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DISCUSSION PAPER - 29
OCTOBER 2025

Climate Shocks, Food Supply, and Prices

Do We Need to Rethink Macroeconomic Policies?

Renu Kohli

CSEP RESEARCH

Centre for Social and Economic Progress (CSEP)
CSEP Research Foundation
6, Dr Jose P. Rizal Marg, Chanakyapuri,
New Delhi - 110021, India

Recommended citation:
Kohli, R. (2025). *Climate Shocks, Food Supply, and Prices: Do We Need to Rethink Macroeconomic Policies?* (CSEP Discussion Paper 29). New Delhi: Centre for Social and Economic Progress.

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Climate Shocks, Food Supply, and Prices

Do We Need to Rethink Macroeconomic Policies?

Renu Kohli
Senior Fellow
Centre for Social and Economic Progress
New Delhi, India

The research assistance of Ankita Garg and Kritima Bhapta in different parts of this work is gratefully acknowledged. I am also grateful to the participants of the CSEP brown bag (January 30, 2025), and the Center for Global Development (CGD) seminar (April 29, 2025), and the reviewers- Udaibir Saran Das, Janak Raj, and Laveesh Bhandari for their feedback and suggestions. The responsibility for errors, if any, is solely mine.

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Abbreviations

AI	Artificial Intelligence
CPI	Consumer Price Index
DGFT	Directorate General of Foreign Trade
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GoI	Government of India
GPM	Global Precipitation Measurement
IGP	Indo-Gangetic Plain
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
LPA	Long Period Average
MP	Madhya Pradesh
MPC	Monetary Policy Committee
MT	Million Tonnes
NASA	National Aeronautics and Space Administration
NFSA	National Food Security Act
PDS	Public Distribution System
PHs	Priority Households
PSF	Price Stabilisation Fund
RBI	Reserve Bank of India
WMO	World Meteorological Organization

Executive Summary

India's recent experience with food inflation reveals a complex and deepening interaction between climate shocks and macroeconomic vulnerabilities. From 2022 to 2024, the country has faced the most intense climate disruptions in recent history—marked by consecutive years of record-breaking heatwaves, erratic monsoons, and sustained rainfall deficits in key agricultural regions. These climate anomalies not only depressed cereal yields, particularly of wheat and rice, but also disrupted public procurement, depleted foodgrain stocks, and sustained food price pressures for nearly five years. The convergence of these shocks created a unique and protracted inflationary episode, posing difficult questions about the adequacy of existing agricultural, trade, and macroeconomic policy frameworks. The paper brings these strands together with a detailed empirical narration in a comparative framework.

It documents the simultaneous disruption of India's wheat and rice production cycles in multiple seasons, with shortfalls exceeding those seen during earlier episodes such as 2009–2010 and 2015–2016. For the first time, all three staple cereal crops (kharif rice, rabi rice, and rabi wheat) underperformed against official targets in two successive years. Procurement shortfalls were most striking in Madhya Pradesh (MP), revealing mismatches between official output estimates and actual market behaviour, possibly exacerbated by data weaknesses (for example, outdated crop-cutting techniques) and policy missteps. Against the successive harvest failures, particularly for wheat, the steep declines in public stocks raised food security concerns.

In response, the government implemented a wide range of supply-side controls, including outright export bans, stockholding limits, elevated import duties, and intensified open market operations. These measures helped moderate price spikes. However, they also generated substantial inefficiencies, for example, discouraging private market participation and blunting the initial policy objective. International trade restrictions, especially on rice exports, strained global markets and attracted criticism. Notably, trade instruments were deployed far more frequently and stringently than in any prior crisis, underscoring the increased need and/or diminished effectiveness in checking prices, including in the absence of imports.

Food inflation dynamics reveal critical differences from historical norms. Since 2021, food price increases have contributed over 70 per cent to headline Consumer Price Index (CPI) inflation in some quarters. Volatility has risen. The traditional mean-reversion of food price spikes within a few months has diverged in this episode, with a marked increase in the price level indicating an indexed process. These changing patterns suggest that the conventional transitory view of food price shocks may not necessarily hold. The persistence of supply shocks amplified the growth–inflation trade-offs for monetary policy, compelling a delay in monetary easing even as core inflation pressures abated.

Comparing these dimensions over time, specifically with similar episodes in 2009–2011 and 2015–2016, the paper identifies changes that may be more fundamental than cyclical. For example, unlike past events, the clustering of heat and rainfall shocks over multiple seasons, the growing correlation between temperature and drought, and the inability of domestic buffers to absorb repeated shocks suggest a shift in the climate–food–economy relationship. This could deepen in the future as climate models project a higher frequency of extreme weather events and deeper yield losses, particularly in the Indo-Gangetic Plain (IGP).

From a policy standpoint, the implications are multifold. Agricultural policy must move beyond traditional self-sufficiency goals—towards internal liberalisation and dynamic risk-sharing mechanisms, including calibrated trade integration and targeted adaptation strategies. Trade policy requires greater transparency, rule-based triggers, and flexibility to enable countercyclical responses. Supply-side management must be modernised through real-time data systems and technological yield assessments. Monetary policy may need to augment headline inflation targeting, for example, with climate-adjusted core measures or conditional bands, to limit credibility risks while adapting to longer periods of disinflation. Finally, fiscal policy will need to accommodate growing welfare costs, rural income support, and investment in climate-resilient agriculture—without crowding out public investment or impairing debt sustainability.

Furthermore, the Indian experience from 2021 to 2024 offers a compelling case for rethinking macroeconomic policy through the lens of rising climate risks. The persistence, simultaneity, and structural nature of recent shocks point to the need to recalibrate policy frameworks and design for sustainability. Without such adaptation, India risks entering a new equilibrium defined by chronic food inflation, rising inequality, and diminished policy effectiveness.

1. Introduction

The past several years have seen unprecedented climate extremes in India. Globally, the World Meteorological Organization (WMO) confirmed that 2024 was the warmest year on record, about +1.55°C above pre-industrial levels (WMO, 2025). India too, experienced its hottest year since 1901, with mean temperatures approximately 0.65°C above the 1901–2000 average (India Meteorological Department [IMD], 2025). While the average national temperature has risen over time, this is concentrated in the last decade and a half. This is accompanied by an increased number of heatwave days: between 1990–2009 and 2010–2023, these rose 36 per cent on average, about 1.4 times higher, compared to little change over 1967–2009. Heatwaves have become more frequent and volatile. For example, India saw unusually early heatwaves in March 2022 and February 2023, while winter temperature patterns have become irregular. Simultaneously, rainfall has grown more erratic: heavy precipitation often falls in intense bursts (National Aeronautics and Space Administration [NASA] Global Precipitation Measurement [GPM], n.d.) while long dry spells become longer (Arasu, 2024). These inconsistencies are also interconnected.

Climate-change-related shocks like these were accentuated in the last three years in India, as successive extreme heat conditions after 2021 combined with uneven and deficient rainfall in the food crop-growing regions (Bal et al., 2022). These climate shocks—successive heatwaves combined with uneven monsoon rains—have strained India's foodgrain production (e.g., Monetary Policy Statements, December 2019, August–September 2022, February 2023). In 2022–2024, the country saw a string of simultaneous crop failures: wheat and rice output repeatedly fell short of targets. The shortfall in wheat output was substantial and continual; that in rice to a lesser extent. Wheat procurement—the purchase of foodgrains for public stocks—dropped sharply, and foodgrain stocks plunged to historic lows.

At the same time, food prices surged and remained elevated (Monetary Policy Statement, December 2019, September 2022, August 2023, February and December 2024). Price pressures spilt over into broad inflation, forcing unusually aggressive policy responses. These ranged from export bans to welfare substitutions in public distribution. Food inflation stayed high for more than four years, complicating monetary policy as risks of generalisation from elevated inflation expectations of households sharpened the trade-off.

Such coincidental climate shocks are rare. The closest precedent was 2009–2010, when an approximately 20 per cent monsoon deficit coincided with record heat (279 heatwave days). But the recent episodes differ in key respects—the three years 2022–2024 were the hottest on record, rainfall deficits struck in critical regions, and supply-management responses have been unusually intensive and stringent. These differences raise concerns about food security, agricultural policy, and inflation dynamics under climate stress.

The future is uncertain. However, climate models project that the frequency and severity of heatwaves and droughts will only increase (Intergovernmental Panel on Climate Change [IPCC], 2023). The three years to 2024 were the warmest on record; 2024 was the first year to cross 1.5°C above the pre-industrial level (Copernicus Climate Change Service, 2025). India's 2024 summer (March–May) was officially declared the hottest on record for the Northern Hemisphere, and winter was the warmest since 1901. Climate change is not just increasing the occurrence of extreme weather events; the lead time for predicting heavy rainfall is also reducing from three days to just one and a half (IMD, 2025). These suggest a new "normal" may be emerging.

Recent predictions of the *National Innovations in Climate Resilient Agriculture* on the impact of climate change on Indian agriculture reveal long-term risks of 6–10 per cent to India's rice and wheat output—by 2100, wheat yields could drop 6–25 per cent while irrigated rice yields could fall by 7 per cent and 10 per cent by 2050 and 2080, respectively. Previous studies also find a 10–20 per cent decline in yields in the long term from climate-change-related factors, while immediate effects are contained by irrigation (Khan & Jadaun, 2023; Lobell et al., 2011). Global climate models estimate losses from climate change (rainfall and temperature) could range from 3–22 per cent for rice yields over 2021–2100 (for example, Gallé & Katzenberger, 2024). Cross-country studies endorse these findings; for example, erratic rainfall is found to lower rice yields in Malaysia (Tan et al., 2021) and China (He et al., 2020). Officials have underscored increasing food security concerns as global warming weakens western disturbances and weather systems underpinning the winter rains in northwest India (PTI, 2025).

This backdrop prompts a closer study of the recent climate shocks. The trends in weather anomalies and the evidence both point to aggregate impacts, meriting deeper evaluation of management frameworks and macroeconomic policies. This paper is an initial attempt in this direction. It provides an empirical narrative account and analysis of India's recent climatic disturbances, their aggregate spillovers, and their management, in order to draw broad policy inferences for deliberation and debate. The research endeavour is modest, previewing contemporary developments at the intersection of climate change and macroeconomics to lay the foundation for future targeted, substantive work in the spheres outlined.

It contributes in several ways: through documentation and analysis of the recent experience; identification of notable departures from past behaviours in four dimensions—the climate-related rise in heatwaves and erratic rainfall, food output and security, supply-side management, and food inflation; and inferences for economic policies, challenges from current structures, management, and critical weaknesses that require redressal to adapt to a riskier climate. It draws policy attention to important macroeconomic issues that could potentially escalate with intensifying climate-change pressures in the future.

