farming Type	Crop	Seeds	Fertilizers	Machinery	Packaging	Finance	Tech Know-how
Contract	Chilli	1	3	1	0	1	3
Non-Contract	Chilli	1	4	2	4	2	0
Contract	Okra	1	4	1	0	1	4
Non-Contract	Okra	1	5	1	4	2	0
Contract	Pomegranate	1	8	2	0	1	8
Non-Contract	Pomegranate	1	12	1	2	4	5
Contract	Grapes	1	6	2	0	1	7
Non-Contract	Grapes	1	7	1	8	3	4

Analysed Variance of Principal Components	
Principal Component	**Variance**
PC1	**60.88%**
PC2	**23.81%**

For fruit crops like pomegranate and grapes, the backward supply chain further highlights the comparative advantages of contract farming. Seed procurement shows no difference between the two systems, as both contract and non-contract farmers rate it equally. However, when it comes to fertilizers and chemicals, contract farmers report lower input procurement burdens (e.g., 8 for contract pomegranate vs. 12 for non-contract). Machinery access is also slightly better for contract fruit farmers, indicating a more structured or facilitated access system. Packaging materials are entirely handled by the contractors in contract farming (rating 0), while non-contract farmers need to procure and bear the costs themselves, with significant disparities (e.g., 8 for non-contract grapes). Finance again remains more accessible under contract farming (rating 1), while non-contract farmers struggle with higher ratings (3–4), reflecting greater dependency on informal sources or limited institutional support.

The most notable benefit of contract farming in fruits lies in the provision of technical know-how. Contract farmers in pomegranate and grape production report receiving regular guidance and expert intervention (ratings 8 and 7), whereas non-contract farmers have limited access to such knowledge (ratings 5 and 4). This clearly shows that contract farming offers a more integrated and efficient input procurement system for fruit growers, helping them lower costs, access better resources, and adopt improved practices.

Together, **PC1 and PC2 explain about 84.69% of the total variance**, which means these two components are sufficient to understand the major patterns in the data.

A Principal Component Analysis (PCA) was applied to assess the variation in input usage between contract and non-contract farming across four major crops—chilli, okra, pomegranate, and grapes. The analysis focused on key input categories such as fertilizers and chemicals,

machinery, packaging materials, finance, and technical know-how, excluding seeds due to its uniform value across all observations. The first principal component (PC1), which explained the majority of the variance (approximately 60–65%), was primarily influenced by packaging material, finance, and technical know-how. This component clearly differentiated contract from non-contract farming systems. Contract farming scenarios tended to be associated with lower packaging material responsibility and significantly better access to technical know-how and financial support. In contrast, non-contract farmers bore higher costs for packaging materials and lacked technical guidance.

The second principal component (PC2), accounting for 20–25% of the variance, highlighted differences in fertilizer and machinery usage, distinguishing crops like pomegranate and grapes, which require higher input intensity. Overall, the PCA revealed that the most significant sources of variation between contract and non-contract farming lie not in the seeds or basic inputs, but in the support infrastructure—specifically, packaging provision, advisory services, and credit access. These findings underscore the practical benefits of contract farming in reducing input-related burdens and enhancing technical support, especially in high-value fruit and vegetable crops.

3.2. Forward Supply Chain:

From the research conducted, it was found that **contract farming** typically involved a **single marketing channel**, where the produce moved directly from the **producer to the consumer**. This direct-to-consumer approach was a characteristic feature of contract farming, where farmers, working under agreements with contractors, would usually have their crops bought directly by the contractors or associated companies. The contractor then either processed, packaged, or marketed the produce, often ensuring a predetermined price and reducing the farmer's exposure to market fluctuations. As a result, the contract farming model simplified the supply chain, bypassing multiple intermediaries and enabling a more streamlined process for both the farmer and the consumer.

In contrast, **non-contract farming** followed a more complex supply chain structure that involved **three distinct marketing channels**:

1. **Producer-Consumer**: In some cases, farmers sold their products directly to consumers, often in local markets, farmer’s markets, or directly through other informal channels. This was typically more common for small-scale or niche products, where direct interaction between producers and consumers was feasible.
2. **Producer-Retailer-Consumer**: In this channel, the farmer sold the produce to a retailer, who then sold it to the final consumer. Retailers could include grocery stores, supermarkets, or small-scale vendors. This added an extra layer to the supply chain and introduced additional costs related to retail handling, logistics, and pricing.
3. **Producer-Wholesaler-Retailer-Consumer**: The most common supply chain for non-contract farming involved the producer selling their produce to wholesalers, who would then distribute it to retailers. The retailer, in turn, would sell the produce to the end consumer. This multi-tiered channel created more complexity and involved more intermediaries, each of whom added their own margin to the price. The research indicated that this system typically resulted in higher overall costs for the consumer compared to contract farming, due to the involvement of wholesalers and retailers who took their share of profits.

