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ABSTRACT

Tomato, onion, and potato (TOP) prices are a recurrent source of food inflation in India. In this paper, we ask whether market depth attenuates the pass-through from rainfall shocks to TOP inflation. We build a monthly district panel from queue-based Agmarknet downloads for 2018-2025, combine it with IMD rainfall and district eNAM mandi counts, and estimate district and month-year fixed-effects models. The main TOP composite uses 253 districts with at least 60 months of price coverage for all three crops. Contemporaneous excess rainfall raises TOP inflation by about 0.011 log points, with a further 0.010 log-point effect after one month. Denser mandi networks weaken this pass-through in continuous-rainfall specifications, marginal-effects calculations, onion regressions, and specifications based on TOP-trading mandis. State reform scores also attenuate excess-rainfall pass-through, while startup-stock interactions do not survive in the broader sample, consistent with startup ecosystems not yet having reached the scale needed to buffer local price shocks. The broader evidence therefore points to market depth and reform quality, rather than startup accumulation alone, as the more credible buffers against TOP price shocks.

Keywords: food inflation, rainfall shocks, eNAM, mandi density, agricultural markets, India

JEL Code: Q13, Q18, Q54, E31

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Abstract

Tomato, onion, and potato (TOP) prices are a recurrent source of food inflation in India. In this paper, we ask whether market depth attenuates the pass-through from rainfall shocks to TOP inflation. We build a monthly district panel from queue-based Agmarknet downloads for 2018-2025, combine it with IMD rainfall and district eNAM mandi counts, and estimate district and month-year fixed-effects models. The main TOP composite uses 253 districts with at least 60 months of price coverage for all three crops. Contemporaneous excess rainfall raises TOP inflation by about 0.011 log points, with a further 0.010 log-point effect after one month. Denser mandi networks weaken this pass-through in continuous-rainfall specifications, marginal-effects calculations, onion regressions, and specifications based on TOP-trading mandis. State reform scores also attenuate excess-rainfall pass-through, while startup-stock interactions do not survive in the broader sample, consistent with startup ecosystems not yet having reached the scale needed to buffer local price shocks. The broader evidence therefore points to market depth and reform quality, rather than startup accumulation alone, as the more credible buffers against TOP price shocks.

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1 Introduction

Tomato, onion, and potato (TOP) prices are a recurrent source of food inflation and policy intervention in India. These crops are highly perishable, production is spatially concentrated, and short-run supply cannot be smoothed easily. When rainfall is far above or below normal, harvest losses, rot, transport disruptions, and abrupt changes in mandi arrivals can all generate large month-to-month price movements. The relevant question is therefore not only whether weather shocks matter, but whether market depth changes how strongly those shocks pass through into local prices.

This paper studies whether districts with deeper market infrastructure show smaller pass-through from rainfall shocks to TOP inflation. Our main market variable is district-level eNAM mandi density, measured as the log of one plus the number of eNAM-integrated mandis in the district. We combine this measure with monthly district prices from queue-based Agmarknet downloads for 2018–2025 and IMD rainfall data, and estimate district and month-year fixed-effects models. We also study two state-level moderators: the Agricultural Marketing and Farmer Friendly Reforms Index (AMFFRI), compiled by NITI Aayog (2016), and a time-varying cumulative stock of agriculture startups constructed from official DPIIT registrations.

The raw queue-based panel contains 517 districts with at least one TOP crop in at least one month. The composite TOP index, however, requires tomato, onion, and potato prices to be observed jointly. To keep the dependent variable comparable across space and time, the main TOP specification is restricted to 253 districts with at least 60 months of coverage for all three crops. Crop-specific regressions use larger eligible samples: 282 districts for tomato, 291 for onion, and 281 for potato. The 253-district restriction is therefore a measurement choice for the composite index,[3] not a sample-selection device designed around a few focal

[3] The broader raw panel contains 517 districts with at least one TOP crop in some month. The 253-district TOP sample is the subset with sufficiently long joint tomato, onion, and potato coverage to define the composite index on a common three-crop basket across district-months. The restriction is therefore about comparability of the dependent variable, not about selecting a small set of favourable districts.

districts.

Three findings stand out. First, excess rainfall raises monthly TOP inflation in the broader composite sample rather than lowering it. In the threshold specification, the contemporaneous excess-rainfall coefficient is about 0.011 and the one-month lag is about 0.010. For perishable crops, that sign is economically plausible: heavy rain can damage standing crops, increase spoilage, disrupt transport, and reduce effective market arrivals. Second, denser mandi networks weaken this pass-through, although the strength of the evidence depends on the specification. The threshold interaction in the main TOP table is negative but imprecisely estimated, while the continuous-rainfall specification, the marginal-effects calculations, the onion regressions, and the TOP-trading-mandi specification all point to smaller rainfall pass-through in deeper markets. Third, the state-level moderators do not contribute equally. The startup-stock interaction is weak once inference respects the state-level variation in the moderator, whereas the continuous AMFFRI interaction remains negative and statistically significant for excess rainfall.

