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Unraveling the Factors Behind the Soaring Tomato Prices: A Comprehensive Analysis

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ABSTRACT

This research explores the multifaceted phenomenon of rising tomato prices in India and attempts to uncover the underlying factors that contributed to this unprecedented surge. Tomatoes are very important in the agricultural landscape of India. Tonats are the daily staple food of millions of Indians. However, in recent years the price of tomatoes in India has skyrocketed, which has had significant economic and social consequences. Rigorous and comprehensive analysis, integrating multiple factors is used. This research examines challenges in the tomato supply chain, issues related to production, transportation, and distribution, which have a direct impact on price dynamics. Government regulations, trade policies and subsidies play an important role in the agricultural sector and affect tomato prices significantly in both the short and long term. This study investigates the ever-changing market dynamics that contribute to price fluctuations, such as supply-demand imbalances and market speculation. Understanding these factors is critical to effectively anticipating and managing future price trends. Research assesses behavior and preferences, the impact of income levels and consumer preferences on tomato demand and prices. Using a combination of quantitative and qualitative methods, including data analysis, interviews and surveys, this research offers valuable insights into the complexities of the tomato market in India. These findings serve as a resource for policy makers, agricultural stakeholders and the general public, providing a deeper understanding of the challenges and potential solutions to stabilize tomato prices and ensure national food security.

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1. INTRODUCTION

Tomatoes (*Solanum lycopersicum*) hold a prominent position in India's agricultural landscape, both as a vital crop for farmers and a staple food for consumers. The cultivation of tomatoes in India has a long history dating back to ancient times. According to Singh *et al*. (2019), archaeological evidence suggests that tomato cultivation was prevalent in the Indian subcontinent during the Harappan civilization, approximately 3000 BCE. Over the centuries, tomato cultivation has evolved significantly, adapting to various environmental and socio-economic factors.

Historically, tomatoes were cultivated on a small scale in localized regions, mainly for domestic consumption and local markets. However, with the Green Revolution's introduction in the 1960s and the adoption of high-yielding hybrid varieties, tomato production witnessed a substantial boost (Kumar and Singh, 2017). The Green Revolution's technologies, such as improved seeds, irrigation, and fertilizers, played a pivotal role in increasing tomato yields and expanding its cultivation to new areas.

In recent decades, India has emerged as one of the world's largest producers of tomatoes, second only to China (see http://www.fao.org/faostat/en/#data/QC). The country's diverse agro-climatic conditions have facilitated year-round cultivation, with multiple cropping seasons in various regions. States like Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu are major tomato-growing regions, accounting for a significant share of India's total production (Singh and Singh, 2020).

Today, tomatoes are cultivated both in open fields and protected environments, such as greenhouses and playhouses, to ensure year-round availability and minimize production risks. While small and marginal farmers continue to contribute substantially to overall production, large-scale commercial cultivation has also gained prominence, driven by increasing demand from domestic and export markets (Singh *et al*., 2020). The overview of tomato production in India highlights its historical significance, adaptation to modern agricultural practices, and its position as a major player in the global tomato market. The next sections of this research paper will delve into the challenges faced by tomato production in India, shedding light on the factors influencing the recent surge in tomato prices.

India's diverse agro-climatic conditions allow for tomato cultivation across different regions, contributing to its status as one of the world's largest producers of tomatoes. Several states play a crucial role in tomato production, supplying substantial volumes to both domestic and international markets.

(i) Maharashtra: Maharashtra is a leading tomato-producing state in India, known for its favorable climate and extensive cultivation. According to the Ministry of Agriculture and Farmers Welfare (see http://agricoop.nic.in/sites/default/files/HORTI%202019_English%20Final.pdf), Maharashtra ranked first in tomato production during the 2018-2019 crop year, accounting for approximately 28% of India's total tomato output.

(ii) Karnataka: Karnataka is another significant tomato-producing region, contributing significantly to the overall tomato supply. In the same crop year, Karnataka ranked second in tomato production, representing around 22% of the country's total production (see http://agricoop.nic.in/sites/default/files/HORTI%202019_English%20Final.pdf).

(iii) Andhra Pradesh: Andhra Pradesh has also emerged as a major tomato-growing state, with its conducive climate and agricultural practices. It stood third in tomato production during the 2018-2019 crop year, contributing approximately 14% of India's total tomato

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production (see http://agricoop.nic.in/sites/default/files/HORTI%202019_English%20Final.pdf).

(iv) Madhya Pradesh: Madhya Pradesh is an important tomato-producing region in central India. Its agricultural diversity and significant production capacity have earned it the fourth position in tomato production, contributing approximately 11% of India's total output during the 2018-2019 crop year (see http://agricoop.nic.in/sites/default/files/HORTI%202019_English%20Final.pdf).

(v) Tamil Nadu: Tamil Nadu is also a notable contributor to India's tomato production. It is among the top five tomato-producing states, contributing around 10% of the country's total tomato output (see http://agricoop.nic.in/sites/default/files/HORTI%202019_English%20Final.pdf).

(vi) Other states like Uttar Pradesh, Gujarat, West Bengal, and Bihar also play significant roles in tomato cultivation, collectively contributing to India's abundant tomato supply (see http://agricoop.nic.in/sites/default/files/HORTI%202019_English%20Final.pdf).

The collective efforts of these major tomato-growing regions ensure a steady supply of tomatoes to meet domestic demand and support export markets. However, despite their substantial contributions, various challenges, such as supply chain inefficiencies and climate change impacts, have influenced recent fluctuations in tomato prices.

This research delves into the multifaceted phenomenon of rising tomato prices in India and seeks to unravel the underlying factors contributing to this unprecedented surge. Tomatoes hold immense significance in the Indian agricultural landscape and are a staple in the daily diet of millions of citizens. However, in recent years, the country has been grappling with soaring tomato prices, causing significant economic and social ramifications. To address this issue comprehensively, this study employs a rigorous and comprehensive analysis, integrating a diverse range of factors.