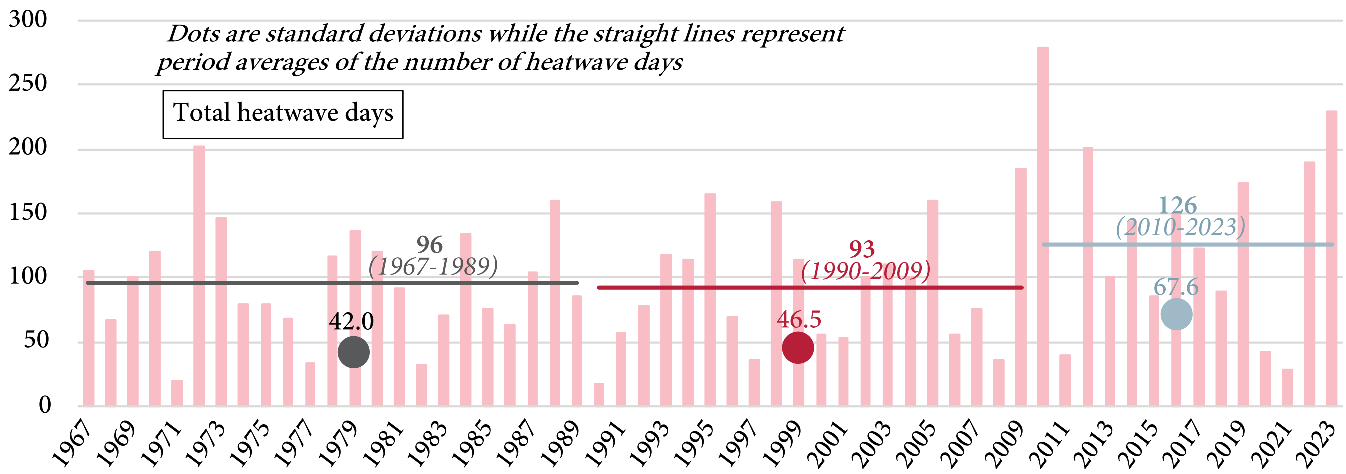
The paper is organised as the following. Section 2 traces the evolution of climate extremes, specifically rising temperatures with heatwaves and erratic rainfall, along with the impact upon cereal crop yields and the pillars of food security, public procurement, and buffer stocks, viz., wheat and rice. Section 3 details the resulting food price shocks and inflation dynamics. The supply-side management of food output deficits and prices are detailed in Section 4. A comparative evaluation between the recent episode and matching events in the past is endeavoured in Section 5 with a view to identifying fundamental changes, if any. Section 6 draws these aspects together for inference and policy implications in a transformed context defined by frequent, persistent climate-related shocks. It focuses on agriculture, trade, supply management, and macroeconomic policies from the standpoint of strengthening and sustainability, with possible solutions for strengthening food security and adaptation. Section 7 concludes with outlining the main contributions, future research, and policy perspectives.

2. Climate Shocks and Foodgrain Output

2.1 Rising Temperatures and Erratic Rainfall

India's long-term climate trend shows sharp warming. Over 1901–2022, the national annual mean temperature rose by approximately 1.7°C. Alongside this, the number and frequency of heatwaves—a period of unusually high temperatures compared to what is normally expected over a region—have also been on the rise. Since 2010, heatwave frequency has jumped dramatically—the annual count of heatwave days rose roughly 35 per cent above its 1990–2009 average. Figure 1 shows that until about a decade and a half ago, the average annual heatwave day count did not change much, at approximately 95, while volatility increased marginally in the period from 1990 to 2009. However, after 2010, the increased occurrence of heatwaves is significantly more volatile, a 21-point increase in deviation from the mean.

Figure 1: Heatwave Days, 1967–2023



Source: EnviStats India, MoSPI & author's calculations.

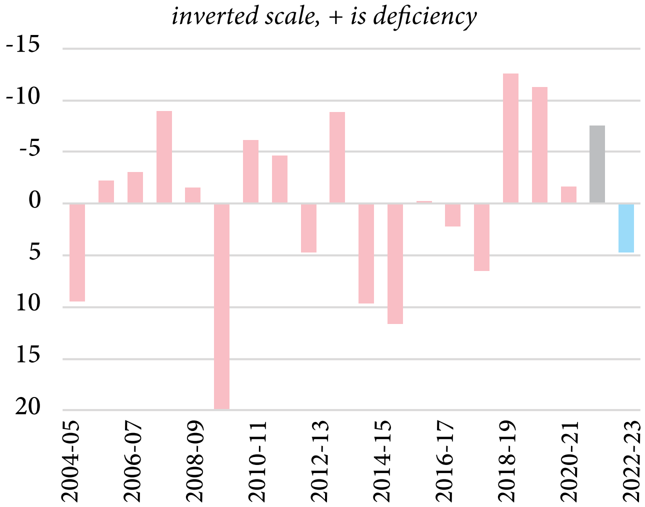
In 2022 alone, heatwave days surged an annual 555 per cent; at 190 days, this was 51 per cent above the 2010s average. Early heatwaves have become common; for example, February 2023 was the hottest since 1901. The year 2024 surpassed both years, including globally, while India again witnessed a further increase in the heatwave day count, duration, and above-normal temperatures by 2–4°C in northwest and central India.

Rising heat puts crops like wheat at risk, since wheat's flowering and ripening occur in these months. Early-season heat can shorten the growing period and reduce yields; experiments show that a temperature above approximately 30°C during grain-filling stages severely harms wheat. Global studies find heatwaves cause significant yield losses: for example, a Euro-Mediterranean study found that the 2003 heatwaves coincided with negative wheat yield anomalies in 13 of 39 production regions (Fontana et al., 2015). In India, research links higher temperatures to reduced wheat yields in the IGP and has documented that the 2010 heatwave cut output by 3–5 per cent in the key states (Punjab, Haryana, and Uttar Pradesh).

Rainfall patterns have also become more erratic. Rising temperatures are linked to extreme rainfall. Climate theory predicts, and observations confirm, that warmer air holding more moisture leads to heavier rainfall when storms occur, along with prolonged droughts elsewhere (US Environmental Protection Agency, 2024; GPM, NASA). However, the precise effects and location remain uncertain—some regions might experience prolonged droughts while others could face extreme rainfall and flooding. Research studies also underline aggravating dryness/wetness in the dry or heavy-rainfall areas with the rise in global temperature (for example, Donat et al., 2016).

In India, rainfall is increasingly more unpredictable and spatially uneven over the season (Prabhu & Chitale, 2024). Indeed, scientists note that India's monsoon is increasingly "punctuated with intense flooding and dry spells" (Arasu, 2024). Over the past decade, the swings in annual rainfall have widened at both national and regional levels. This especially occurs in the southwest monsoon season (June–September), where nearly three-fourths of India's annual rainfall is concentrated despite a large spatial dispersion (Guhathakurta et al., 2014). For instance, a string of five straight monsoon deficits in 2014–2018 were followed by four surplus years, displaying a more volatile pattern than in the earlier decades (Figure 2). Regional divergence has increased, with the IGP, a crucial rice-growing belt (Box 1), seeing comparatively more unpredictable rainfall patterns than the nation as a whole (Figure 3). In 2022–2023, consecutive El Niño years brought below-normal rains in the IGP (–20 per cent and –16 per cent, respectively, in 2022–2023), even as national monsoons remained near average.

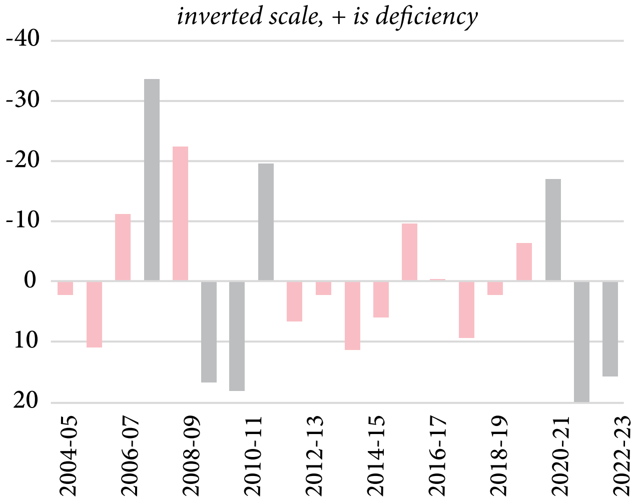
Figure 2: India: Rainfall Deficiency



Source: Indiastat with author's calculations. Deficiency = 100-Index of wetness.

*Index = Rainfall in any year at a given place/avg. annual rainfall *100.*

Figure 3: Indo-Gangetic Plain: Rainfall Deficiency



Source: Indiastat with author's calculations. Deficiency = 100-Index of wetness.

*Index = Rainfall in any year at a given place/avg. annual rainfall *100.*

The average rainfall surplus lowered to around 6 per cent a year over 1999–2023 from an annual average of 7.4 per cent in 1971–1998. Further, the distribution of rainfall is shifting toward more shortages: monsoon rainfall in the critical wheat and rice growing regions (especially the IGP) shows an increasing skew toward more frequent extreme deficit years—over 2012–2013 to 2023–2024, the skewness measures –0.39 for the IGP and –0.22 nationally, a remarkable swing from the corresponding 0.16 and 1.52 in the preceding decade. Much of the declining trend in the key monsoon season rainfall (southwest) is concentrated in the IGP, Northeast, and Western Ghat regions. The IGP is relatively more vulnerable to changing climate conditions and rainfall (Bhatla et al., 2023), inclining more sharply towards scarcity, with an accentuation in the most recent decade.

Box 1

The IGP are a meteorological sub-division with fertile soil and favourable climate, accounting for nearly one-third of the total rice output and with more than two-thirds of cultivated area. The IGP region (four sub-regions of IGP viz. East and West Uttar Pradesh, Bihar, Jharkhand, and West Bengal) alone contributes approximately 30 per cent of the total rice and paddy procured on average each year. Besides Odisha and Chhattisgarh, two other rice-cultivating states that are not strictly part of the core IGP, occasionally figure alongside because of similar geographical attributes, cropping patterns, and practices. Altogether, these states account for approximately 40 per cent of total rice/paddy procured; Uttar Pradesh, Punjab, and West Bengal dominates the kharif rice production at approximately 38 per cent in 2023–2024. The kharif produce in the IGP states makes up 16–17 per cent of the total public procurement of rice and paddy (with India exporting approximately 40 per cent). IGP states are major producers of non-basmati rice, forming approximately 99 per cent (Rice of India, n.d) of India's total rice production; this is mostly small-scale farming for self-consumption. Non-basmati rice is a cheaper, coarse white grain rice that is the main mass consumption and export (approximately 75–81 per cent of export volumes in 2020–2022, before the export ban).

Basmati, on the other hand, is long-grain white rice, cultivated relatively large scale in Punjab and Haryana, and approximately 25 per cent of total rice export. The winter or rabi crop is located mostly in the southern states of Telangana, Andhra Pradesh, and Tamil Nadu. These together account for 22.5 per cent of total rice production. These three states dominate the rabi rice production (nearly 100 per cent).

2.2 Impacts on Wheat and Rice Yields

Heat and rainfall shocks directly threaten foodgrain yields, especially wheat (a rabi or winter crop) and rice (a kharif or summer crop). High temperatures during flowering and grain-filling accelerate crop maturation and can drastically cut yields. For example, agronomists note that each degree Celsius above 30°C during wheat's critical stages lowers pollination and grain development (Bal et al., 2022; Dubey et al., 2020). Similarly, erratic rainfall—both excesses and deficits—can harm crops. While the interlinkages between rising temperatures and rainfall extremes can jointly affect wheat and rice crops, the effects are unpredictable and varied, as the changes are complex and incompletely understood.

A multi-country analysis over 1990–2017 reveals rice yields rise with rainfall up to an optimal level but fall by approximately 20–34 per cent when rainfall is either 33 per cent above or below normal levels (Maiti et al., 2024). For Indonesia, wetland and dryland paddy crops show raised probabilities of lower yields with climate-related events like droughts and floods (Prasetyo & Kadir, 2023). Declining rainfall during the reproductive growth phase of Thai Jasmine rice significantly affected yields in Thailand, exceeding the impact from temperature changes; as a result, a significant decline in yields is predicted by the 2080s (Boonwichai et al., 2019).