The findings revealed that **contract farming** was more efficient in terms of supply chain management as it eliminated multiple intermediaries, leading to cost reductions in packaging, transportation, and marketing. Farmers involved in contract farming were also less exposed to market risks, as they typically had a guaranteed buyer for their produce. On the other hand, the **non-contract farming** model often involved more stakeholders, which meant more complexities and higher costs, both for the farmers and consumers. Additionally, farmers in non-contract farming were more vulnerable to price fluctuations, market competition, and demand variability, as they were dependent on the broader market or intermediaries.

It is clear that **contract farming** simplified the supply chain to a single producer-to-consumer channel, whereas **non-contract farming** relied on three distinct marketing channels, each introducing additional costs and complexities. The contract farming model, with fewer intermediaries, was found to be more cost-effective and stable for farmers, while non-contract farming presented more risks and inefficiencies due to the multiple stages of distribution.

Table: 3.4 Matrix Comparison Model for Contract vs Non-Contract Farming:

Sr. No.	**Factors**	**Contract Farming**	**Non-Contract Farming**
1	Number of Intermediaries	1–2 (Direct Buyer)	2–4 (Wholesaler, Retailer)
2	Supply Chain Complexity	Simple	Complex
3	Farmer's Market Risk	Low	High
4	Input Support (Seeds, Fertilizer etc.)	Provided by Contractor	Purchased Independently
5	Price Stability	High	Unstable
6	Marketing & Packaging Cost	Low	High
7	Profit Margin for Farmers	Stable	Variable
8	Vulnerability to Price Fluctuation	Low	High

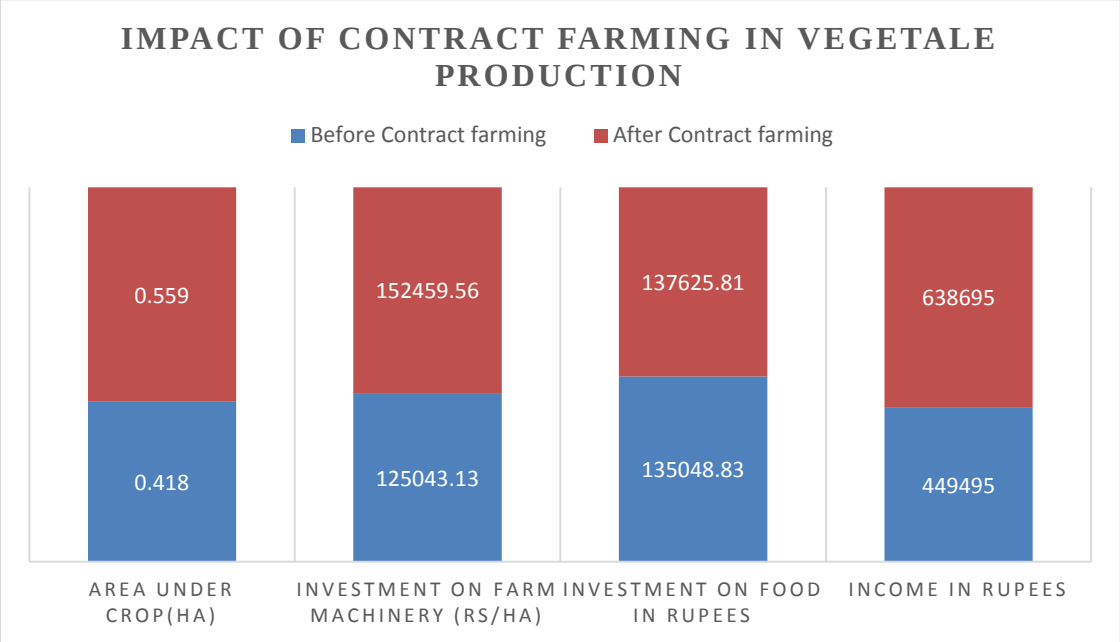
The comparison between contract farming and non-contract farming across several key factors highlights the efficiency and stability advantages of contract farming. In contract farming, the **number of intermediaries** is minimal—typically just 1 or 2—such as the producer and the contracting company. This streamlined setup contributes to a **simple supply chain**, which in turn reduces complexity and logistical hurdles. The **market risk faced by farmers** is also significantly lower in this model, primarily because they have a pre-arranged buyer, and input support like seeds and fertilizers is usually **provided by the contractor**. This not only lowers production costs but also ensures timely access to quality inputs. Due to these controlled conditions, **price stability** remains high, as farmers are often assured of a fixed price, shielding them from market volatility. Additionally, **marketing and packaging costs** are typically borne by the contractor, further reducing the financial burden on the farmer. These factors collectively ensure a **stable profit margin** and **low vulnerability to price fluctuations**, making contract farming a more secure and cost-effective model for many producers.

On the other hand, **non-contract farming** involves **2 to 4 intermediaries**, including wholesalers and retailers, which makes the **supply chain more complex**. Farmers operate independently and must procure all inputs on their own, often at higher costs. Without any contractual agreement, farmers are fully exposed to **market risks**, such as fluctuating demand and prices, leading to **unstable income**. This lack of guaranteed pricing also introduces **price instability**. Moreover, farmers must handle or pay for **marketing and packaging**, which adds to their operational expenses. As a result, the **profit margins are more variable**, and farmers in this model are **highly vulnerable to price fluctuations**, making it a riskier and often more expensive alternative.