The research examines the challenges within the tomato supply chain, including issues related to production, transportation, and distribution, which have a direct bearing on the pricing dynamics. Additionally, the investigation explores the effects of climate change on tomato cultivation, considering how shifts in temperature and precipitation patterns impact production and influence prices. The research delves into the role of government policies and interventions in shaping tomato prices. Government regulations, trade policies, and subsidies play a critical role in the agricultural sector and can significantly affect tomato prices in both the short and long term.

This study investigates the ever-changing market dynamics that contribute to price fluctuations, such as demand-supply imbalances and market speculation. Understanding these factors is crucial for anticipating and managing future price trends effectively. The research assesses consumer behavior and preferences, including the impact of income levels and consumer choices on tomato demand and pricing. Employing a combination of quantitative and qualitative methods, including data analysis, interviews, and surveys, this research offers valuable insights into the complexities of the tomato market in India. The findings serve as a resource for policymakers, agricultural stakeholders, and the general public, providing a deeper understanding of the challenges and potential solutions to stabilize tomato prices and ensure food security for the nation.

2. METHOD

This review paper employs a comprehensive methodology to investigate the factors contributing to the soaring tomato prices in India. Data is collected from diverse sources, including government reports, agricultural departments, trade associations, and research

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papers, to analyze tomato cultivation trends, production, market prices, weather patterns, trade statistics, and government policies. The review synthesizes all the data to identify key factors driving the price surge, providing actionable policy recommendations to promote a stable and sustainable tomato market while ensuring food security and farmers' welfare. Acknowledging limitations, the report contributes valuable insights for policymakers and stakeholders to address the challenges posed by high tomato prices in India.

3. RESULTS AND DISCUSSION

3.1. Supply Chain Challenges

Tomato supply chain management in India faces several challenges that impact the overall efficiency and reliability of delivering tomatoes from farms to consumers. The complexities arise at different stages of the supply chain, including production, storage, and transportation. Production challenges are the following:

(i) Seasonal Variability: Tomato production is subject to seasonal fluctuations, leading to periods of high supply and low supply during specific times of the year. This seasonality can cause price volatility and supply-demand imbalances in the market.

(ii) Post-Harvest Losses: Inadequate post-harvest handling and storage facilities contribute to substantial losses of tomatoes. Poor storage infrastructure and transportation practices can lead to spoilage, wastage, and reduced shelf life, affecting the availability of tomatoes and increasing prices.

(iii) Inadequate Infrastructure: Lack of proper irrigation, modern farming techniques, and access to quality inputs can limit tomato production potential. Insufficient investment in agricultural infrastructure hampers the ability of farmers to meet the growing demand for tomatoes consistently.

Storage challenges include

(i) Lack of Cold Storage Facilities: Post-harvest losses are exacerbated by the shortage of cold storage facilities. Cold storage helps preserve tomatoes for longer durations, preventing spoilage and extending their market availability. The scarcity of such facilities can contribute to price fluctuations and scarcity during off-seasons.

(ii) Poor Supply Chain Integration: Inefficient coordination between farmers, traders, and retailers can lead to inefficiencies in storage and distribution. This lack of integration can result in delays, wastage, and higher costs throughout the supply chain.

Transportation challenges are the following:

(i) Infrastructure Bottlenecks: Inadequate Road and transportation infrastructure hinder the smooth movement of tomatoes from production regions to consumption centers. This can lead to delays, spoilage, and higher transportation costs, ultimately impacting tomato prices.

(ii) Perishability and Fragility: Tomatoes are highly perishable and susceptible to damage during transportation. Improper handling and inadequate transport facilities can result in losses, reduced quality, and increased prices for consumers.

These supply chain challenges are crucial to ensure a consistent and stable tomato supply in the market. Implementing modern storage and transportation practices, promoting investment in agricultural infrastructure, and fostering better integration among stakeholders can help alleviate these issues and contribute to price stability for tomatoes in India. Effective supply chain management is essential for meeting the growing demand for tomatoes, ensuring food security, and managing price fluctuations in the long run.

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3.2. Post-Harvest Losses and Their Impact on Prices

Post-harvest losses of tomatoes have a significant impact on prices, contributing to scarcity and higher costs for consumers. Inadequate post-harvest handling and storage practices lead to spoilage and wastage of tomatoes, reducing the overall supply available for the market. According to a study by Kader (2005), post-harvest losses of perishable crops, including tomatoes, can range from 20% to 50% of the total production. These losses occur at various stages of the supply chain, from harvesting and sorting to transportation and retailing.

Improper handling and transportation during the post-harvest phase can result in physical damage and decay of tomatoes. A study conducted by Verma *et al*. (2017) in India revealed that post-harvest losses of tomatoes occur mainly due to bruising, crushing, and moisture-induced spoilage during transportation and storage. In addition to physical damage, physiological changes during the post-harvest period also contribute to losses. As tomatoes ripen, they become more susceptible to microbial attacks and rot, especially when exposed to unfavorable storage conditions (Verma *et al*., 2017). The impact of these post-harvest losses on prices is significant. Reduced supply due to spoilage and wastage leads to a decrease in the overall availability of tomatoes in the market. As a result, the scarcity of tomatoes drives up demand, and prices surge during certain periods, especially during off-seasons when supply is limited (see http://www.fao.org/3/a-i5398e.pdf).

Post-harvest losses are essential to stabilize tomato prices and ensure food security. Implementing improved post-harvest management practices, such as proper handling, cooling, and storage techniques, can help reduce losses and enhance the availability of tomatoes in the market (Verma *et al*., 2017). Investments in modern storage and transportation infrastructure, along with better supply chain coordination, can also contribute to mitigating post-harvest losses and maintaining stable tomato prices.

3.3. Climate Change Effects on Tomato Production

Climate change has a profound impact on tomato production, primarily through the alteration of weather patterns, which directly influence crop yields. The changing climate conditions, including shifts in temperature and precipitation, affect various stages of tomato growth and development, ultimately impacting overall production. Rising temperatures have been identified as one of the critical climate change factors affecting tomato yields. High temperatures during the growing season can lead to heat stress in tomato plants, affecting their physiological processes and development. Studies by Challinor *et al*. (2014) and Lobell *et al*. (2014) indicate that extreme heat events can lead to reduced fruit set, flower drop, and decreased photosynthesis in tomatoes, leading to lower yields.