For India, rising temperatures are found to be a major driver of wheat loss in the IGP (Zachariah et al., 2021). The 2010 heatwaves are estimated to have lowered wheat yields in the northern Indian region by 4.9, 4.1, and 3.5 per cent in Punjab, Haryana, and Uttar Pradesh, respectively (Chakraborty et al., 2019). More recent research (Narayanan & Behera, 2025) underlines the impact of increasing rainfall variability upon food-crop production in India. The extent of damage from climate-change-driven dry or hot anomalies in temperature and rainfall varies; these are unique for different crop yields, for example, high temperatures mainly impact wheat fertilisation, whereas volatile temperatures and rainfall together have a significant impact upon aggregate output (Gupta et al., 2023).

Empirical data reflects such damage in 2022–2024. Wheat production fell by 1.7 per cent in 2021–2022 (Rabi 2022) when March heat struck, then stagnated over 2022–2024; the four-year growth averaged only approximately 1.2 per cent, a quarter of the pre-2020 pace (Table 1). Rice output also dipped: below-normal rains in key rice zones (IGP) caused rice production to undershoot official estimates by 19 per cent in rabi 2023 and 8 per cent in rabi 2024 (Table 3). These concurrent crop failures were unprecedented. Notably, both wheat and rice suffered shortfalls: all three of India's major crops—rabi wheat, rabi rice, and kharif rice—saw production below targets in 2022–2024. Such a "trifecta" of rice and wheat shortfalls is rare; the last comparable event was more than a decade ago.

2.3 Foodgrain Output and Procurement Trends

The climate shocks impacted cereal output as well as official procurement (Tables 1–3). In wheat, the climate stress of 2022 hit output modestly, while production held up thereafter despite continuing weather aberrations, viz., unseasonal rains (in March 2023), intense cold and fog in MP (in November 2023), and untimely heavy rains and hail (February 2024). Yet procurement, or the share of output bought by government agencies, collapsed: wheat procurement fell from approximately 35 per cent of output in the pre-2020 period to about 17 per cent in 2021–2022, a shortfall of 24.5 million tonnes (MT) in one year. For consecutive rabi marketing seasons to 2024–2025, procurement was short of target by 58, 23, and 29 per cent, respectively.

Wheat stocks—key to India's food security buffer—plunged even more: by early 2024, buffer stocks were down over 90 per cent relative to 2019–2021 levels (Column 5, Table 1). In effect, rising output in 2023–2024 did not translate into higher public stocks or procurement, leaving carryover supplies at a precarious minimum.

State-level data reveal MP as the epicentre of this mismatch (Table 2). The state has emerged as India's largest wheat producer (surpassing Punjab) with expanding acreage in the last decade and a half. In 2021–2022, MP's wheat output rose by approximately 6 MT, yet its procurement share fell to just 20 per cent of its harvest, down from 66–70 per cent in the prior two years and a 40 per cent annual average in 2016–2019. This is stark: MP had contributed approximately 42 per cent of national procurement in 2012–2019, rising to roughly the same share as Punjab and Haryana by 2019. However, in 2022–2024, MP's procurement share collapsed to roughly 25 per cent, while Punjab and Haryana saw only modest declines in their purchase rates in line with the drop in production.

Table 1: Wheat—Production, Procurement, Stocks

Agriculture Crop Year (July-June)	Production (MT)	Procurement (MT)	Procurement/ Production	Stock (MT)
2012–13	93.5	25.1	0.27	24.2
2013–14	95.9	28.1	0.29	17.8
2014–15	86.5	28.1	0.32	17.2
2015–16	92.3	23.0	0.25	14.5
2016–17	98.5	30.8	0.31	8.1
2017–18	99.9	35.8	0.36	13.2
2018–19	103.6	34.1	0.33	17.0
2019–20	107.9	39.0	0.36	24.7
2020–21	109.6	43.3	0.40	27.3
2021–22	107.7	18.8	0.17	19.0
2022–23	110.6	26.1	0.24	8.3
2023–24	112.9	26.5	0.24	7.5

Source: Various issues of Food Grain Bulletin, Department of Food and Public Distribution, GoI.

Table 2: Wheat—Procurement-to-Production Ratio in Key States

June–July	Madhya Pradesh				Punjab				Haryana			
	Area (1000 Hectares)	Pro-duction (MT)	Procure-ment (MT)	Procure-ment/ Produc-tion	Area (1000 Hectares)	Pro-duction (MT)	Procure-ment (MT)	Procure-ment/ Produc-tion	Area (1000 Hectares)	Pro-duction (MT)	Procure-ment (MT)	Procure-ment/ Produc-tion
2012-13	5300	13.1	6.4	0.48	3512	16.6	10.9	0.66	2497	11.1	5.9	0.53
2013-14	5380	12.9	7.2	0.56	3512	17.6	11.6	0.66	2499	11.8	6.5	0.55
2014-15	6002	17.1	7.3	0.43	3505	15.1	10.3	0.69	2601	10.4	6.8	0.65
2015-16	5911	17.7	4.0	0.23	3508	16.1	10.6	0.66	2576	11.4	6.8	0.59
2016-17	6028	17.9	6.7	0.37	3495	16.4	11.7	0.71	2558	11.5	7.4	0.64
2017-18	5316	15.9	7.3	0.46	3512	17.8	12.7	0.71	2440	10.8	8.8	0.82
2018-19	5520	16.5	6.7	0.41	3520	18.3	12.9	0.71	2553	12.6	9.3	0.74
2019-20	6551	19.6	12.9	0.66	3521	17.6	12.7	0.72	2534	11.9	7.4	0.62
2020-21	6083	18.2	12.8	0.70	3530	17.2	13.2	0.77	2564	12.4	8.5	0.69
2021-22	6500	23.0	4.6	0.20	3525	14.9	9.6	0.65	2305	10.4	4.2	0.40
2022-23	7150	24.0	7.1	0.30	3508	16.5	12.1	0.74	2376	11.1	6.3	0.57
2023-24	–	–	4.8	–	–	–	12.5	–	–	–	7.1	–

Source: (i) RBI Handbook of Statistics on Indian States; (ii) Various issues of Food Grain Bulletin, Department of Food and Public Distribution, Government of India; and (iii) Agricultural Statistics at a Glance 2022, Department of Agriculture & Farmers Welfare, GOI.

Table 3: Rice—Procurement-to-Production Ratio

Agriculture Crop Year (July–June)	Production (MT)	Procurement (MT)	Procurement/ Production	Stocks (as on April 1)
2012-13	105.2	34.0	0.32	NA
2013-14	106.7	31.8	0.30	NA
2014-15	105.5	32.0	0.30	17.1
2015-16	104.4	34.2	0.33	22.2
2016-17	109.7	38.1	0.35	23.1
2017-18	112.8	38.2	0.34	24.9
2018-19	116.5	44.4	0.38	29.4
2019-20	118.9	51.8	0.44	32.2
2020-21	124.4	60.2	0.48	29.1
2021-22	129.5	57.6	0.44	32.3
2022-23	135.8	56.9	0.42	24.9
2023-24	136.7	50.1	0.37	30.2

Source: Various issues of Food Grain Bulletin, Department of Food and Public Distribution, GoI.

The MP anomaly is unusual. The reasons could be several; for example, region-specific vulnerabilities and/or weather disturbances because other states saw milder or no declines. There could also be methodological issues with yield estimation that merit deeper examination; the traditional "crop-cutting experiment,"[1] the basis of official production estimates, is centuries-old[2] (Bera, 2022) and could be failing to capture localised dissimilarities. Differential cross-district damage to wheat yields in Punjab and MP following the recent shocks was reported in a wide range of 5–30 per cent in MP. The causes of the widening cross-state and cross-district variations amongst wheat producers require scientific evaluation for understanding damage to yields from weather anomalies. This is important from the standpoint of foodgrain sufficiency and security, as MP has been the key source of the increase in India's wheat production in the last 15 years, and a major contributor to public purchases.

For rice, similar patterns emerged (Table 3). Sequential rainfall shortfalls in the IGP pushed down yields in 2023 and 2024. In 2022–2023, rice output fell approximately 19 per cent below targets in the rabi season and approximately 1 per cent below in kharif; a repeated approximately 8 per cent rabi shortfall followed in 2023–2024. Rice procurement ratios also dipped: only approximately 37 per cent of production was procured in 2021–2024, versus an average of 45 per cent in the prior period.

To manage the crisis, the government increased rice procurement beyond normal requirements for the Public Distribution System (PDS) to substitute for wheat shortages, partly offsetting the crop losses. Increased offtake of foodgrains, and the consequent decline in wheat stocks, during these years was also owed to pandemic-relief measures providing extra foodgrains—5 kg for each eligible person per month above the National Food Security Act (NFSA), 2013, entitlement[3] to 800 million persons (Department of Food and Public Distribution, n.d.).

In sum, the dual crop failures of 2022–2024—wheat and rice in back-to-back years—strained the food supply. The unusual outcomes—record heat, regional drought, and mismatches between production and procurement—suggest that such disturbances may differ from past volatility. While the simultaneous cereal crop failures in succession are cautionary from several perspectives, viz., future predictions of higher

1 Crop-cutting experiments are conducted in specific plot sizes of random selection to estimate yields of the harvested grain amounts.
2 Todar Mal, finance minister of Mughal Emperor Akbar (1556–1605), instituted the framework for revenue collections after a thorough survey of crop production and prices.
3 National Food Security Act, 2013, covers up to 75 per cent of rural and 50 per cent of urban populations, entitling 35 kg of foodgrains per family/month to the poorest of the poor (Antyodaya Anna Yojana), while priority households (PHs) receive 5 kg per person/month. The pandemic time relief (April 2020) doubled allocation from 10.6 million tons (2020–2021) to 20.2 million tons next year, moderating to 7.44 million tons in 2022–2023. The scheme was extended by another year to December 2022, merging thereafter with the NFSA entitlements extended by five years in January 2024.

temperatures, heatwaves, and deficient rains, the coincident impact upon foodgrain yields, and consequences for food security, prices, supply management, and policy challenges are considered later.

3. Supply-Side Response and Policy Management

India has long managed food prices, especially for core cereals like wheat and rice. A prominent strand of food policy focuses upon security and price stabilisation, objectives that are realised by maintaining public stocks with specified quarterly norms and regular public purchases for public distribution, welfare schemes, and market interventions. Another strand, since the 1960s, starting with the green revolution, is centred around improving crop productivity—the main elements include research and development of newer and resilient grain varieties, knowledge extension and technology dissemination, public investments in irrigation and marketing infrastructure, farm price support, and input subsidisation (for example, fertilisers, fuels, etc.). Agricultural trade remains highly restricted to maintain a net exporter status.

