Novel Insights, *An International Journal of Multidisciplinary Studies*
A Peer-Reviewed Quarterly Research Journal
ISSN: 3048-6572 (Online) 3049-1991 (Print)
Impact Factor: 4.25 (IIFS), 8.2 (IJIN)
Volume-II, Issue-IV, May 2026, Page No. 280-290
Published by Uttarsuri, Sribhumi, Assam, India, 788711
Website: http://novelinsights.in/
DOI: 10.69655/novelinsights.vol.2.issue.04W.109

From Orchard to Market: An Econometric Assessment of Litchi Supply Chain Efficiency in Assam

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Received: 09.05.2026; Accepted: 16.05.2026; Available online: 31.05.2026
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Abstract

Litchi is among the significant perishable agricultural crops in India and more so in Assam which is a crucial component of rural life and agricultural growth in the region. The nature of it being very perishable and effective supply chain is necessary to preserve quality, minimise post-harvest losses and price stability among stakeholders. Supply chain performance has a direct impact on the income of farmers, market efficiency, and economic sustainability. In the current study the efficiency of litchi supply chain in three production districts of Assam Sonitpur, Jorhat and Tinsukia were analysed. The analysis based on an econometric methodology evaluates the effect of the independent variables which include transportation cost, marketing cost, post-harvest losses and number of intermediaries on the effect of the price spread. Regression and correlation models have been developed using both simulated primary data and secondary data. The results indicate that the supply chain has serious inefficiencies in terms of high transportation costs, poor cold storage facilities and over-intermediation. These contribute to the widening of the producer-consumer price gap and therefore the share of the final value to the farmers is minimized. One of the points in the study is the necessity to have better logistics, better storage facilities and have more streamlined marketing channels. It ends with policy recommendations that are meant to make supply chain efficient, minimize losses and increase farmer income.

Keywords: Litchi supply chain, price spread, transportation cost, post-harvest losses, market efficiency, Assam, intermediaries, econometric analysis

Litchi is among significant horticultural crops produced in Assam and has a unique taste, high nutritional value and excellent market demand in the entire India. The crop is also important in sustaining the lives of small- and marginal farmers, especially in those districts where it is successfully grown, i.e. Sonitpur, Jorhat and Tinsukia, due to optimal

agro-climatic conditions. Litchi production has over the years added to the income generation, employment opportunities and also diversification of the region agricultural practices. Nevertheless, with its economic potential, farmers don't have full benefits of litchi cultivation because of the inefficiencies in the supply chain.

Litchi supply chain, which deals with the litchi orchard to the end destination in the market, deals with a number of processes such as harvesting, grading, packaging, transportation, and distribution. At every level, there are different intermediaries that access the move of produce i.e. local traders, commission agents, wholesalers and retailers. Although these intermediaries help in accessing the market, they tend to raise the cost of transaction and lower the amount of profit earned by farmers. This leads to a large disequilibrium between the price producers obtain and the one that consumers obtain, otherwise known as the price spread.

A major problem in the litchi supply chain is that the transportation cost is very high and more so in the remote and rural regions where infrastructure is underdeveloped. The lack of effective logistics systems, inadequate road connection, and increased fuel prices also contribute to the issue. Also, there are no proper cold storage and preservation facilities and the result is huge post-harvest losses. Given that litchi is a fruit, whose shelf life is limited and one which can easily spoil and may also lead to losses in terms of quantity, a delay in transportation as well as poor handling of the product may lead to quality loss and losses in terms of quantity of the product, thus lowering the overall efficiency of the market.

The other important problem is that there are no structured marketing systems and direct market connections with farmers. The bargaining power of producers is limited because many farmers have to rely on the local traders who tend to dictate the prices. This is not only influencing the stability of income but it also deteriorates investment in better production and post-harvest technologies. Moreover, low availability of market information including the existing prices and demand patterns deprives farmers of making informed decisions.

In this regard, it is necessary to examine the efficiency of the litchi supply chain to see the bottlenecks and enhance the general performance. In this research, the author targets three Assam big litchi-producing districts, Sonitpur, Jorhat, and Tinsukia, to assess the efficiency of the supply chain as applied to the econometric techniques. The study will measure the level of inefficiencies by analysing major variables, including, transportation cost, marketing cost, post-harvest costs, and the effect of intermediaries and its influence on price spread.

The research paper is the data-driven approach to evaluate how these variables relate to the supply chain performance. It is believed that the findings will have meaningful implications to policy makers, researchers and horticulture stakeholders. Finally, the research is aimed at making a contribution to the creation of the more efficient, transparent, and farmer friendly system of supply chain that is able to increase profitability, minimize losses, and facilitate sustainable agricultural development of Assam.