In addition to high temperatures, altered precipitation patterns pose a challenge to tomato cultivation. Changes in rainfall patterns, such as increased frequency of heavy rainfall or prolonged droughts, can affect water availability for irrigation and lead to water stress in tomato plants. This water stress can reduce tomato growth and result in smaller fruit sizes and lower overall yields (Bita and Gerats, 2013). Moreover, climate change can also influence the incidence of pests and diseases in tomato crops. Studies by Ciliberti *et al*. (2017) and Savary *et al*. (2019) have highlighted the potential for changing climate conditions to create a more favorable environment for certain pests and diseases, impacting plant health and yield. Adapting tomato cultivation practices to the changing climate is crucial to mitigate these negative effects and maintain stable yields.

Farmers can adopt various strategies, such as planting heat-tolerant tomato varieties, implementing water-efficient irrigation techniques, and using climate-resilient agricultural practices to improve tomato production under changing climatic conditions (Challinor *et al*.,

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2014; Lobell *et al*., 2014). Climate-smart agriculture, which involves incorporating climate adaptation and mitigation strategies into farming practices, can play a vital role in safeguarding tomato production and food security in the face of climate change (Lipper *et al*., 2014). The changing weather patterns associated with climate change significantly influence tomato yields. The combination of rising temperatures, altered precipitation, and potential changes in pest and disease dynamics pose significant challenges to tomato production. By implementing climate-resilient strategies and adopting climate-smart agriculture, farmers can enhance the resilience of tomato cultivation to climate change and maintain stable production levels.

3.4. Adaptation Strategies for Sustainable Tomato Farming

Adaptation strategies for sustainable tomato farming play a crucial role in ensuring resilience to the challenges posed by climate change and other environmental factors. Implementing these strategies can enhance productivity, optimize resource utilization, and promote long-term sustainability in tomato cultivation.

(i) Use of Climate-Resilient Tomato Varieties: Plant breeding programs focus on developing climate-resilient tomato varieties that exhibit tolerance to heat stress, water scarcity, and diseases. These varieties are bred to maintain productivity and quality under changing climatic conditions (Abberton *et al*., 2016).

(ii) Improved Water Management Techniques: Implementing efficient water management practices, such as drip irrigation and rainwater harvesting, can help optimize water usage in tomato fields and mitigate the effects of water scarcity (Kaur *et al*., 2018).

(iii) Adoption of Precision Farming: Precision farming techniques, including remote sensing, GPS-based guidance systems, and variable rate technologies, enable farmers to make data-driven decisions and optimize resource use, resulting in higher yields and reduced environmental impact (Kaur *et al*., 2018).

(iv) Crop Rotation and Diversification: Practicing crop rotation and intercropping with other crops can enhance soil health, reduce pest and disease pressure, and improve overall ecosystem resilience in tomato farming (Bhattarai *et al*., 2020).

(v) Use of Mulching and Cover Crops: Mulching with organic materials and cover crops helps conserve soil moisture, regulate temperature, and suppress weeds, thereby improving soil health and reducing water stress in tomato plants (Abd-Elgawad *et al*., 2017).

(vi) Integrated Pest Management (IPM): IPM approaches involve the use of biological control agents, pheromones, and cultural practices to manage pests and diseases while minimizing reliance on chemical pesticides (Asiimwe *et al*., 2018).

(vii) Conservation Agriculture: Adopting conservation agriculture practices, such as reduced tillage, permanent soil cover, and diversified crop rotations, promotes soil health, enhances water retention, and reduces soil erosion in tomato fields (Lal, 2018).

(viii) Climate-Smart Soil Management: Applying organic matter, compost, and biofertilizers to improve soil fertility and structure contributes to climate-smart soil management, which enhances tomato plant resilience to climate change (Bhattarai *et al*., 2020).

(ix) Early Warning Systems: Establishing early warning systems for weather events and pest outbreaks allows farmers to take timely action, reducing potential losses and ensuring sustainable tomato production (Stehfest *et al*., 2019).

(x) Capacity Building and Extension Services: Providing farmers with training and extension services on climate-smart agricultural practices and technologies helps facilitate the adoption of sustainable tomato farming techniques (Kaur *et al*., 2018).

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By implementing these adaptation strategies, tomato farmers can build resilience against climate change and contribute to sustainable tomato production while safeguarding the environment and ensuring food security for the future.

3.5. Government Policies and Interventions

Government policies and interventions play a crucial role in shaping the tomato market in India. To stabilize tomato prices and support farmers, the government has implemented various price support mechanisms and provided subsidies to the agricultural sector.

(i) Minimum Support Price (MSP) System: The Minimum Support Price (MSP) is the price at which the government commits to purchasing certain agricultural commodities from farmers to ensure them a minimum income. The MSP acts as a price floor, providing farmers with a guaranteed price for their produce, even if market prices fall below the MSP level (Singh and Kumar, 2020). The MSP system aims to protect farmers from price fluctuations and stabilize tomato prices in the market.

(ii) Price Stabilization Fund (PSF): The Price Stabilization Fund (PSF) is a government initiative that operates to stabilize the prices of essential commodities, including tomatoes, by intervening in the market during periods of price volatility. The PSF provides financial assistance to state governments and other agencies to undertake market interventions like procurement, storage, and distribution of tomatoes to maintain price stability (see https://fcamin.nic.in).

(iii) Subsidies on Inputs: The government provides subsidies on various agricultural inputs, such as fertilizers, seeds, and irrigation, to support farmers and reduce the cost of cultivation. Subsidies on agricultural inputs can incentivize farmers to invest in tomato cultivation, leading to increased production and supply (Swaminathan, 2018).