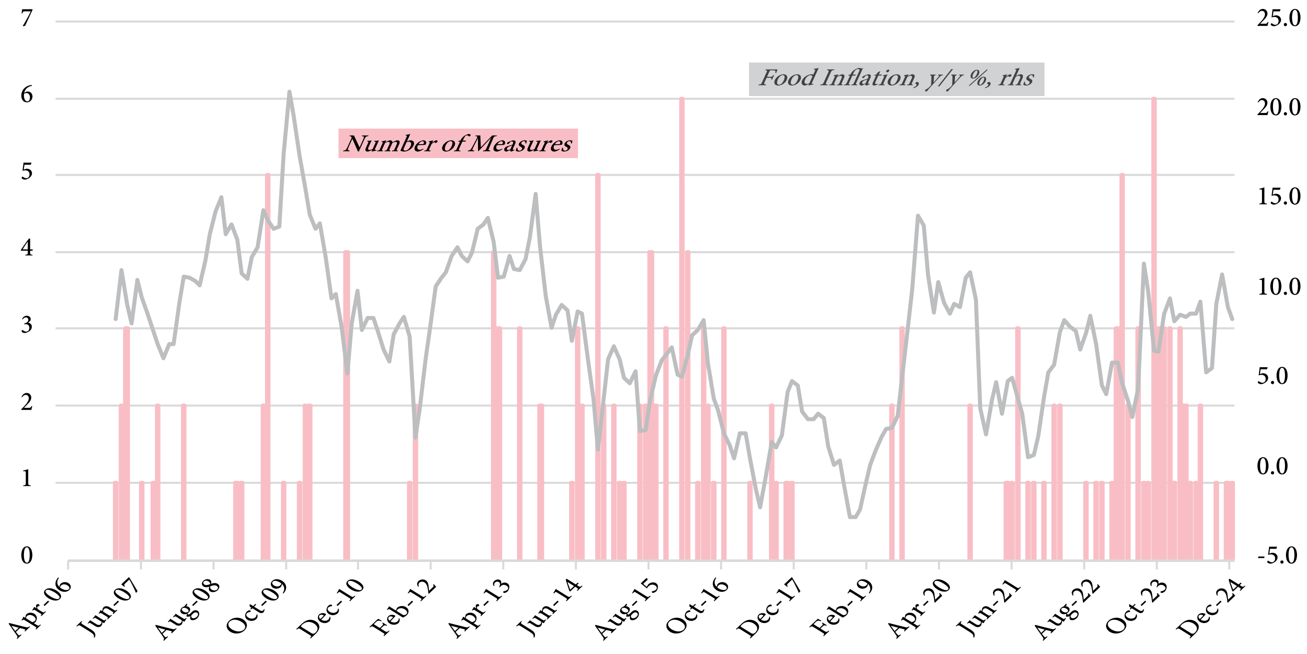
Against this backdrop, India's response to the foodgrain shortfalls has involved aggressive supply-side interventions. The strategy has been two-pronged. One, a broad-based deployment of tools spanning administrative controls, market interventions, tariffs, price caps, and outright export prohibition. The second is substitution in public distribution and welfare programmes to counter the rapid relative price rise of wheat. The supply management has been comparably far more aggressive than in the past.

3.1 Market Interventions and Restrictions

As shown in Figure 4, the number of different restrictions upon domestic and external trade of rice and wheat, besides some other important food items of daily consumption like pulses, onions, etc., has increased steadily from June 2005 to end-2024. The comprehensive coverage includes quantitative, administrative, and price limits at various intervals. Since 2021, authorities have deployed a wide range of tools: controlling exports, raising import duties, restricting stockpiling, and mandating higher distribution of alternative staples. The number of restrictions and interventions has grown steadily.

For example, as of 2024, India had imposed over twice as many trade and stock limits in recent years—28 measures in 2023–2024 alone—as in the preceding two-year period (12 measures during 2021–2023). Every month since mid-2022 has seen at least one new curtailment: six different measures were added in September 2023, including three successive rounds of wheat stockholding limits. These measures have been more severe and enduring than in previous episodes. By comparison, the 2009–2011 and 2015–2016 food crises also saw controls, but none matched the density and duration of the 2021–2024 period.

Figure 4: Agriculture Restrictions and Food Price Movements



Source: Various Press Information Bureau (PIB) releases.

Major crops were directly targeted. Wheat and non-basmati rice exports were banned outright or subject to strict limits to conserve domestic supplies. India's switch from being a net rice exporter to banning exports (for non-parboiled white rice starting July 2023) also disrupted global markets: Thailand's rice price index rose approximately 22 per cent after the ban while India's rice exports are estimated to have fallen approximately 21 per cent to about 4.2 MT in 2023–2024 (Glauber & Mamun, 2024). A 40 per cent duty on wheat imports also remained throughout 2022–2024, despite mounting shortages, reflecting a preference for self-sufficiency over imports.

These policies helped stabilise domestic prices by augmenting domestic supply and curbing external outflows, but at the cost of global price spikes and narrowed import avenues. In practice, India's status as the world's second-largest rice exporter and a top wheat producer implies that export bans had significant international repercussions, especially for poorer importers.

Additional measures included extensive open market sales of wheat through public auctions to dealers and millers; these tripled from 3.5 to 9.4 MT per year by 2023–2024. Quantitative limits were imposed on traders' stock holdings for wheat, rice, and even pulses, capping private inventories to curb speculation. Retail price caps on certain staples, tightened quality and movement controls, and incremental changes to state procurement rules also featured. In short, policy emphasis has been on administrative supply constraints rather than market liberalisation.

These aggressive controls have indeed slowed the price acceleration of cereals, but at a cost. Distortions are evident: export bans and stock caps fragment markets and reduce private participation. For instance, after export bans, India's broken rice exports plunged - a reported 95 per cent year-on-year drop in broken rice shipments in late 2023 (Glauber & Mamun, 2024). Domestic traders faced disincentives: consistent export controls and import taxes meant they could not use trade to smooth shortages, dampening the price-stabilising effects of global markets.

3.2 Substitution

A parallel strategy was rationing and substitution. Substitution is an appropriate response to sharp relative price changes because poorer consumers often substitute cheaper grains when faced with rising wheat prices, especially if households' real incomes lag. However, it raises fiscal costs—buying and distributing more rice—and may distort crop choices if prolonged.

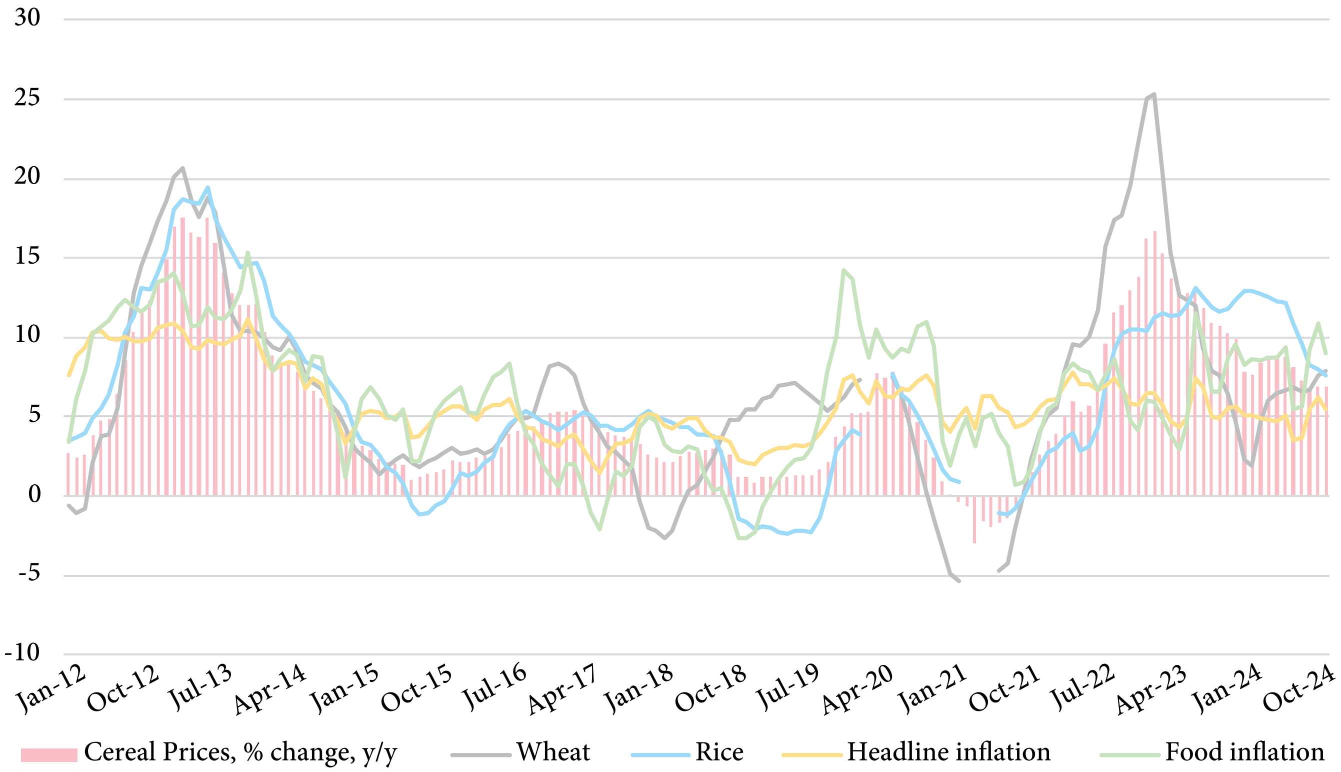
In 2022, noticing that wheat prices were outpacing rice, the government doubled the quantity of rice versus wheat[4] (long-term ratio, 1.3:1) supplied through welfare food programmes in 2022–2024 (Sharma, 2022). This shift aimed to conserve wheat stocks, prevent further price rises, and utilise the overflowing rice stocks from higher procurement and a robust production recovery. By increasing rice in the PDS, authorities limited the depletion of wheat stocks, whose deficit was compounded by the extension of the supplementary food relief (an additional demand of 13.7 MT) after December 2022 (see Footnote 4).

Overall, policymakers have relied almost exclusively on supply management: expanding public procurement, releasing food from stockpiles, and legally forcing lower private stocks. The immediate effect has been to contain food inflation to some extent; possibly, the price rise may have been far higher without the supply-side responses. But it raises questions about efficiency, spillovers to other sectors (for example, discouraging private investment in storage), and sustainability if climate shocks persist and aggravate. For instance, the persistence of the wheat price rise is notable despite steady open market sales since 2020–2021. Likewise, a discord in rice output, procurement, and stock abundance with the sustained price pressures despite increased public distribution and open market sales is equally puzzling. It is unclear if the latter reflects a lower stock of non-basmati rice, the major consumption and export item that was banned in early 2022, or overestimated output in the IGP, where rainfall has been deficient.

[4] On May 4, 2022, the Indian government revised the rice–wheat allocations for the poor relief (supplemental food assistance) scheme (Pradhan Mantri Garib Kalyan Package) for May–September 2022. On May 14, 2022, officials stated that the rice-wheat allocation ratios for public distribution under the NFSA programmes had been changed.