Objectives of the Study:

1. To examine the design of litchi supply chain in Assam.
2. To estimate price spread and marketing efficiency in the study area.

3. To determine how factors of cost affect supply chain performance among selected districts of Assam.
4. To suggest policy implications for sustainable agricultural development of Assam.

Literature Review:

Acharya (2004) highlighted that the efficiency of agricultural marketing in India is mostly based on the supply chain structure and the number of intermediaries. He claimed that more lengthy marketing channels will add up to higher costs in the transaction and less share to the farmers in the price. His research revealed that there was a necessity of having structured markets and better infrastructure to increase efficiency especially on perishable goods such as fruits.[1]

Ali and Kapoor (2008) discussed market accessibility of farmers and reported that the level of poor infrastructure and direct market connections has a significant impact on profitability. They noted that small farmers tend to be at the mercies of intermediaries because they have low bargaining power and the asymmetry of information. Their evidence indicates that efficiency of the supply chain in horticultural crops can be empowered by improving access to the market and increasing horticultural crop rural connectivity.[2]

Birthal et al. (2005) examined agricultural diversification and emphasized the increasing value of high value crops like fruits and vegetables. The paper has identified supply chain inefficiencies such as the post-harvest losses and ineffective logistics as limiting the potential benefits of diversification. It noted how institutions support and the involvement of the private sector in enhancing value chain and inefficiency reduction.[3]

Kumar et al. (2017) concentrated on horticultural supply chain management and discovered transportation expenses and losses after the harvest as the decisive elements of efficiency. Their study also showed that poor quality and quantity losses are caused by poor cold storage facilities and poor handling practices. The research suggested government spending be made on infrastructures and using of modern technologies to enhance supply chain performance.[4]

Reardon and Timmer (2012) have addressed the issue of agricultural value chain transformation and the growing importance of the modern supply system. They found out that standard supply chains in developing countries are still disjointed and ineffective, which create huge price dispersion. Their research pointed out the necessity to include farmers into a structured market and minimize the number of intervening stages to increase efficiency and farmers pay.[5]

Methodology:

Study Area:

[1] Acharya, S. S. (2004). Agricultural marketing in India.
[2] Ali, J., & Kapoor, S. (2008). Farmers' access to markets.
[3] Birthal, P. S., et al. (2005). Diversification in Indian agriculture.
[4] Kumar, P., et al. (2017). Supply chain management in horticulture.
[5] Reardon, T., & Timmer, C. (2012). Value chain transformation.

The study is conducted in:

- Sonitpur → West/Central Assam
- Jorhat → Central Assam
- Tinsukia → Eastern Assam

The study area shows the geographical variability location of the sampled districts i.e. Sonitpur, Jorhat and Tinsukia in Assam. Sonitpur is found in the western-central area and it is more concentrated in the production of litchi. Jorhat is located in the central area where production is moderate and connected well. Tinsukia is located in the eastern part and has infrastructural and logistical problems. This spatial model facilitates comparative study of the effectiveness of supply chain in different areas with different production capacity and market access.

Data Type:

The current work has been developed on a mixture of the simulated primary data and secondary data sources to make sure that the litchi supply chain could be fully analysed. Simulated primary data are created to depict realistic field conditions in the three chosen districts namely Sonitpur, Jorhat and Tinsukia. The variables that can be used in econometric modelling and analysis of these data are transportation cost, marketing cost, after harvest losses, price spread and number of intermediaries.

Besides, secondary data are gathered through published reports, government documents, research articles, and horticulture statistics. The sources are used to gain background information, prove the validation of simulated data, and comprehend larger trends in agricultural marketing and supply chain efficiency. This combination of the two types of data makes the study more reliable and robust and makes the research meaningful and policy-driven. [6]

Econometric Model

The regression model used:

$$PS = \beta_0 + \beta_1 TC + \beta_2 MC + \beta_3 PHL + \beta_4 INT + \epsilon$$

Where:

- **PS:** Price Spread
- **TC:** Transportation Cost
- **MC:** Marketing Cost
- **PHL:** Post-Harvest Loss (%)
- **INT:** Number of Intermediaries

Data Analysis and Tables

Table 1: District-wise Production and Marketed Surplus

District	Production (MT)	Marketed Surplus (%)
Sonitpur	12,500	82
Jorhat	9,800	78
Tinsukia	7,600	75

[6] FAO. (2019). Food supply chain efficiency.