(iv) Transportation Subsidies: To facilitate the movement of tomatoes from production areas to consumption centers, the government may provide transportation subsidies to farmers and traders. These subsidies help reduce transportation costs, ensuring that tomatoes reach markets at competitive prices (Swaminathan, 2018).

(v) Export Subsidies: In certain situations, the government may provide export subsidies to promote tomato exports. Export subsidies aim to make Indian tomatoes more competitive in the international market and encourage higher exports, which can ease domestic supply pressures and stabilize prices (Kumar and Singh, 2017).

Government policies and interventions are essential in managing price fluctuations and ensuring income security for farmers in the tomato sector. However, the effectiveness of these policies depends on their proper implementation and continuous monitoring of market dynamics.

3.6. Trade Policies and Their Impact on Tomato Imports and Exports

Trade policies have a significant impact on tomato imports and exports in India. Government regulations and trade agreements influence the flow of tomatoes across international borders, affecting domestic supply, demand, and prices.

(i) Tariffs and Import Duties: The imposition of tariffs and import duties on tomato imports affects the cost of imported tomatoes, making them more expensive for domestic consumers. Higher tariffs create a disincentive for imports and encourage the consumption of domestically produced tomatoes (Chand *et al*., 2020).

(ii) Quotas and Import Restrictions: Government quotas and import restrictions can limit the volume of tomatoes that can be imported into the country. These measures are designed

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to protect domestic farmers from competition with cheaper imports, ensuring market access and price stability (Majeed, 2019).

(iii) Export Subsidies: Export subsidies provided by the government can incentivize tomato exporters by reducing their production and transportation costs. These subsidies make Indian tomatoes more competitive in the global market and promote higher export volumes (Kumar and Singh, 2017).

(iv) Free Trade Agreements (FTAs): Free Trade Agreements between India and other countries can influence tomato trade dynamics. FTAs can lead to reduced or eliminated tariffs on specific products, including tomatoes, making imports and exports more accessible and cost-effective (Chand *et al*., 2020).

(v) Non-Tariff Barriers: Non-tariff barriers, such as sanitary and phytosanitary regulations, technical standards, and quality control measures, can impact tomato trade. Complying with these regulations can be a significant challenge for exporters and may affect trade volumes (Majeed, 2019).

(vi) Currency Exchange Rates: Fluctuations in currency exchange rates can impact the competitiveness of Indian tomatoes in the global market. A weaker domestic currency makes exports more attractive, while a stronger currency can make imports relatively cheaper (Chand *et al*., 2020).

Trade policies are essential instruments that governments use to manage domestic and international tomato trade. By carefully regulating imports and exports, policymakers aim to strike a balance between ensuring fair prices for domestic producers and providing consumers with access to a stable supply of tomatoes.

3.7. Market Dynamics and Price Fluctuations:

Market dynamics and the interplay between demand and supply have a significant impact on tomato prices, leading to fluctuations in the market. Demand-supply imbalances arise due to various factors, affecting the availability and pricing of tomatoes.

(i) Seasonal Variations in Demand and Supply: Tomato production in India is subject to seasonal variations, leading to fluctuations in supply throughout the year. During peak harvest seasons, tomatoes are abundant, resulting in a surplus supply and relatively lower prices. Conversely, during off-seasons, the supply decreases, causing a shortage and leading to higher prices (Singh *et al*., 2019).

(ii) Changing Consumption Patterns: Shifts in consumer preferences and dietary habits can impact tomato demand. Increased awareness of the health benefits of tomatoes and the growth of processed tomato products have driven higher demand. Moreover, changing demographics and urbanization have also influenced consumption patterns, leading to fluctuations in demand (Singh and Singh, 2020).

(iii) Market Speculation and Traders' Influence: Market speculation and the actions of traders and middlemen can influence tomato prices. Speculation based on anticipated changes in supply or demand can lead to price volatility. Additionally, traders' decisions on stockholding and timing of supply can also affect market dynamics (Das *et al*., 2018).

(iv) External Factors: External factors, such as weather-related events, transportation disruptions, or changes in international trade policies, can impact tomato supply and prices. Extreme weather events, like floods or droughts, can damage crops, leading to supply shortages and price fluctuations (Chand *et al*., 2019).

(v) Import and Export Trends: Tomato imports and exports can also influence domestic prices. Increased imports during periods of low domestic supply can stabilize prices,

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while higher exports can lead to reduced domestic availability and increased prices (Chand *et al*., 2019).

(vi) Government Interventions: As discussed earlier, government policies and interventions, such as MSP, subsidies, and trade regulations, can influence supply and demand dynamics in the tomato market, leading to price fluctuations (Kumar and Singh, 2017).

Demand-supply imbalances create price volatility in the tomato market. Understanding these market dynamics is crucial for policymakers, traders, and farmers to make informed decisions, anticipate price trends, and implement measures to stabilize prices and ensure food security for consumers.

3.8. Role of Market Speculations and Traders in Price Volatility

Market speculations and the actions of traders play a significant role in price volatility in agricultural commodity markets, including tomatoes. Speculation refers to the act of trading or making financial decisions based on anticipated changes in prices, rather than on the intrinsic value of the commodity. Traders, including wholesalers and middlemen, can influence market dynamics through their decisions on stockholding, timing of supply, and price negotiations.

(i) Market Speculation: Market speculations involve buying or selling tomato contracts in anticipation of future price movements. Speculators may use technical analysis, historical price patterns, and other market indicators to predict price trends. While speculators do not have physical possession of the commodity, their trading activity can impact market sentiment and price movements (see http://www.fao.org/3/a-ap918e.pdf). Speculation can lead to price volatility, as it introduces additional demand or supply into the market based on traders' perceptions of future price movements. Speculative trading can amplify price fluctuations beyond what might be driven solely by fundamental supply and demand factors (Antoniadis *et al*., 2021).

(ii) Traders' Influence: Traders, such as wholesalers and middlemen, play a crucial role in connecting producers with consumers and retailers. They buy tomatoes from farmers and sell them to retailers or processors. Traders often hold inventories of tomatoes, making decisions on when and at what price to release them into the market.