4. Food Inflation Dynamics

Figure 5: Price Dynamics



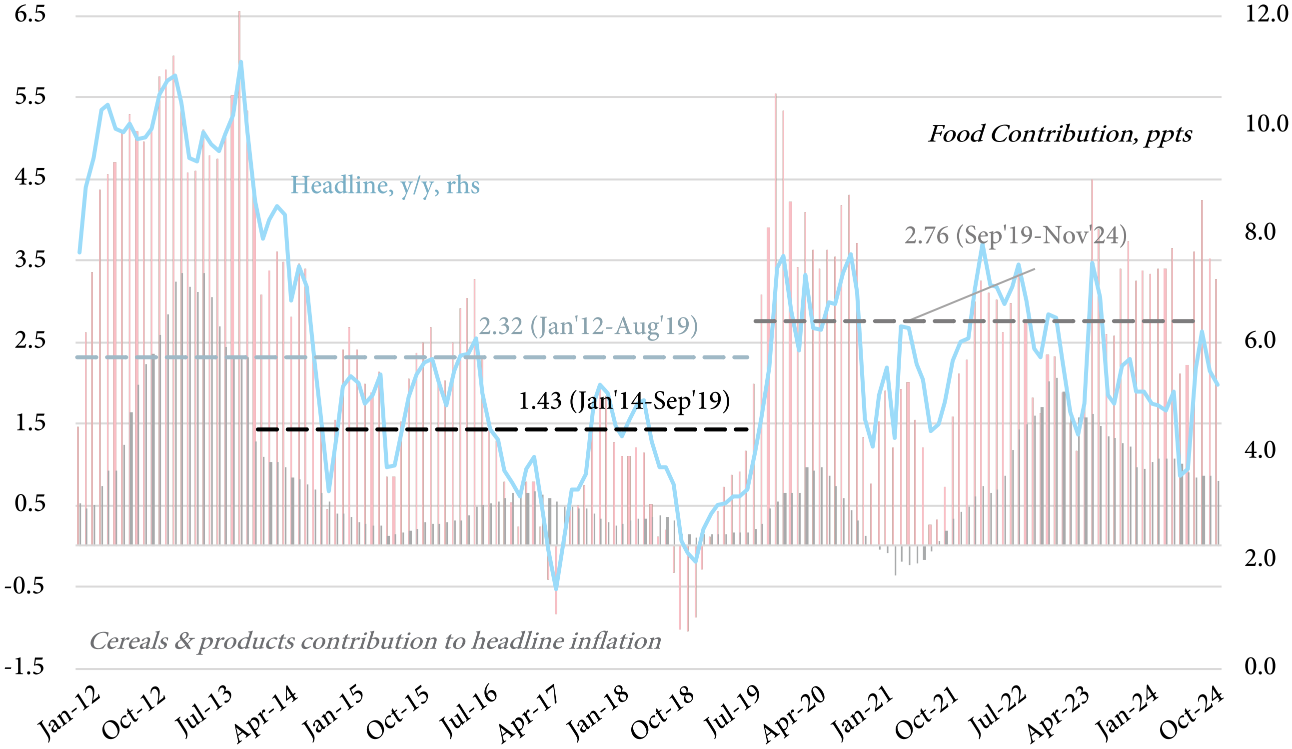
Source: NSO and author's calculations.

The economic implications of climate-induced agricultural shocks extend well beyond production shortfalls. For over five years, food inflation has displayed a pronounced persistence, increasing divergence from core inflation, and heightened volatility—all pointing to significant changes in inflation dynamics. Unlike past inflation cycles, inflationary pressures have remained elevated even during periods of moderate harvests, suggesting deeper and more chronic supply constraints due to an unprecedented combination of climate extremes. Several factors appear to have sustained this food-price surge. First, repeated crop shocks have kept supply tight. Second, market uncertainties have been accentuated. Third, forceful supply management may have potentially impacted prices. Finally, expectations and second-round effects may have contributed to making food inflation "sticky"; given successive bad weather years, households expect food will stay expensive.

Persistent Price Pressures: Figure 5 shows retail inflation has been above the 4 per cent target (range ±2 per cent) for nearly five years. The upward pressures largely originated from output deficits in wheat and rice (index weight: 45.86), along with intermittent disruptions from vegetables and oilseeds. Mathematically, food price indices are up by 40–50 per cent in three years. Monthly price volatility has also increased, particularly in cereals; for example, the standard deviation in month-on-month wheat inflation has nearly doubled since 2021. Moreover, inflation patterns now vary significantly across states, depending on the severity of local weather anomalies and access to market buffers.

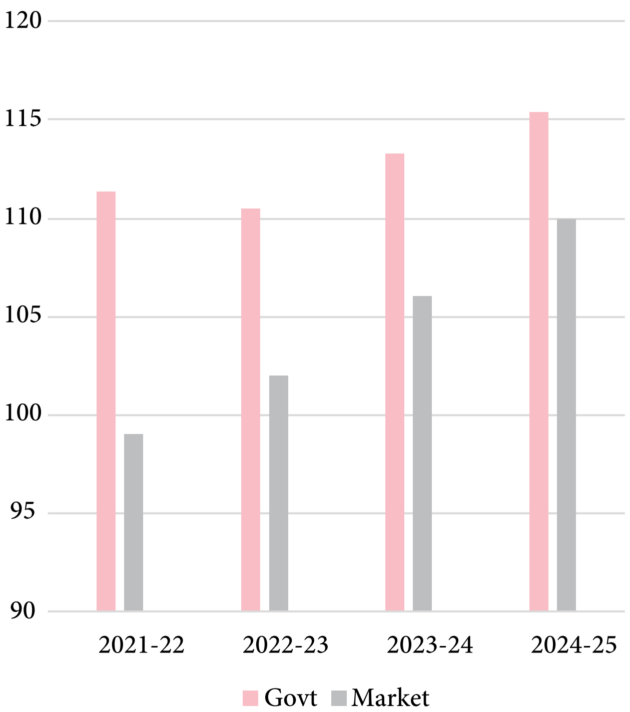
Changing Contribution to Headline Inflation: From late 2019, food prices emerged as the dominant driver of headline inflation. Between September 2019 and November 2024, food inflation added an average of 2.76 percentage points each month to retail price growth against a substantially lower contribution (1.43 points) in the preceding interval from January 2014 (Figure 6). Disaggregation shows that cereals—particularly wheat and rice—have disproportionately driven this trend. These accounted for more than one-fifth (21 per cent) of total inflation since February 2022, when heat conditions first intensified. The cumulative buildup of supply shocks further raised the contribution to headline inflation after July 2023 to more than 63 per cent, which was double the average monthly addition in the previous period.

Figure 6: Food and Cereal Inflation: Contribution to Headline Inflation



Source: CSO and author's calculations. Dashed lines are period averages, food inflation contibutions to headline.

Figure 7: Wheat Output Estimates: Increasing Divergence with Markets (in MT)



Source: Second Advanced Estimates, MoSPI and Flour Miller Association.

Market Uncertainties: Market behaviour and price responses are also influenced by divergent estimates of expected crop losses and supplies, including privately held stocks, and government policy reactions. These factors may be a likely force for the unusual continuity in food inflation and its changed behaviour. Figure 7 illustrates the wide divergence in market assessments and official output estimates, an indication that market signals and prices were aligned with a bigger-than-expected production deficit.

The production–procurement–stock inconsistencies detailed previously undoubtedly caused confusion and uncertainty, adding to the price build-ups from 2022. Figure 5 shows wheat prices surged along with temperature, defying government estimates predicting little damage on February 16, 2022 (111.3 MT, second advance estimate). Instead, market beliefs converged towards a significant shortfall, conviction about official overestimation or miscalculated crop damage grew,[5] expectations of wheat imports to bridge the gap rose, lifting wheat prices continuously to a 25 per cent high in February 2023. Higher future price expectations likely led farmers to withhold stocks as well.

[5] Private trade assessed wheat output at 90–100 MT; US Department of Agriculture's Foreign Agricultural Service field visits-based assessment in late May was under 99 MT. Official estimates contrasted at 106.4 MT (third round, May 16, 2022), approximately 5 MT lower than in February, while the fourth (August 17) and final estimates were a respective 106.8 and 107.7 MT (Table 1).

Policy Interventions: There are hints that these have had mixed effects. The relentless price increase, for instance, is exceptional in light of the extreme and numerous steps to restrict trade; several followed in quick succession, verging upon panic and coalescing price expectations. For instance, despite massive open market wheat sales—a trebling to 9.4 MT in 2023–2024 and steady stock releases—retail food price growth stayed high (Kohli, 2024b). Food supply management was also pressured because of the failure to replenish the additional 38.1 MT of wheat distributed by the government for the three pandemic years (Kohli, 2024a). Likewise, rice stocks filled up (due to substitution),[6] but substitution also buoyed rice demand and prices. For example, in 2022, rice prices surged simultaneously with wheat, although the crop was unaffected (Figure 5; Das, 2025). Open market sales of rice in 2024–2025 were tenfold (1.96 MT) than the year before (0.19 MT) to cool prices amidst plentiful stock.

Then, continued export bans and high import duties prevented international price relief. Even as record wheat was sold domestically, it faced higher domestic wheat prices because international arbitrage was blocked, which further aggravated the price rise. Altogether, the interactions and feedback of concurrent crop failures, market pressures, and the severity of trade restrictions could form a sustained price spiral, which was seen in this instance. *While* extreme supply-side controls seem to have slowed price rises, these also removed traditional outlets (export/import) that might have eased pressure. Policy may have also miscalculated supplies when continuing additional foodgrain relief beyond 2022 expectation of replenishing from normal harvest ahead. Altogether, these events fed into and fuelled future expectations of both wheat and rice prices in further entrenchment (Kohli, 2023). A formal investigation is essential to underpin the interlinkages and disentangle the individual effects.

[6] Das (2025) reported that at 59 MT, rice stocks exceeded the July 1 norms (13.5 MT) despite record releases in 2024–2025 for public distribution, ethanol, Bharat rice, and open market sales. High procurement and output contributed to the surplus, raising concerns over storage, and rising food subsidy costs.

5. Are Recent Shocks Structurally Different?

A critical policy question is whether the recent climate shocks and their economic consequences reflect temporary anomalies or signify a structural transformation. The clustering of extreme climate shocks and food stress in 2022–2024 are marked departures from the past with few parallels. To evaluate this, the 2021–2024 episode is compared with past instances of major agri-climatic disruptions such as 2009–2010 and 2015–2016 across four dimensions: climate severity, crop outcomes, supply-side responses, and price behaviour. Table 4 outlines key differences compared to past episodes.

Climate Intensity and Frequency: The recent period has not only witnessed record-breaking temperatures but also a shift in the distribution and clustering of extreme events. In contrast to past episodes, current patterns reflect a more systemic and sustained deviation from historical norms. Notably, 2022–2024 featured record-breaking continuity: three consecutive years of unprecedented heat, with each beating previous records. In contrast, past heat spells were relatively isolated. Heatwaves have also advanced: major heat events now begin in March or even February, against the usual April–June. This change is critical because an earlier heat onset hits winter crops before full maturity.

Rainfall anomalies are also less synchronised than before. In 2022–2024, the national monsoon and IGP rainfall diverged in ways rarely seen. The IGP saw deep deficits in 2022 and 2023 (−20 and −16 per cent) at the same time that national rainfall was near normal. Such consecutive deficient monsoon years in the IGP occurred only once a decade ago (2010–2011). Temperature and rainfall shocks are also becoming correlated: during 2014–2024, hotter years have tended to coincide with drier monsoons, indicating a compounding effect—the India-wide correlation in the last decade, 0.31, is remarkably stronger than the long-term 0.17 (1901–2024). The three-year streak of extreme heat in 2022–2024 strengthens this: 2024 alone was India's hottest year ever, with a mean temperature of +0.65°C above the 1981–2010 normal. Such multi-year alignment of heat and region-specific rainfall deficit deviates from past patterns, hinting that climate change may be raising the odds of these trifecta events.