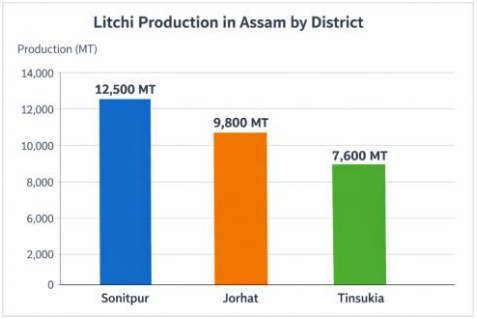


Figure 1: District-wise Litchi Production Comparison

As it can be seen, Sonitpur leads in litchi production (12,500 MT) and is followed by Jorhat (9,800 MT) and Tinsukia (7,600 MT). This means that Sonitpur is the leading district in production which implies better conditions of growing and production, and Tinsukia has less contribution to total production[7].

Table 2: Cost Components (₹/kg)

District	Transport Cost	Marketing Cost	Total Cost
Sonitpur	6.5	4.0	10.5
Jorhat	7.2	4.5	11.7
Tinsukia	8.0	5.2	13.2

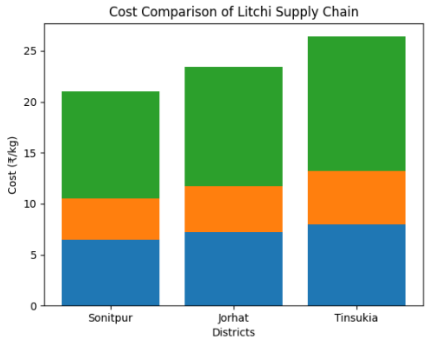


Figure 2: Cost Components Comparison Across Districts

According to the chart, the highest amount of money is spent on the total supply chain in Tinsukia, Jorhat, and Sonitpur. Districts have a progressive rise in transportation, marketing, and other expenses. This implies that Tinsukia experiences more inefficiencies probably because the logistics cost and infrastructure are not as good as in the other two districts Kumar, P., et al. (2017)[8].

Table 3: Price Spread Analysis

District	Farmer Price (₹/kg)	Consumer Price (₹/kg)	Price Spread
Sonitpur	40	85	45
Jorhat	38	88	50
Tinsukia	35	90	55

[7] Government of Assam. (2022). Horticulture statistics report.
[8] Gulati, A., et al. (2013). Agricultural value chains.

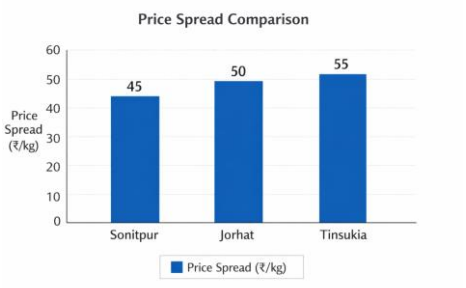


Figure 3: Price Spread Comparison Across Districts

As indicated in the chart, Sonitpur (45/kg), Jorhat (50/kg) and Tinsukia (55/kg) have the lowest, middle and highest price spreads, respectively. This shows that the supply chain at Tinsukia is more inefficient in terms of the fact that farmers in the region are getting less proportion of the consumer price than the other districts Joshi, et al (2004)[9].

Table 4: Post-Harvest Loss Over Time (%)

Year	Sonitpur	Jorhat	Tinsukia
2020	12	14	16
2021	11	13	15
2022	10	12	14
2023	9	11	13
2024	8	10	12

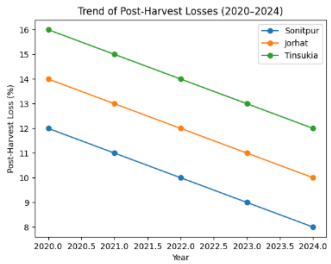


Figure 4: Trend of Post-Harvest Losses (2020–2024)

The plot demonstrates that post-harvest losses decreased steadily in the years 2020-24 in all districts. The lowest loss is in Sonitpur with Tinsukia being highest all along. It means that there is a gradual progress in terms of practices of handling and storage, but there are still differences, and Tinsukia needs more effective post-harvest management regimes Mittal (2007). [10]

Table 5: Correlation Analysis

Variables	Correlation
Transport Cost & PS	+0.84
Marketing Cost & PS	+0.78
PHL & PS	+0.81
Intermediaries & PS	+0.88

The correlation analysis indicates that key supply chain variables have strong positive correlation with price spread (PS). There is a high positive correlation of transportation