Traders' decisions on stockholding can influence prices. If traders hold onto large inventories expecting prices to rise, it can lead to a temporary supply shortage, driving prices higher. Conversely, if traders release large quantities of tomatoes into the market simultaneously, it can lead to a supply glut and lower prices (see http://www.ifpri.org/publication/transmission-world-food-price-changes-markets-sub-saharan-africa). Additionally, traders can influence prices through price negotiations with farmers. When there are few alternative buyers for farmers' produce, traders may have significant bargaining power, allowing them to dictate prices to some extent. While market speculations and traders can contribute to price volatility, it is essential to note that they are just one aspect of the broader market dynamics that influence tomato prices. Other factors, such as weather events, demand-supply imbalances, and government policies, also play critical roles in shaping price fluctuations.

3.9. Consumer Behavior and Preferences

Consumer behavior and preferences play a crucial role in shaping tomato consumption patterns across different demographic groups in India. Various factors, including cultural, social, economic, and health considerations, influence how different segments of the population consume tomatoes.

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(i) Urban vs. Rural Consumers: Urban consumers generally have greater access to a variety of food choices, including processed tomato products like ketchup, sauces, and canned tomatoes. In contrast, rural consumers often have more direct access to fresh tomatoes and may use them in traditional dishes and local cuisines (Aggarwal *et al*., 2019).

(ii) Income Levels: Higher-income consumers tend to have greater purchasing power and may prefer higher-quality tomatoes or processed tomato products. In comparison, lower-income consumers may prioritize fresh and affordable tomatoes as a staple ingredient in their daily meals (Babu *et al*., 2017).

(iii) Age Groups: Younger consumers, especially millennials and Gen Z, are more likely to experiment with innovative tomato-based recipes and incorporate tomatoes into various dishes, including salads, sandwiches, and pasta sauces. On the other hand, older generations may have more traditional culinary preferences for using tomatoes (Saxena *et al*., 2021).

(iv) Cultural and Regional Preferences: Tomato consumption patterns vary significantly across different regions in India. In certain regions, tomatoes are extensively used in daily cooking, while in others, they are less commonly consumed. Regional dishes and cuisines heavily influence tomato usage in various parts of the country (Kumar and Kaur, 2020).

(v) Health Considerations: Tomatoes are known for their health benefits, containing essential nutrients and antioxidants. Health-conscious consumers may increase their tomato consumption, by incorporating them into salads, smoothies, and health-focused recipes (Rautela *et al*., 2020).

(vi) Convenience and Processed Products: Modern lifestyles have led to an increased demand for convenience, driving the popularity of processed tomato products like tomato paste, puree, and ready-to-use sauces. Busy urban consumers often prefer such products for their ease of use and time-saving attributes (Jat *et al*., 2017).

(vii) Dietary Preferences: Vegetarians and vegans often use tomatoes as a key ingredient in their plant-based diets, incorporating them into various dishes as a meat substitute or as a source of umami flavor (Kumar *et al*., 2019).

Understanding these consumer behavior and preference trends is essential for farmers, traders, and policymakers to align tomato production and marketing strategies with the evolving demands of different demographic groups, ensuring a stable and profitable tomato market.

3.10. The Influence of Income Levels and Consumer Choices on Demand and Pricing

Income levels and consumer choices have a significant impact on the demand and pricing dynamics of tomatoes in the market. Consumers' income levels play a crucial role in determining their purchasing power and willingness to spend on different goods and services, including tomatoes. Higher-income levels often result in increased disposable income, enabling consumers to afford higher-quality products and premium tomato varieties. Such consumers may be more willing to pay a premium for organic or specialty tomatoes, leading to a higher demand for these products. On the other hand, lower-income consumers may have more budget constraints and prioritize affordability, driving higher demand for economical tomato varieties.

Consumer choices and preferences also heavily influence the demand for different tomato products and varieties. Some consumers may prefer fresh tomatoes and prioritize them in their daily cooking, while others may opt for processed tomato products like ketchup, sauces, and canned tomatoes for their convenience and taste. Additionally, growing health awareness among consumers has led to an increased demand for tomatoes due to their

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nutritional benefits and antioxidant properties. These consumer preferences not only influence the overall demand for tomatoes but also impact the demand for specific tomato varieties and products.

The interplay of income levels and consumer choices affects the pricing of tomatoes in the market. When demand outstrips supply, prices tend to rise due to scarcity. Higher-income consumers, who may be less price-sensitive, are more likely to absorb price increases for tomatoes they consider essential. On the other hand, lower-income consumers, who are more price-sensitive, may adjust their consumption or seek more economical alternatives when faced with higher prices. Price elasticity of demand also plays a role, with the substitutability of tomatoes influencing how consumers respond to price changes. If consumers view tomatoes as irreplaceable, demand may be relatively inelastic, while perception of substitutability may lead to more elastic demand and greater sensitivity to price fluctuations.

Income levels and consumer choices are vital for producers, traders, and policymakers to effectively gauge demand trends and adjust pricing strategies. Adapting to consumer preferences and catering to different income groups can help ensure a stable and profitable tomato market. By offering a diverse range of tomato varieties and products that align with consumer demands, producers can enhance market competitiveness and build stronger customer loyalty. Policymakers can also use this knowledge to design targeted interventions that support tomato production and ensure equitable access to affordable tomatoes for all segments of the population. Overall, recognizing the influence of income levels and consumer choices is essential for maintaining a balanced and sustainable tomato market.

3.11. Case Studies of Tomato Price Surges

3.11.1. Case study 1: Tomato price surge due to weather-related events

In 2022, India experienced an unusual weather pattern, including erratic rainfall and extreme heat waves, which severely impacted tomato cultivation. Several major tomato-growing regions faced water scarcity and heat stress, leading to reduced yields and lower production. As a result, the supply of tomatoes in the market plummeted, leading to a sharp increase in prices. During the peak season, when tomatoes are usually abundant and affordable, consumers faced soaring prices that were almost three times higher than the previous year. The price surge not only affected household budgets but also impacted food businesses and restaurants that heavily rely on tomatoes as a key ingredient. To cope with the situation, some farmers resorted to importing tomatoes from neighboring countries to meet the demand. However, import costs and transportation expenses further contributed to the increase in retail prices. The price volatility and uncertainty prompted the government to intervene by implementing short-term measures, such as releasing buffer stocks, capping wholesale prices, and providing subsidies on transportation to stabilize the market.