Simultaneous and Sustained Crop Impacts: The differences in climatic patterns are reflected in agricultural outcomes. Previous shocks typically affected either wheat or rice or were localised to specific growing seasons. By contrast, the 2021–2024 phase impacted both wheat and rice more severely than before. Although wheat production recovered in 2023–2024 to decade highs in absolute terms, procurement and stocks did not: the rabi 2023 and 2024 procurement shortfalls of −58 and −23 per cent of targets, respectively, far exceed anything in 2009–2011 or 2015–2016. In rice, 2022–2023 saw unusually large losses, at −20 per cent. In both crops, the "output–procurement gap" widened: wheat stocks by late 2023 were 96 per cent below their pre-crisis level, compared to much smaller drawdowns in past shock events.

Wheat has suffered from terminal heat stress in the rabi seasons, while rice has faced late sowing and moisture deficits in both seasons. In particular, the growing severity of heatwaves and rainfall deficiency, especially in the IGP (West and East Uttar Pradesh, Bihar, Jharkhand, and Gangetic West Bengal), could be early hints of the potential impact of climate change. The simultaneity of these effects suggests not a one-off crisis, but a deepening mismatch between climate rhythms and cropping calendars. The most concerning feature of recent years is the concurrent impact on both wheat and rice—crops that typically have offsetting seasonal cycles. This simultaneous disruption underscores a broader systemic risk emerging from climate volatility.

Escalation in Policy Response Intensity: The frequency and layering of supply-side policy tools, viz., export bans, open market sales, and substitution of PDS allocations, suggest a sensitive and strained policy environment. Since 2009–2010, the number, frequency, and endurance of restrictions to manage supplies have become progressively more demanding. Illustratively, a review of trade notifications from the Directorate General of Foreign Trade (DGFT) reveals a threefold increase in agriculture export circulars from the 2015–2019 period to the 2020–2024 period. An outstanding feature is that the supply shocks to foodgrains have not been offset through imports as they have for pulses; rather, outright prohibition of exports (e.g., rice) is favoured. This leaves policymakers with one less instrument to deal with food shocks, especially when they are continuous and uncertain. Moreover, inflation outcomes have remained sticky, possibly an indication of diminishing marginal returns to such interventions. This raises questions about the sustainability of these measures under prolonged climate stress.

Table 4: Is it different this time?

	2009–10, 2010–11	2015–16, 2016–17	2021–22, 2022–23, 2023–24
Climate-Change-Related Shocks			
Heatwave days			
percentage increase, y/y	414, 51 1/	-40.2, 74.4 1/	555.2, -41.6, 1/
duration	Apr–Aug, Apr–Jun	Mar–Jun, Apr–July	Mar–May, Mar–Jun, Mar–Jun
Temperature			
absolute, °C	26.05, 26.04	25.93, 26.21	25.93, 26, 26.15
percentage increase	1.92, -0.04	0.74, 1.08	0.58, 0.27, 0.58
Rainfall deficiency			
per cent deviation from long period average2/			
National	19.8, -6.11	9.6, 11.6	-1.67, -7.5, 4.7
Indo-Gangetic Plains	16.8, 18.1	11.3, 5.9	17.1, 19.8, 15.6
Production, Procurement, Stocks			
Wheat			
change in output, million tons	0.12, 6.1	5.8, 6.2	1.7, 2.6, 2.1
period change in procurement, %	-0.44	-9.7	-38.8
period change in stocks, %	14.2	-53.2	-69.6
Rice			
change in output, million tons	-10.1, 6.9	-1.1, 5.3	5.1, 6.3, 0.9
period change in procurement, %	0.29	19.1	-16.8
period change in stocks, %	30.6	35	-6.5
Supply Management			
Number of restrictions			
year 1	11	16	12
year 2	6	20	12
year 3		6	28
Prices 3/			
Wheat			
y/y per cent, cum	10.37, -1.47	10.6	35.4
change in index	10.05, -1.46	13.6	52
Rice			
y/y per cent, cum	10.80, -0.43	6.5	30.2
change in index	10.63, -0.44	8.4	44.1
Food			
y/y per cent, cum	25.3	7.3	21

Source: Foodgrain bulletin, Mospi, Environstats with author's calculations 1/ When actual maximum temperature remains 45°C or more irrespective of normal maximum. 2/Long Period Average (LPA)-rainfall in specific region, interval over 30-35 years. Current LPA (All India southwest monsoon, 2004-05 to 2023-24 average, 860.26 mm). Large excess, excess, normal, deficient, and large-deficient rainfall =≥60, 20-59, -19-19, -59 to -20, -99 to -60% of LPA (IMD) respectively. 3/2009-11 - CPI (Industrial Workers).

Emergence of Persistent Price Shocks: These have been unique and exceptional in relation to the past in the case of food prices. Several metrics point to changed behaviours, the foremost being a shift in the food price level and non-mean reversion. Over 2021–2024, domestic wheat prices rose approximately 52 index points, nearly doubling, while rice prices increased by approximately 44 points. These exceed the typical pre-pandemic movements. For context, Indian food inflation rose approximately 41 points (year-on-year headline CPI) during 2009–2011, coinciding with the global surge—the Food and Agriculture Organization (FAO) cereal price index increased 45 points—before falling back thereafter. Whereas in 2021–2024, domestic cereal prices have stayed very high despite the decline in international prices in 2022–2023. The recent price surge rivals 2009–2011 levels and suggests that domestic factors are the key drivers, as indeed acknowledged by the government (Government of India [GOI], 2025).

In summary, the 2022–2024 shocks stand out for their intensity, duration, and coincidence. Three back-to-back record heat years, a growing divergence of national versus regional rains, and simultaneous rice and wheat crop failures are unique. Collectively, these patterns suggest more than just weather-related volatility. It could signify changes in the climate-food-economy relationship that could endure or aggravate with intensifying anomalies related to climate change. It is difficult to ascertain if the shift is structural at this early stage. While holding such conclusions, the differences and experience in managing these shocks have policy implications covered in the next section.

6. Policy Implications and Possible Solutions

The detailed patterns and evidence also unearth multiple weaknesses and contradictions in existing policy frameworks when exposed to sustained supply pressures. Policy must regard these as potentially the new normal rather than transitory anomalies in light of heightening climate risks and associated concerns expressed by policymakers. For example, the central bank has regularly flagged the increased frequency and persistence of supply shocks due to climate change and “climate risk” as a key uncertainty in its policy statements and review deliberations (Reserve Bank of India [RBI], April 2024). Past policy templates may no longer suffice, and new frameworks must incorporate climate risk as an important determinant of both food security and macroeconomic management. The following inferences can be drawn for further policy considerations.

Food Security and Self-Sufficiency: A long-standing policy has been to ensure foodgrain self-sufficiency via procurement and buffer stocks. However, increasingly frequent extreme weather may challenge this model. Persistent heatwaves and erratic rains undermine crop yields even in irrigated areas and could hurt India’s cereal self-sufficiency, undermining its Green Revolution successes. Short-term disruptions triggered by El Niño weather conditions and droughts have so far been manageable through expanding irrigation networks, watershed management, etc. However, the longer patterns in which simultaneous heat and drought events will become more common (IPCC, 2023) point to the need for preparation for such eventualities with lasting policy solutions and responses.

The 2022–2024 experience, with all major staples faltering, suggests that purely domestic self-sufficiency may become elusive unless specifically addressed. In the short run, policymakers must weigh whether to continue disincentivising imports (e.g., via high duties) or to allow more international trade as a shock absorber. So far, import tools have been largely unused, which leaves only domestic measures. In the future, having some import flexibility could provide an important safety valve, although it may face political resistance as well as global challenges.

Over the medium and longer term, suitable adaptation strategies in the wheat-growing states assume importance. It is widely acknowledged that wheat output fell across Punjab, Haryana, and MP with extreme heatwaves in March 2021–2022; e.g., Sidhu (2023) estimates that relative to a normal year (median of 1992–2021 climate), national wheat production is expected to have fallen by 4.5 per cent in 2022, with some regions experiencing wheat yield losses of up to 15 per cent. However, there’s no clarity about the steep fall in procurement in MP in FY2023–FY2024 despite an enhanced cultivation area, extensive irrigation, and without reported crop damage from extreme hailstorms. It is possible that wheat yields in states like MP may be affected by milder but persistent heatwave conditions, or that the region may be more vulnerable to winter onset, duration, and untimely rains. Accounting for almost 24 per cent of India’s wheat production in recent years, MP’s growing share has significantly bolstered supply, imparted stability, and helped offset ecological pressures in Punjab and Haryana. Given these factors, the government must reassess regional vulnerabilities.

Third, the conscious reform agenda for Indian agriculture has been to encourage farmers in Punjab and Haryana to switch to cash crops, given the lower water table contributing to salinity and deteriorating soil fertility. The strength of this critical advice was based on significant output increases in MP in recent years, assuring self-sufficiency. A temporary pause or recalibration of the crop-switch initiative in Punjab and Haryana may, however, be necessary until climate-resilient wheat varieties and adaptive measures are more widely adopted, including in MP. This is a scientific call, as the groundwater conditions are believed to be acute and irreversible in Punjab.[7] Alternatives like raising yields in Uttar Pradesh, expanding irrigation in wheat belts or diversifying cropping patterns can also be considered (Kohli, 2024a).

Fourth, persistent mismatches between production, procurement, and stock data underscore the need to modernise crop assessment methodologies. Integrating remote sensing technologies, satellite imagery, and artificial intelligence (AI)-based yield prediction to replace or supplement the traditional crop-cutting experiments would avoid misalignments in data or incentives as hinted at by the output–procurement gaps in states like MP. Updating yield assessment methods, investing in weather-resilient farming, and improving storage infrastructure might address root causes more sustainably. Strengthening market information and forecasting; for example, better satellite monitoring of sowing, could prevent late surprises in procurement planning. Finally, long-term investments in agricultural research and development, climate-resilient seed development, extension services, and localised agro-climatic modelling are vital to anticipate and mitigate region-specific risks to cereal yields.

Trade Policy: Economic theory suggests that the most efficient choice to alleviate temporary supply constraints or even enduring shortfalls of a product, commodity, or raw material is to import. This alternative can be considered as a mitigation strategy against deficits owing to climate shocks. Irrespective of a restrictive agricultural trade regime, global prices impact domestic prices, e.g., the 2010–2011 surge in global cereal prices, the opposite in 2015–2017, and the recent synchronisation in 2021–2022 with subsequent decoupling due to severe import restrictions.

Yet the pressures of self-sufficiency and the need to remain a net foodgrain exporter while supporting domestic producers with affordability for households lead to inconsistent trade policy responses. For example, the reluctance to lower import duties during domestic shortages, and the continued 40 per cent wheat import tariff during tight supply, removes a key lever for stabilising internal prices. This followed the delayed supply response at the initial resurgence of food inflation in 2019, when the central bank urged open market sales[8] to restrain the price rise in cereals (Kohli, 2020).

This is a delicate balance: reliance on imports raises affordability risks if global prices soar. Conversely, liberalising trade could help stabilise domestic prices through international supply. The sizeable Indian demand has global repercussions as it undoubtedly impacts international prices, hurting poorer and food-importing nations. There could also be spillovers to overall food availability amidst global warming and heatwave occurrences across other similarly impacted wheat-growing countries—India is a major wheat producer, contributing 14 per cent of total world production in 2023–2024[9] (US Department of Agriculture, Foreign Agricultural Service, n.d.).