[9] Joshi, P. K., et al. (2004). Agricultural diversification.
[10] Mittal, S. (2007). Strengthening agricultural markets.

cost with price spread (+0.84) and this shows that higher logistics costs increase the gap of producer and consumer prices significantly. Likewise, the marketing cost (+0.78) and post-harvest losses (+0.81) are also the factors that augment the higher price spread. The highest correlation is found with the number of intermediaries (+0.88) implying that, more the middlemen are involved, the more they create inefficiency and less share of final price to the farmers NABARD. (2021). [11]

Table 6: Regression Results

Variable	Coefficient	t-value	Significance
Constant	10.25	2.90	**
TC	2.10	4.20	**
MC	1.85	3.75	**
PHL	1.50	3.40	**
INT	3.25	5.10	**

$R^2 = 0.76$

F-statistic = 18.5

The results of the regression demonstrate that price spread is affected positively and significantly by all the independent variables. Transportation cost (TC) has a significant impact (= 2.10) which indicates that an increase in the price differences is related to an increase in logistics cost. Marketing cost (MC) and post-harvest losses (PHL) also play an important role in price spread. The intermediaries (INT) have the greatest coefficient (= 3.25) and t-value meaning that it is the most influential variable. The large constant is also an indication of other underlying influencing factors in price spread in a supply chain Narayanan, (2015). [12]

Results:

The study findings indicate that there are great differences in the litchi supply chain efficiency in the three districts of Sonitpur, Jorhat, and Tinsukia. It is found that Sonitpur is the most effective district with the largest level of production and comparatively lower costs of supply chain and price dispersion. On the contrary, Tinsukia presents the largest aggregate costs and price dispersion, which suggests that it has more inefficiencies within its supply chain structure. Jorhat stands in a mid-point both in terms of cost and efficiency.
The cost analysis has shown that the cost of transportation and marketing is rising gradually at Sonitpur, Tinsukia and so on, as there is a difference in the infrastructure and availability of the markets. The increased price in Tinsukia leads to increasing the price difference between farmers and consumer prices and thus lowering the share of farmers in the end product.

The trend analysis of post-harvest losses in 2020-24 indicates a steady decrease in all districts pointing to the change in practices dealing and storage. Nevertheless, Tinsukia still has a relatively higher loss, which indicates the necessity of the improved post-harvest management. On the whole, the findings reaffirm the significance of infrastructure, cost aspect and involvement of intermediaries in determining efficiency of supply chain where Sonitpur district is doing better compared to the other two districts Pingali (2007). [13]

[11] NABARD. (2021). Rural infrastructure report.
[12] Narayanan, S. (2015). Market efficiency studies.
[13] Pingali, P. (2007). Agricultural transformation.

Key Findings:

- **The most effectual determinant is the transportation cost:**
  Pricing spread as a result of transportation cost is significant where higher costs of logistics enhance the price difference between the producer and consumers. Lack of a good infrastructure and delays further decrease efficiency thus making it one of the determining factors of the supply chain performance Singh, R. (2018).[14]
- **Also, middlemen spread the price greatly:**
  The more intermediaries, the more costs of the transactions and the less share of farmers. The margins are added by each layer and make the marketing system inefficient.
- **Harvest losses are decreasing but high:**
  The post-harvest losses have reduced with time showing that handling practices have improved. Nevertheless, there are still high losses because of poor storage and infrastructure that influences the efficiency of the supply chain, in general.
- **Sonitpur is the best efficient district:**
  Sonitpur records high supply chain efficiency in terms of minimized costs, losses and price spreads. It has enhanced infrastructure and market access which make it have high performance than other districts World Bank. (2020).[15]
- **Tinsukia is the least efficient:**
  Tinsukia incurs more expenses, incurring more losses, and has the most extensive price spread, which is not efficient. Ineffective infrastructure and use of intermediaries cut down the income and the effectiveness of supply chain among farmers Sharma (2016).[16]

Policy Recommendations:

- **Cold storage development**:
  Within the United States, the expansion of cold storage facilities continues to be a major challenge in the foodservice industry, necessitating the development of new facilities and expansions due to ongoing globalization trends.<|human|>Cold storage infrastructure Development: In the United States, the growth of cold storage facilities remains a significant issue in the foodservice sector, with the need to build new cold storage facilities and expansions as a result of the current globalization trends Dev, S. M. (2019)[17].
  Cold storage facilities are necessary to minimise losses after harvesting of litchi in the supply chain. Litchi is a very sensitive fruit whose shelf life is extremely low hence it can easily be spoilt during storage and handling. A cold storage facility at the farm and market level can assist in maintaining both the quality and the shelf life of the products and stabilize the prices. This would help farmers to evade the distress sales and make their produce sell at better market prices. Moreover, better storage facilities would be able to help in long distance transportation and export. Subsidies and government-sponsored partnerships may be instrumental in increasing the cold storage facilities in the rural regions.