3.11.2. Case study 2: Speculation-driven tomato price surge

In 2019, the tomato market witnessed an abrupt price surge due to speculative activities in futures trading. Speculators anticipated an upcoming shortage of tomatoes due to adverse weather forecasts in key tomato-producing regions. This led to a surge in trading activity in tomato futures contracts, creating an artificial demand in the futures market. As the speculative activities intensified, tomato prices in the spot market (physical market) also started to rise. Traders and middlemen, influenced by the perception of future scarcity, started holding on to their tomato stocks, waiting for even higher prices. This resulted in a temporary supply shortage in the physical market, further exacerbating the price surge.

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The speculative bubble eventually burst when the anticipated supply shortage did not materialize, and the actual tomato harvest turned out to be relatively stable. As a consequence, speculators rushed to offload their futures contracts, leading to a sudden crash in tomato prices. This caused losses for many traders and farmers who had purchased tomatoes at inflated prices during the peak of the speculation. To mitigate such speculative price fluctuations in the future, policymakers and market regulators implemented stricter regulations and surveillance on futures trading. Additionally, awareness campaigns were initiated to educate farmers and traders about the potential risks of speculative trading and to promote more stable and sustainable market behavior.

The recent surge in June-July 2023 in tomato prices in India has caused significant distress among consumers and farmers alike (see **Figure 1**). The sudden increase in retail prices can be attributed to a combination of factors, including delayed monsoons, inadequate production, and extreme heat. The rising temperatures during March and April led to pest attacks on tomato crops, resulting in lower yields and higher market rates. Furthermore, the supply of tomatoes has been disrupted in the past few weeks from the producing states due to challenges in harvesting and transportation processes. As a result, the availability and affordability of tomatoes have been severely impacted, leading to skyrocketing prices.

These case studies illustrate how various factors, such as weather events, supply-demand imbalances, and speculative activities, can lead to significant tomato price surges. The volatility in tomato prices can have far-reaching consequences for consumers, farmers, traders, and the overall food industry, emphasizing the importance of effective market regulation and measures to ensure price stability and food security.

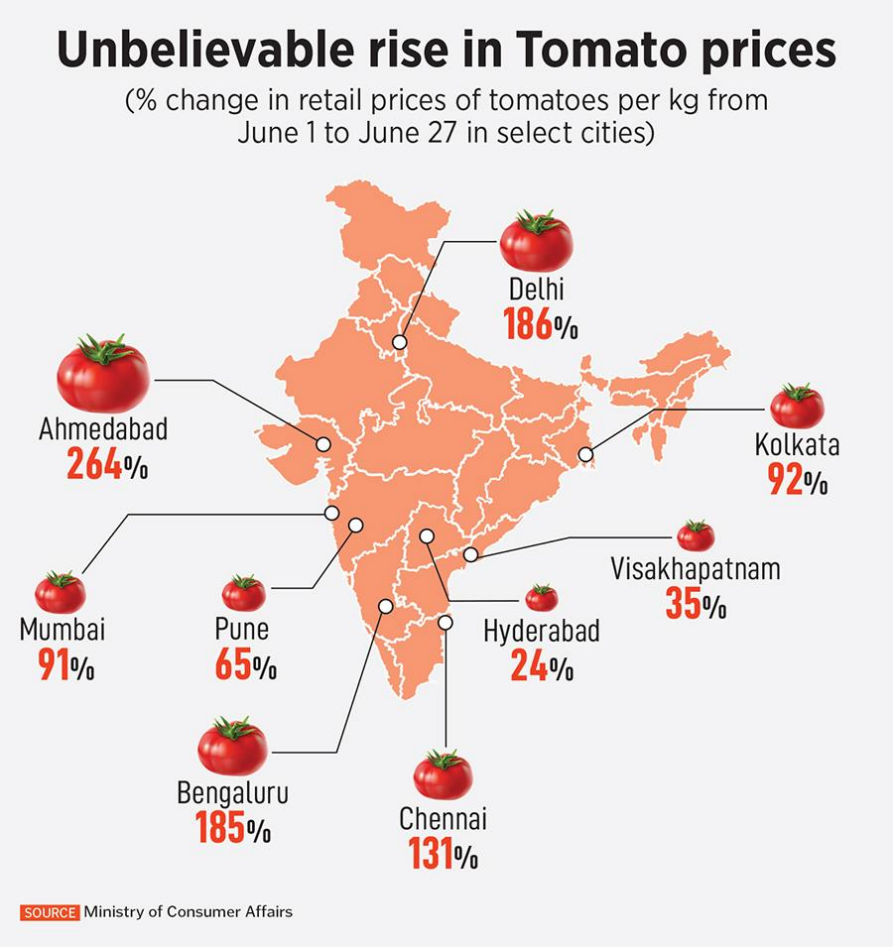

Figure 1. Ministry of consumer affairs.

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3.12. Stakeholder Perspectives

Farmers play a crucial role in tomato cultivation and are directly impacted by the challenges and experiences associated with this agricultural activity. Several factors affect their perspectives on tomato cultivation, including production challenges, market dynamics, and economic considerations.

(i) Production Challenges: Tomato farmers face various production challenges that affect crop yields and overall profitability. Pests and diseases, such as early blight, bacterial wilt, and whitefly infestations, can cause significant damage to tomato crops (Hassan *et al*., 2017). Additionally, adverse weather conditions, including extreme heat, heavy rainfall, and unseasonal rains, can impact crop health and yield (Kumar *et al*., 2020). The lack of access to quality seeds and modern agricultural technologies also hinders productivity and efficiency for many farmers (Sharma *et al*., 2017).