The impact of contract farming on income level of farmers:

Table 3.5 Impact of Contract farming on Income of Vegetable Farmers:

Sr. No.	Crops	Before Contract farming	After Contract farming
1	Area under crop(ha)	0.418	0.559
2	Investment on Farm Machinery (Rs/ha)	125043.13	152459.56
3	Investment on food in Rupees	135048.83	137625.81
4	Income in Rupees	449495	638695



Vegetable cultivation area grew from 0.418 to 0.559 hectares. This shows an increase in vegetable farming, possibly due to increasing demand or profitability. The cost has increased from 125,043.13 to 152,459.56. This considerable growth could be attributed to investments in more advanced machinery or equipment, which can boost efficiency and output in vegetable cultivation.

There has been a significant increase in household income, showing that increased land area and machinery investment have likely contributed to higher productivity and profitability in vegetable growing. The growth of 189,200 (from 449,495 to 638,695) is noteworthy and suggests a return on investment. Farmers are devoting resources to develop or maintain their operations. The change is small, indicating that food investment methods would remain constant.

Table 3.6 Impact of contract farming of Fruits on Income of Farmer

Crops	**Before Contract farming**	**After Contract farming**
Area under crop(ha)	0.907	1.004
Investment on Farm Machinery (Rs/ha)	248211.57	278007.40
Investment on food in Rupees	96758.78	134641.06
Income in Rupees	2938608.3	3131408.3

The rise in investment from □ 96,758.79 to □134,641.06 is considerable. This shows a more aggressive approach to increasing fruit production, possibly due to increased demand or a shift in cultivation practices that necessitates more resources. Similarly, there is a significant increase in income from fruit growing, with a □192,800 increase (from □ 2,938,608.3 to □ 3,131,408.3), indicating that improvements in farming procedures and increased cultivated area have had a direct influence on financial returns.

Paired t-test of Impact of contract farming on farmer's income:

A **paired t-test** is conducted to assess whether there is a significant difference in farmers' income and associated variables (e.g., area under crop, machinery usage, investment on food, and family income) due to contract farming. A paired t-test compares two related samples — in this case, the "before" and "after" situations in the context of contract farming.

Table: 3.7 Paired t-test of Impact of contract farming on farmer's income:

Particulars	**t Stat**	**P(T<=t) one-tail**	**t Critical one-tail**	**P(T<=t) two-tail**	**t Critical two-tail**
Area under crop(ha)	-2.1464	0.01652	1.652547	0.033045	1.971957
Farm Machinery/ha	-24.2563	1.2E-61	1.652547	2.4E-61	1.971957
Investment on food Before	-13.1504	3.88E-29	1.652547	7.77E-29	1.971957

Family income/Income	-68.5925	9.7E-141	1.652547	1.9E-140	1.971957

The analysis of the impact of contract farming across multiple socio-economic indicators—specifically area under crop, farm machinery usage, food investment, and family income—reveals a consistent and statistically significant positive transformation. Using paired t-tests to compare "before" and "after" scenarios, the results show that the area under crop increased significantly from 0.6625 to 0.7815 hectares, while investment in farm machinery saw a highly significant surge from 186,627.35 to 215,233.48 units. Similarly, household welfare indicators improved markedly, with food-related investments rising from 95,064.86 to 136,133.44 and total family income showing a substantial growth from 1,694,051.65 to 1,885,051.65. In all cases, the observed t-statistics far exceeded their respective critical values, leading to a robust rejection of the null hypotheses and suggesting that contract farming systematically enhances agricultural scale, modernization, and overall financial flexibility for farmers through improved market access and resource support.

4. Conclusion

The research demonstrates that contract farming serves as a vital bridge between fragmented smallholder production and organized market demands. By integrating the supply chain, contract farming removes the complexities of multi-tiered traditional marketing—which often involve up to four intermediaries—replacing them with a streamlined, cost-effective direct model. **Input Optimization:** Contract farming significantly shifts the burden of input procurement. While traditional farmers struggle with high costs for packaging and limited technical guidance, contract farmers benefit from contractor-provided materials and expert technical know-how, as highlighted by the Principal Component Analysis. **Economic Transformation:** The adoption of contract agreements has led to a statistically validated "before and after" improvement in farmer welfare. The significant rise in family income and the expansion of cultivated land area suggest that guaranteed pricing and assured buy-back mechanisms provide the financial security necessary for farmers to scale their operations. **Modernization:** There is a clear correlation between contract farming and agricultural modernization. The substantial increase in investment in farm machinery indicates that the stability provided by contracts encourages farmers to reinvest in technology, enhancing long-term productivity. **Risk Mitigation:** By stabilizing prices and reducing vulnerability to market fluctuations, contract farming addresses the primary "bottleneck" of Indian agriculture: price instability.

In summary, contract farming offers a superior alternative to traditional open-market systems for high-value crops like fruits and vegetables. It not only increases the net income of the farming community but also creates a more resilient and modern agricultural ecosystem.

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