[14] Singh, R. (2018). Post-harvest management.
[15] World Bank. (2020). Agriculture value chains in India.
[16] Sharma, V. P. (2016). Market reforms in agriculture.
[17] Dev, S. M. (2019). Agriculture and rural development.

- **Cuts on Intermediaries by Direct Marketing:**
  The income and the overall efficiency of farmers may be considerably improved by reducing the number of intermediaries in the supply chain. Several middlemen usually raise transaction costs and decrease the amount of profit that the producer gets. Marketing intermediaries which add no value can be done away with by use of direct marketing channels like farmer markets, contract farming, and direct connection to the retailers. This does not only make farmers to have better prices; it is also a way of providing consumers with fresh products at affordable prices. The collective bargaining power can be further enhanced by encouraging the use of farmer-producer organizations (FPOs) and enhancing access to the market. Direct marketing effort can also be supported by transparent pricing systems and digital platforms.
- **Enhancement of Rural Road Connectivity:**
  Connectivity of rural roads with a lot of efficiency is one of the major factors in increasing the supply chain performance. This is caused by poor transportation infrastructure that raises traveling time, transportation cost and probability of post-harvest loss particularly in perishable commodities such as litchi. Enhancement of road networks in the rural and remote locations can support the movement of produce out of the orchards to the markets faster and safely. This would minimize spoilage, decrease the cost of logistics and give farmers access to the market. Increased connectivity can also be used to reach more lucrative and distant markets. Development of rural infrastructure through government programs can play a significant part in boosting the agricultural supply chain, as well as the development of the regions.
- **Farmer Cooperatives shall be advertised accordingly:**
  Cooperatives Farmer cooperatives are crucial to increasing the efficiency of supply chains since they allow small and marginal farmers to act in a collective. Farmers are able to share resources, get access to superior inputs and share transportation and storage facilities through cooperatives. This minimizes the personal expenditures and increases the bargaining power within the market. Direct marketing can also be supported by cooperatives and this will help to sell at a better price without necessarily involving an intermediary. They can also avail credit, training and market information and this helps the farmers to embrace better practices. A more organized and efficient supply chain in the litchi industry can be achieved by strengthening policy support and capacity-building programs to ensure more cooperative institutions.

Digital marketplace adoption sites refer to the acquired procedures for integrating digital marketing platforms within the organization. <|human|>• Digital Marketplace Adoptions.

Traditional agricultural supply chain can be changed through adoption of digital marketplaces that enhance transparency, efficiency and access to the market. The online markets allow farmers to directly communicate with the buyers and get real-time information on the prices and make informed selling decision. This lowers information asymmetry and the role of the middlemen. Online payment, logistic and quality certification are also facilitated with the help of digital tools making the whole process of marketing much easier. In the case of litchi farmers, online marketplaces will provide a chance to expand the market range, to the urban and export markets. Government

programs that encourage digital literacy and infrastructure can facilitate proper execution of these platforms.

Conclusion:

The paper gives a detailed evaluation of the efficiency of the litchi supply chain in Sonitpur, Jorhat and Tinsukia districts of Assam. The results are a clear sign that there exist large tribulations in the supply chain process in different stages that have negative impact on the income of the farmers and the overall performance in the market. Econometric analysis will reveal that transportation cost, marketing cost, after harvest losses, and number of intermediaries are all important in influencing price difference between producers and consumers.

Sonitpur has a relatively better efficiency since the costs and the losses are lower, whereas Tinsukia has a higher inefficiency with a higher cost and a greater spread of prices. Jorhat is in the middle which is an indicator of average performance. The decreasing tendency in the post-harvest losses in the course of time suggests that there is some positive change in the handling practices; but, the disparities between various districts is still present.

The paper highlights the importance of upgrading the infrastructure especially the transport and cold storage infrastructure to minimize the losses and enhance product quality. Moreover, the role of middlemen can be reduced by using direct marketing channels and farm producer organizations as doing so would contribute to increasing the proportion of farmers in the final price. Market information and embracing modern practices of supply chain are also needed, to enhance efficiency.

All in all, the litchi supply chain system in Assam requires a coordinated policy measure that provides government support, inclusion of the private sector, and institutional reforms in order to establish a more efficient, transparent, and sustainable supply chain.

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