Similar complexities also arise for rice, of which India is the second-largest exporter and a price-setter. Therefore, any export curbs reverberate globally. In a world of interconnected markets, such actions push up world prices and can worsen volatility. In the recent instance, the policy choice to ban rice exports likely helped cool domestic prices, although at the expense of global markets. For instance, the export bans on wheat and rice coincided with Russia's invasion of Ukraine in early 2022, which pushed up international wheat prices sharply. Knock-on effects from the rice export ban were equally visible, for example, a 62 per cent plunge in two months in rice exports and a 32 per cent annual decline by September 2023. There are reputational and credibility damages from

[7] Central Ground Water Board's block-wise groundwater resources assessment in 2020 found that most of Punjab's districts had over-exploited the groundwater levels; if the present depletion continues, Punjab's groundwater is expected to drop below 300 metres by 2039.

[8] "Further, if open market sales and public distribution offtake of cereals are expanded on the back of significantly higher procurement, it would help in easing of cereal price pressures during the latter part of the year." (Monetary Policy Committee, 2020).

[9] In 2023–2024, it accounted for 110.55 million metric tons of wheat as compared to global wheat production of 790.54 million metric tons.

sudden bans that elicit international criticism and challenge India's reliability as a supplier.

In this light, policymakers should consider automatic triggers or better criteria for trade measures—e.g., transparent parity conditions—rather than sudden, ad hoc bans. A more calibrated trade policy that balances domestic food sufficiency, global price impacts, and India's international credibility is essential. More so because it remains the second-largest producer and exporter of rice and among the top wheat producers globally.

Supply Management and Intervention Strategy: The magnitude, frequency, and duration of supply-side interventions like export bans, stockholding limits, and open market operations raise questions about their long-term sustainability, consistency, and unintended consequences. If the climate-change disruptions are increasingly the new norm, these measures are not sustainable. This is evident from the persistence of cereal price pressures for nearly five years with mounting stringency of constraints upon trade and public stocks. In this context, the precise role of supply measures in food price formation, persistence, and volatility needs formal examination.

Further, the effectiveness and broader spillovers of agricultural market interventions also need careful evaluation from the standpoint of second-order effects. These can potentially be several. For instance, sudden, strict actions can signal panic, induce or increase uncertainty and volatility, and trigger adverse market reactions or counterproductive responses from economic agents. These are disincentives for trade as they raise transaction and operation costs, for example, weekly stock reports, while stockholding limits and bans increase market frictions. Participation is discouraged when traders are kept out of markets to enable a sufficient or desired level of public purchases of foodgrains, as in the last two years (Jadhav & Bhardwaj, 2024; The Wire, 2023). Inconsistent supply responses also weaken or blunt the value of open market sales if private agents exit the market (PTI, 2023) or limit participation (Athrady, 2023), undermining the stabilisation objective. In tight supply situations, extreme actions disallowing market dynamics can turn counterproductive and perpetuate a shortage-price spiral. The abrupt swings to surplus and excess rice stocks overrunning storage capacities for more than a year (Bloomberg News, 2024; Dash, 2024), while prices have remained firm, is one example in this regard.

Next, although cereal substitution is an appropriate strategy to overcome temporary shortages and as a response to relative price increases, a prolonged use of this policy tool may be untenable. As seen from the relentless firmness of rice prices despite the plentiful stock, a protracted cereal switch is eventually inconsistent with the initial policy goal, either because of increased demand for the substitute or due to rigidities in individual preferences that increase demand for wheat in the open market. An assessment of the substitution strategy, which is sound in theory and observed empirically in the sales of substitution goods, is difficult: the sustained price growth of wheat would suggest the wheat-eating population segments shifted to market purchases instead, hence offsetting the overall supply strategy to limit price increases. On the other hand, excess rice stocks with firm prices are counterintuitive.

Future supply shocks may therefore demand more flexible and anticipatory tools. These could include improved early warning systems based on real-time, regional climate and satellite data that can be aligned or adjusted to dynamic procurement and buffer stock strategies. A persistent mismatch between production, procurement, and stock data underscores the need to modernise crop assessment methodologies—integrating remote sensing technologies, satellite imagery, and AI-based yield predictions to replace or supplement the traditional crop-cutting experiments. The recent output–procurement gaps in states like MP hint at misalignments in data or incentives that can be addressed by updating yield assessment methods, investments in weather-resilient farming and improving storage infrastructure for sustainability.

Other options like expanding irrigation in wheat belts and diversifying cropping patterns, e.g., adjusting the pace of the shift from water-intensive crop cultivation in Punjab (Kohli, 2024a), and accelerating the development of heat-resistant wheat varieties in process for wider adoption can facilitate adaptation in future. From the standpoint of better market functioning, strengthening information and forecasting, e.g., better satellite monitoring of sowing could help prevent speculation, conflicting estimates, and late surprises in procurement planning.

Macroeconomic Policies: A large agriculture-dependent population (approximately 45 per cent) and an almost two-fifths share of food in the national consumption basket, with a 54.2:36.3 rural–urban distribution, establishes the macroeconomic importance of production deficits, price increases, and supply interventions. The foremost implications are for monetary policy, which is challenged by supply shocks and other complexities arising therefrom. There are also fiscal implications of prolonged supply management, and welfare costs of persistent food price increases that have socio-political implications.

Monetary Policy: This is particularly strained by persistent, atypical inflation dynamics induced by frequent and unpredictable supply shocks. One, although traditional interest rate tools have limited efficacy in addressing supply-side shocks, monetary action is forced to contain spillover risks to other prices and generalised inflation. For instance, core inflation rose to a 7 per cent peak in April 2022, propelled additionally by fuel prices, eliciting a cumulative tightening of 250 basis points in May 2022–February 2023. Two, the persistence and climate-linked origins of food inflation complicate the central bank's disinflation strategy, forcing it to walk a narrow path and withhold its response to demand developments (RBI, 2024)[10]—despite a widening divergence between headline inflation (the policy target), which stayed high owing to food prices, and core inflation (the demand gauge), which fell steeply from mid-2023, monetary easing was delayed to anchor expectations. Three, relative price changes compound policy stress by slowing down disinflation, as happened in this instance. For the first time in a decade and since late 2019, food prices have grown 1.75 times faster than prices in other segments, a wide margin.

Four, climate-linked risks have posed unique and new issues. For instance, the understanding of inflation has been clouded by its non-dissipation in a few months, deviating from past behaviour. Historically, food inflation has tended to self-correct within 4–6 months post-harvest. Since 2019–2020, however, food prices have remained high across multiple procurement and release cycles. A decomposition of inflation drivers shows that supply-side shocks, especially those that are climate-induced, contributed over half the variance compared to less than one-third in the preceding decade. This indicates a deepening climate-inflation nexus with an uncertain future path. Monetary policy typically saw through such price spikes before, but this is no longer certain, implying spillovers into core inflation and wage-setting (Kohli, 2024b) if not responded to appropriately. Moreover, a lasting shift in the food price level also deepens contractionary effects through the permanently higher cost of food items, even if inflation settles into the target range (4 per cent).

Increased and wider forecast errors follow frequent and unpredictable weather disruptions, leading to recurrent revisions. For example, in 2022–2023, the gap between the initial inflation projection and the outcome was as much as 115 basis points, while consecutive revisions of inflation projections at bimonthly intervals were significant; subsequent years, too, saw substantial reconsiderations. As a result, the central bank's inflation models and forecasting credibility were dented. These are fresh sources of uncertainty and aggravate that created by the sudden, unexpected supply-side actions. Uncertainty also grows because the gap in market and official foodgrain estimates adds to price uncertainties—entrenched for the last four years, there are hints of this uncertainty becoming endemic.

There's explicit recognition of the fresh climate-linked inflation risks by the central bank through regular flagging of the higher frequency and persistence of supply shocks due to climate change (e.g., *Monetary Policy Report*, RBI, April 2024), the related difficulties in inflation forecasting, and the emergence of "climate risk" as a key uncertainty in monetary policy formulation. Recent research from the central bank (Patra et al., 2024) examining this finds a close match in the attributes of food and core inflation, hinting at structural changes in the former. The increasing divergence between core and headline inflation, the latter driven largely by food prices, indicates that food inflation in India now reflects more than transient disruptions, although it is premature to be certain (Kohli, 2020, 2023, 2024b).

From an adaptation standpoint, the changed behaviour of food prices in response to changing climate patterns may require a rethinking of inflation forecasting models, more granular and climate-responsive data systems, and tighter integration of fiscal and monetary policy strategies to address persistent climate-induced shocks. If the innovations to food prices become more frequent due to climate change, monetary policy will need better coordination with fiscal policy for supply-side actions to anchor inflation.

[10] "The speed of the easing of inflation has been disappointing so far, even from a cross-country perspective. Food prices are persisting for too long as the principal impediment to a faster disinflation… Food prices are holding back any consideration of possible changes in the monetary policy stance" (RBI, 2022).

Fiscal and Welfare Policy: These policy strains arise from shortfalls in foodgrains as the price rise influences public policies and finances. One, there are fiscal costs associated with sustained interventions and expanded coverage of food items, e.g., increased costs of procurement and subsidies, welfare transfers and populist measures to mitigate the squeeze in real incomes of poorer households and/or the political fallout of a persistent food price rise. Specifically, the protracted intensity of supply-side actions impacts public finances beyond normal budgetary provisioning through higher support pricing, procurement, and stock maintenance to safeguard against frequent climate-linked disturbances affecting major crops, including vegetables, pulses, etc. Over time, more items of common consumption are being enveloped under the supply-management umbrella for price stabilisation; for example, the onion buffer stock under the Price Stabilisation Fund (PSF) for market intervention. The adoption of an inflation-targeting monetary policy regime with price stability as the primary objective has increased pressures for fiscal responses to build credibility.

Two, costlier staple foods compel the continuation of free grain programmes for poor beneficiaries while raising the economic costs of stockholdings and perpetuating budgetary subsidies that become sticky. Real wages, farm and non-farm, have either stagnated or been depressed, with inflation squeezing incomes until the recent softening (*Monetary Policy Report*, RBI, October 2024, April 2025). Although higher farm incomes have usually been regarded as a silver lining of food price increases, a large fraction of rural households are net consumers.[11] In the current instance, the price rise was reflected in significant input cost increases (fertiliser, diesel, feedstock, etc.), compressing farm margins until the moderation of producer prices from mid-2023 (*Monetary Policy Report*, RBI, October 2023).

Three, the political economy surrounding inflation compels offsets like income-support relief or programmes to mitigate discontent and for consumption support. Inflation, especially in food staples, aggravates inequalities, and when prolonged, is a regressive shock for the poor. High food inflation also coincided with an asymmetric recovery from the pandemic, thereby compounding income inequalities and weakening consumer sentiments and purchases (Kohli, 2025). Further, the increased food price level has combined with persistently high inflation, depressing sentiments and expectations. These developments indicate substantial real economic effects. An indirect reflection of demand compression is the significant rise of income transfers in 2023–2024 to approximately 0.6 per cent of gross domestic product (GDP) (Rs 1.9 lakh crore) from approximately 0.2 per cent the previous year (Mishra et al., 2024), partly for populist reasons ahead of specific state elections with increased targeting of female voters. The drop in consumer spending also elicited a fiscal policy response—personal income tax reductions—to boost private consumer spending (Ministry of Finance, 2025).