(ii) Input Costs and Financial Strain: Rising input costs, including seeds, fertilizers, pesticides, and labor, place financial strain on tomato farmers (Raja *et al*., 2019). Fluctuating prices of agricultural inputs and lack of access to credit facilities further add to their financial challenges (Siddiqui *et al*., 2020). The cost of irrigation and water management is also a concern, particularly in water-scarce regions (Kumar and Goyal, 2017).

(iii) Price Volatility and Market Risks: Farmers face uncertainties in tomato prices due to market dynamics, supply-demand imbalances, and external factors like weather events and import-export regulations (Chand *et al*., 2019). Sudden price fluctuations can impact their income and profitability, making it difficult for them to plan for the future (Raja *et al*., 2019).

(iv) Post-Harvest Losses: Post-harvest losses are a significant challenge for tomato farmers in India. The lack of proper storage and transportation facilities leads to spoilage and wastage of harvested tomatoes, resulting in financial losses for farmers (Kumar *et al*., 2017).

(v) Government Support and Policies: Farmers look to the government for support in addressing their challenges. They expect timely information on weather forecasts, market trends, and price outlooks to make informed decisions (Mallikarjuna *et al*., 2021). Adequate support in terms of subsidized agricultural inputs, infrastructure development, and extension services can help farmers improve their productivity and income (Hassan *et al*., 2017).

(vi) Sustainable Agriculture and Climate Resilience: Given the increasing concerns about climate change, many farmers express the need for sustainable agricultural practices and climate-resilient crop varieties to cope with changing environmental conditions (Siddiqui *et al*., 2020). They seek access to training and knowledge on climate-smart farming techniques to reduce their vulnerability to climatic uncertainties (Kumar *et al*., 2020).

The perspectives of farmers are crucial for policymakers and agricultural experts to design effective interventions and policies that address the challenges faced by tomato farmers and promote sustainable and profitable tomato cultivation practices.

3.13. Perspectives of Traders, Retailers, and Wholesalers on Price Movements

Perspectives of traders, retailers, and wholesalers on the price movements of tomatoes in India are influenced by market dynamics, supply-demand imbalances, and various external factors. These stakeholders play a crucial role in the tomato supply chain and are directly impacted by price fluctuations.

(i) Traders' Perspectives: Traders involved in the tomato market closely monitor price movements and seek profit opportunities. They are particularly sensitive to supply

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fluctuations, as a sudden shortage can lead to increased demand for tomatoes and higher prices. Traders may also speculate on future price movements based on factors such as weather forecasts, crop conditions, and market trends. Their trading decisions can influence short-term price volatility (Antoniadis *et al*., 2021). During periods of price surges, traders may exercise caution in holding onto inventories in anticipation of further price increases. This behavior can lead to reduced supplies in the market, exacerbating the price surge. On the other hand, if traders anticipate declining prices, they may rush to offload their stocks, contributing to price drops (see http://www.ifpri.org/publication/transmission-world-food-price-changes-markets-sub-saharan-africa).

(ii) Retailers' Perspectives: Retailers are the final link in the tomato supply chain and have a direct impact on consumers. They closely observe wholesale price fluctuations and adjust their retail prices accordingly. When wholesale tomato prices rise, retailers may pass on the cost to consumers, leading to higher retail prices (Henderson and O'Keefe, 2015). Retailers also consider consumer preferences and demand patterns while setting prices. During periods of high demand, such as festival seasons or adverse weather conditions when consumers tend to stock up on tomatoes, retailers may adjust prices to maximize profits (Gangadharappa and Kavyashree, 2015).

(iii) Wholesalers' Perspectives: Wholesalers act as intermediaries between farmers and retailers, and their perspectives on price movements are influenced by supply levels and transportation costs. Wholesalers buy tomatoes from farmers at wholesale rates and then sell them to retailers at higher prices. When tomato supplies are abundant, wholesalers may negotiate lower prices with farmers to maximize their profits. However, during periods of scarcity, wholesalers may face challenges in sourcing sufficient quantities of tomatoes, which can drive up wholesale prices (Mohanty *et al*., 2018).

Additionally, wholesalers may also consider transportation costs and logistical challenges in setting their prices. Long distances between production centers and consumption regions can result in higher transportation expenses, which are often passed on to retailers and, ultimately, consumers (Devi and Singh, 2015). The perspectives of traders, retailers, and wholesalers on tomato price movements are influenced by their roles in the supply chain and market dynamics. While traders may seek opportunities for profit through speculation, retailers and wholesalers closely monitor wholesale prices to adjust their retail and wholesale prices accordingly. The interactions and decisions of these stakeholders can significantly impact price volatility in the tomato market, and understanding their perspectives is crucial for policymakers to design effective measures for price stabilization and to ensure a fair and sustainable tomato market for all participants.

3.14. Policy Recommendations

To stabilize tomato prices and ensure food security, policymakers can implement a combination of short-term and long-term strategies aimed at addressing supply-demand imbalances, improving market efficiency, and promoting sustainable agricultural practices. Here are some policy recommendations:

(i) Enhance Cold Storage and Infrastructure: Investing in modern cold storage facilities and post-harvest infrastructure is crucial to reduce post-harvest losses and extending the shelf life of tomatoes. Proper storage facilities can help manage supply fluctuations and stabilize prices during peak and off-peak seasons. Financial incentives and subsidies can encourage private sector participation in building and maintaining cold storage facilities.

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(ii) Promote Climate-Resilient Farming Practices: Supporting farmers in adopting climate-resilient agricultural practices can help mitigate the impact of weather-related events on tomato production. This includes promoting drip irrigation, rainwater harvesting, and the use of climate-resistant tomato varieties. Providing technical assistance and access to climate-smart technologies can enhance farmers' resilience to climate change-induced challenges.

(iii) Strengthen Market Information Systems: Implementing an efficient market information system that provides real-time data on tomato prices, production, and supply across different regions can help traders and farmers make informed decisions. Such systems facilitate better market coordination and prevent price manipulation due to information asymmetry. The government can collaborate with private entities to develop and maintain robust market information platforms.