A fourth welfare policy implication is the uncertainty and increased probability of policy errors. Retrospective analysis suggests that the extension of foodgrain relief measures in 2022 created additional demand pressure upon public stockholdings, which were insufficiently recouped with procurement from subsequent harvests that were successively damaged by extreme heat. The prolonged substitution of cereals also sharpened the conflict with price stabilisation goals. The important insight drawn from these is that assuming typical weather patterns, e.g., a normal harvest following one or two deficit harvests, can cause or accentuate policy errors.

7. Conclusion

India's recent experience underscores a worrisome nexus: intense climate anomalies coinciding with persistent food shortages and price surges. Three consecutive years of record heat and erratic rainfall in critical regions from 2021–2022 led to repeated production drops in staple cereals, especially wheat. The policy response largely relied on supply controls and market interventions, which have been unprecedented in scope, intensity, and duration. While these actions damped price spikes, they have not prevented more than four years of increased food inflation. Neither has this eliminated uncertainty for farmers and consumers, while begetting new uncertainties for macroeconomic policies. Compared to past shocks, the current crisis appears deeper and more structural.

[11] MPC member Jayanth R. Varma notes that many rural, non-agricultural households are hurt by rising food prices, experiencing a negative terms-of-trade shock that reduces their purchasing power. This challenges the idea that food inflation always benefits the rural economy and highlights the need for government policies to balance food inflation control with better farmer incomes.

This paper provides the first comprehensive narrative record of the experience, its impact, and the policy challenges in managing the persistent disturbances.

The paper has documented these trends to evaluate whether the recent climate events and the policy challenges they posed vary fundamentally from past episodes and the need to rethink policies in light of the experience. Tracing the evolution of two climate extremes that have driven the recent episode, viz., heatwaves and erratic rainfall, the paper identifies their atypical collation and consequences for crop yields and food prices. The next contribution is a comprehensive compilation of agricultural restrictions and interventions for two decades, which reveals an unprecedented increase in the range and stringent usage of these instruments for managing the recent supply shocks. Numerically and in strictness, these exceed any past such deployments, raising several important policy questions, *inter alia*, the pressures of an inflation-targeting monetary policy regime. Assuming a future escalation in the frequency and persistence of supply shocks as predicted by climate models, sustaining a fiscal defence through such tools to preserve the credibility of the inflation targets and managing the output sacrifice is an important policy question with multiple implications. Future work aims to build upon this.

The third value of this research is a comparative examination of this experience with two close previous episodes across four dimensions—weather anomalies, output and public procurement, and stocks, interventions, and food prices—for the identification and better understanding of deviations, if any. It finds outstanding differences that could hint at climate-driven changes of macroeconomic significance. The final, and by far the most valuable contribution of this paper is in the policy domains spanning food security, trade, supply management, and macroeconomic policies, especially monetary and fiscal. Based on empirical trend and comparative analysis of climate shocks in India, the paper identifies several fresh challenges to the current policy frameworks.

Illuminating these strains and pressures with a narrative empirical account, the paper draws attention to their weakened effectiveness with increased frequency and persistence of food supply shocks for policymakers' deliberation and possible adaptations. It finds important differences in all these aspects. Specifically, heatwaves are more frequent and intense; rainfall is more erratic with an increasing propensity towards deficits in critical crop-growing regions; while the coincidence in twin anomalies is mostly unobserved before. Two, the supply management, i.e., collating the changing weather anomalies and the recent changes to these economic outcomes and policy responses for inference and understanding from a future perspective.

The anomalies of 2022–2024 may portend changes in settings where climate volatility and food inflation become intertwined challenges. As the paper emphasises, climate models and recent trends suggest that extreme weather events will become more common, not less. If so, India may face a future of similar continuous shocks. This paper highlights the urgency of adaptation to such an environment. Using climate projections and other relevant data, policymakers, and researchers could examine how the food and economic policy outlines could be reworked for better functioning and sustainability. Aspects that arise in these contexts are several: from crop insurance and irrigation to strategic trade and inflation management. Importantly, all policy levels—agriculture, trade, fiscal, and monetary—must coordinate better. For example, if fiscal authorities build buffers ahead of bad monsoons and free trade to tide them over shortfalls, that could give the RBI more flexibility to cut rates in good times. Likewise, open and transparent policy frameworks could address many of the supply-side uncertainties for markets and inflation forecasting. It remains to be seen if, in this different environment, headline inflation targeting needs supplementation, such as conditional inflation bands or climate-adjusted core measures, towards alternative frameworks.

The future is challenging. 2025 could be the fourth consecutive year of above-normal temperatures for India (IMD, 2025), matching the global outlook (WMO, 2025). The key implication is that adaptation and resilience must become policy priorities if climate change is indeed making extreme crop shocks more likely.

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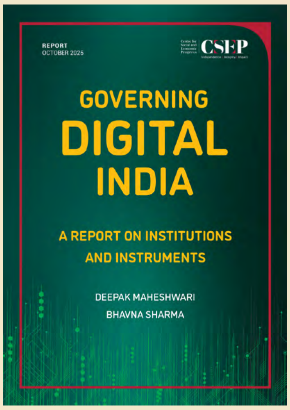
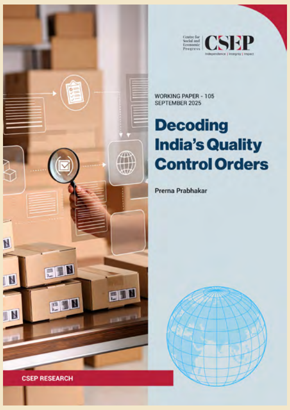
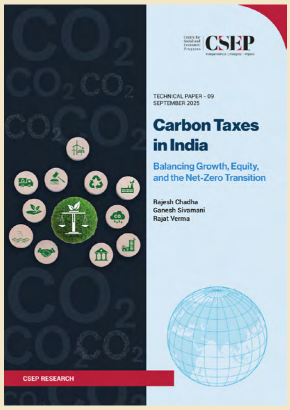
About the author

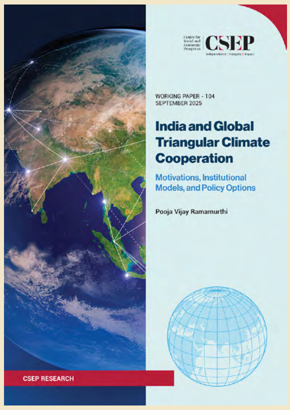
Renu Kohli is an economist with research and practitioner experience on macroeconomic policies and issues. She has previously worked with the RBI, the IMF and other thinktanks. Her work has focused on capital account and financial liberalization, exchange rate management, monetary policy, international macroeconomic coordination, sovereign debt resolution, G20, climate change and macroeconomic impacts including food security and inflation. She has published widely in refereed journals such as the *Review of Development Economics, Journal of Development Studies, Journal of Asian Economics,* Oxford University Press, IMF *Working Papers,* RBI *Staff papers,* and contributed to several edited volumes. She writes regular opeds on monetary policy, macroeconomic policy, and other economic matters in prominent Indian newspapers. She has exposure to IMF multilateral surveillance and training missions as short-term expert (IMF Institute) in financial programming & policies and macroeconomic diagnostics. Dr. Kohli has wider engagement with the private financial sector and investors through talks, presentations and consultation on Indian macroeconomic policies. She serves as an independent director on the boards Catholic Syrian Bank, NCML Ltd, and NFIN Ltd.

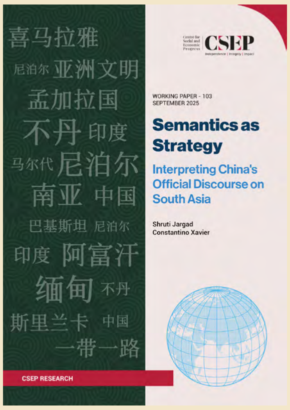
Other publications

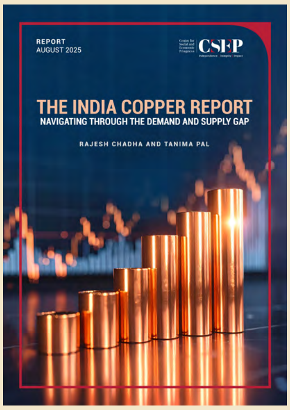


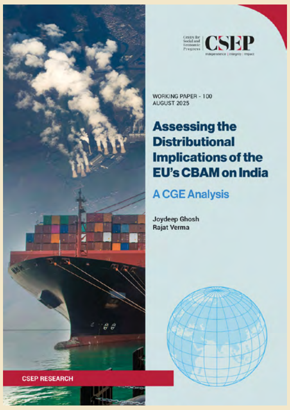


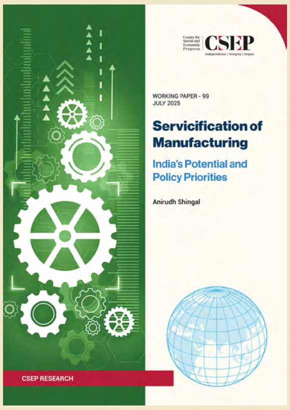


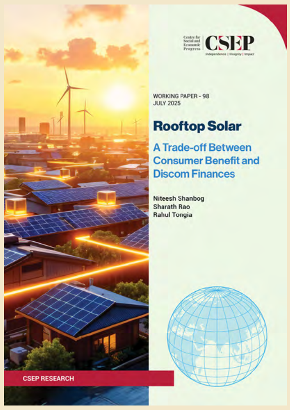


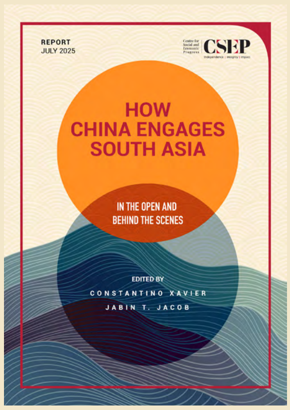


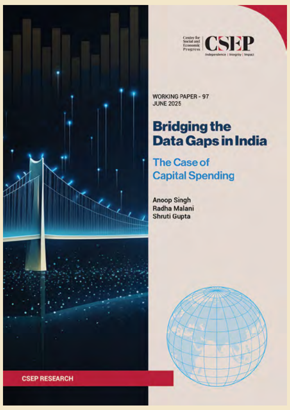


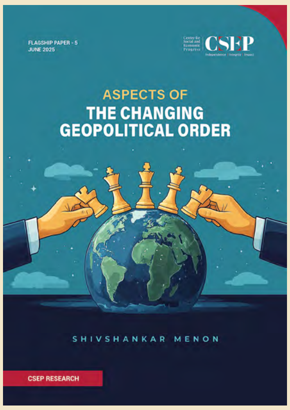


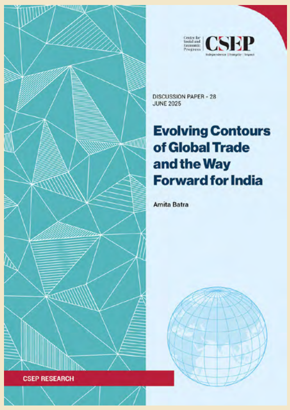


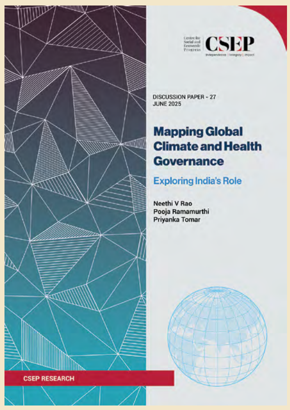












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