(iv) Increase Investment in Research and Development: Funding research and development initiatives focused on improving tomato production, pest and disease management, and post-harvest technologies can lead to higher yields and better-quality produce. Developing hybrid and genetically modified tomato varieties with enhanced resistance to pests and diseases can help reduce production risks and improve overall supply.

(v) Implement Price Stabilization Mechanisms: The government can intervene during times of price volatility by implementing price stabilization mechanisms. This could include the creation of a Tomato Price Stabilization Fund to buffer against price fluctuations and provide financial support to farmers during adverse market conditions. Price support programs and Minimum Support Prices (MSPs) for tomatoes can provide price floors to protect farmers' income.

(vi) Enhance Transportation and Logistics: Improving transportation infrastructure and reducing logistical bottlenecks can enhance the efficiency of tomato supply chains. Upgrading roads, establishing dedicated tomato transport corridors, and incentivizing private players to invest in cold chain logistics can facilitate the smooth movement of tomatoes from production centers to consumption regions.

(vii) Encourage Contract Farming and Farmer Producer Organizations (FPOs): Encouraging contract farming and supporting the formation of Farmer Producer Organizations can strengthen farmers' bargaining power and reduce their vulnerability to price fluctuations. Contract farming agreements can provide assured markets and stable prices for farmers, while FPOs can collectively negotiate better prices with traders and retailers.

(viii) Monitor and Regulate Speculative Trading: To prevent speculative trading from exacerbating price volatility, policymakers can introduce regulations to monitor and control speculative activities in the tomato futures market. Transparent reporting and stricter surveillance on futures trading can help prevent excessive price swings caused by speculators.

By implementing these policy recommendations, policymakers can work towards achieving price stability, ensuring food security, and promoting sustainable tomato cultivation practices in India. A well-coordinated approach involving the government, private sector, and farmers can lead to a more resilient and equitable tomato market.

3.15. Future Outlook for Tomato Prices in India

The future outlook for tomato prices in India is influenced by a combination of factors, including climate change, sustainable farming practices, market integration, government interventions, global trade, and consumption trends. Climate change remains a significant concern for tomato cultivation, with changing weather patterns and extreme events affecting

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yields and production. As climate variability intensifies, farmers may face challenges in maintaining stable supplies, leading to fluctuations in tomato prices. However, the adoption of sustainable agricultural practices, such as organic farming and climate-resilient varieties, may improve productivity and crop resilience, potentially positively impacting tomato supplies and prices in the long run.

Advancements in technology, such as better market information systems and digital payment mechanisms, are expected to improve market integration and efficiency. As the tomato market becomes more connected and transparent, it may help in minimizing price disparities between regions and stabilize tomato prices. Government policies and interventions will also play a crucial role in shaping future tomato prices. Price stabilization mechanisms, minimum support prices, and strategic buffer stocks can help manage price volatility and ensure food security during periods of supply-demand imbalances. Effective implementation of these measures will be essential for stabilizing tomato prices and protecting farmers' interests.

The global trade dynamics and import-export policies will also influence domestic tomato prices in India. Changes in trade agreements, global demand-supply trends, and international market conditions can impact the availability and prices of tomatoes in the country. Monitoring global market trends will be critical for anticipating the impact on domestic prices and planning domestic production accordingly.

Demographic shifts and consumption preferences will play a significant role in determining future tomato prices. Urbanization, rising incomes, and changes in dietary habits may lead to increased demand for fresh and processed tomatoes. Understanding consumer behavior and preferences can help anticipate demand trends and adjust production accordingly to ensure adequate supplies and price stability.

The future outlook for tomato prices in India is subject to a complex interplay of factors. Short-term price fluctuations are likely due to weather events, market dynamics, and supply-demand imbalances. However, long-term sustainability efforts, technological advancements, proactive policy interventions, and monitoring of global market trends can contribute to price stability and ensure food security in the tomato market. Continuous efforts to address supply chain inefficiencies, promote sustainable farming practices, and foster market integration will be crucial for managing price volatility and supporting the interests of all stakeholders in the tomato supply chain.

4. CONCLUSION

In conclusion, the rising tomato prices in India have become a critical concern, impacting both consumers and farmers. A comprehensive analysis of the factors behind the soaring tomato prices reveals a complex web of challenges, including production issues, supply chain inefficiencies, climate change effects, and market dynamics. Tomato cultivation in India faces numerous hurdles, including pest and disease outbreaks, weather-related disruptions, post-harvest losses, and inadequate storage and transportation facilities. These challenges contribute to fluctuations in tomato supplies and subsequently lead to price volatility in the market. Government policies and interventions, such as price support mechanisms and subsidies, play a crucial role in stabilizing tomato prices and providing a safety net for farmers. Additionally, market speculations and traders' activities can exacerbate price fluctuations, necessitating better monitoring and regulation.

Understanding consumer behavior and preferences is vital for anticipating demand patterns, which can aid in managing supply-demand imbalances and mitigating price surges. Moreover, the role of market speculations and traders must be carefully managed to prevent

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artificial price volatility. To ensure a sustainable and stable tomato market in India, policymakers should focus on promoting sustainable agricultural practices, investing in infrastructure, enhancing market information systems, and fostering farmer collectives and cooperatives. These long-term measures will not only address supply chain inefficiencies but also improve market efficiency and coordination. Furthermore, climate change resilience should be a priority, with research and technology adoption supporting climate-resistant varieties and climate-smart farming practices. This will enable farmers to cope with changing weather patterns and minimize production risks.

With collaborative efforts from the government, private sector, and stakeholders, India can achieve price stability in the tomato market, ensuring food security and sustainable livelihoods for farmers. Proactive policy interventions, supported by efficient implementation and monitoring mechanisms, will be key to achieving a balanced and resilient tomato market that benefits all participants. By addressing the underlying challenges and focusing on sustainable strategies, India can work towards a future where tomato prices remain stable and accessible to consumers while providing fair returns to farmers.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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