This paper speaks to three related literatures. First, work on Indian food inflation emphasizes supply shocks, perishability, and bottlenecks in storage, transport, and marketing. Chand (2010), Chand et al. (2011), Bhattacharya and Sen Gupta (2018), Sekhar et al. (2018), and Gulati and Saini (2013) argue that weather disturbances, weak storage, and supply-chain adjustment problems are central to repeated spikes in food prices. That perspective is particularly relevant for TOP crops, where short shelf life and concentrated production can turn local disruptions into large month-to-month price movements.

Second, a literature on agricultural market integration asks whether deeper trading networks improve spatial arbitrage and price discovery. Sekhar (2012) shows that Indian agricultural markets remain segmented, with commodities facing inter-state movement restrictions integrating poorly across regions. Aggarwal et al. (2017), Chand (2016), Reddy and Mehjabeen (2019), and Andrle and Blagrave (2020) study eNAM and related market integration reforms, focusing on digital trading, price discovery, and market outcomes. What remains less clear is whether deeper local market networks matter most precisely when weather shocks hit and short-run food inflation accelerates.

Third, the paper relates to work on price stabilization under volatile food markets. Gouel (2014) stresses that stabilization depends not only on average output but also on the institutions through which shocks are absorbed, while Negi and Anand (2015) identify weak supply-chain and cold-storage infrastructure as a source of losses and inefficiency in perishable fruit and vegetable markets. We bring that question to district-month data for highly perishable crops and ask whether districts with denser mandi networks show smaller inflation responses to rainfall shocks. The paper's main contribution is therefore not another average-price study of agricultural reform, but evidence on how market depth changes weather-shock transmission in perishable crop markets.

The rest of the paper proceeds as follows. Section 2 describes the broader-sample panel and the sample-construction rules behind the 253-district TOP index. Section 3 outlines the fixed-effects design. Sections 4 and 5 present the main results and robustness checks. Section 6 concludes.

2 Data

2.1 Sample Construction

The price data come from queue-based monthly Agmarknet downloads for all districts and states available in the 2018–2025 window. The cleaned broader sample is constructed in the separate queue-based workflow and summarized in the paper descriptives. The main TOP composite sample contains 253 districts across 19 states with at least 60 months of coverage for tomato, onion, and potato jointly. This yields 23,152 district-month rows in the descriptive panel and 15,216 observations in the main TOP-index rainfall regression once lags and missing rainfall are accounted for.

The distinction between the broader raw panel and the main composite sample matters.

There are 517 districts with at least one TOP crop in some month, but many of these districts have incomplete coverage for one or two crops. If the composite index were constructed from changing crop subsets across districts and months, the dependent variable would not have a stable interpretation. The paper therefore uses the 253-district all-three-crop sample for the TOP index and larger crop-specific samples for tomato, onion, and potato separately.

2.2 Prices

Monthly average mandi arrival prices in INR per quintal are drawn from Agmarknet. For each crop, the paper winsorises district-level price series at the 99th percentile within district, takes logs, and computes month-on-month inflation. The TOP composite is the log of the geometric mean of tomato, onion, and potato prices:

$$\pi_{dt}^{TOP} = \log\left((P_{dt}^{T} P_{dt}^{O} P_{dt}^{P})^{1/3}\right) - \log\left((P_{d,t-1}^{T} P_{d,t-1}^{O} P_{d,t-1}^{P})^{1/3}\right). \tag{1}$$

Figure 1 plots cross-district mean inflation by crop. The series show large short-run spikes and reversals, consistent with the high-frequency volatility expected in perishable produce markets.

2.3 Rainfall

Daily district rainfall comes from IMD gridded data. Monthly totals are compared with district-by-calendar-month long-period averages from the 1991–2020 baseline. The paper defines monthly deficient and excess rainfall as:

$$\text{Deficient}_{dt} = \mathbf{1}[R_{dt} < 0.80 \times \text{LPA}_{dm}] \tag{2}$$

$$\text{Excess}_{dt} = \mathbf{1}[R_{dt} > 1.20 \times \text{LPA}_{dm}], \tag{3}$$

with normal rainfall as the omitted category. In the broader TOP sample, 51.0 per cent of observed district-months are classified as deficient, 14.8 per cent as normal, and 34.2 per cent as excess (Figure 2).

2.4 Market Infrastructure, Reform, and Startups

District mandi density is measured using the audited eNAM mandi list and enters the regressions as $\log(1 + \text{mandi count})$. Because this variable is time-invariant in the current panel, its level effect is absorbed by district fixed effects and only the interaction with rainfall is identified.

The state-level reform measure is the AMFFRI score from NITI Aayog (2016), centred at the sample mean for interpretation. The paper also uses a binary indicator for states with AMFFRI scores of at least 70. The time-varying startup variable is a cumulative agriculture-startup stock built from DPIIT state-year registrations from 2016 onward. All districts within a state inherit the same state-year startup value.

2.5 Summary Statistics

Table 1 reports summary statistics. Mean TOP inflation is close to zero, but dispersion is substantial. Average mandi density is modest because the panel includes many districts with sparse market infrastructure. Startup stock varies widely across states, with Maharashtra, Gujarat, Karnataka, and Uttar Pradesh showing the fastest cumulative growth over the sample window.

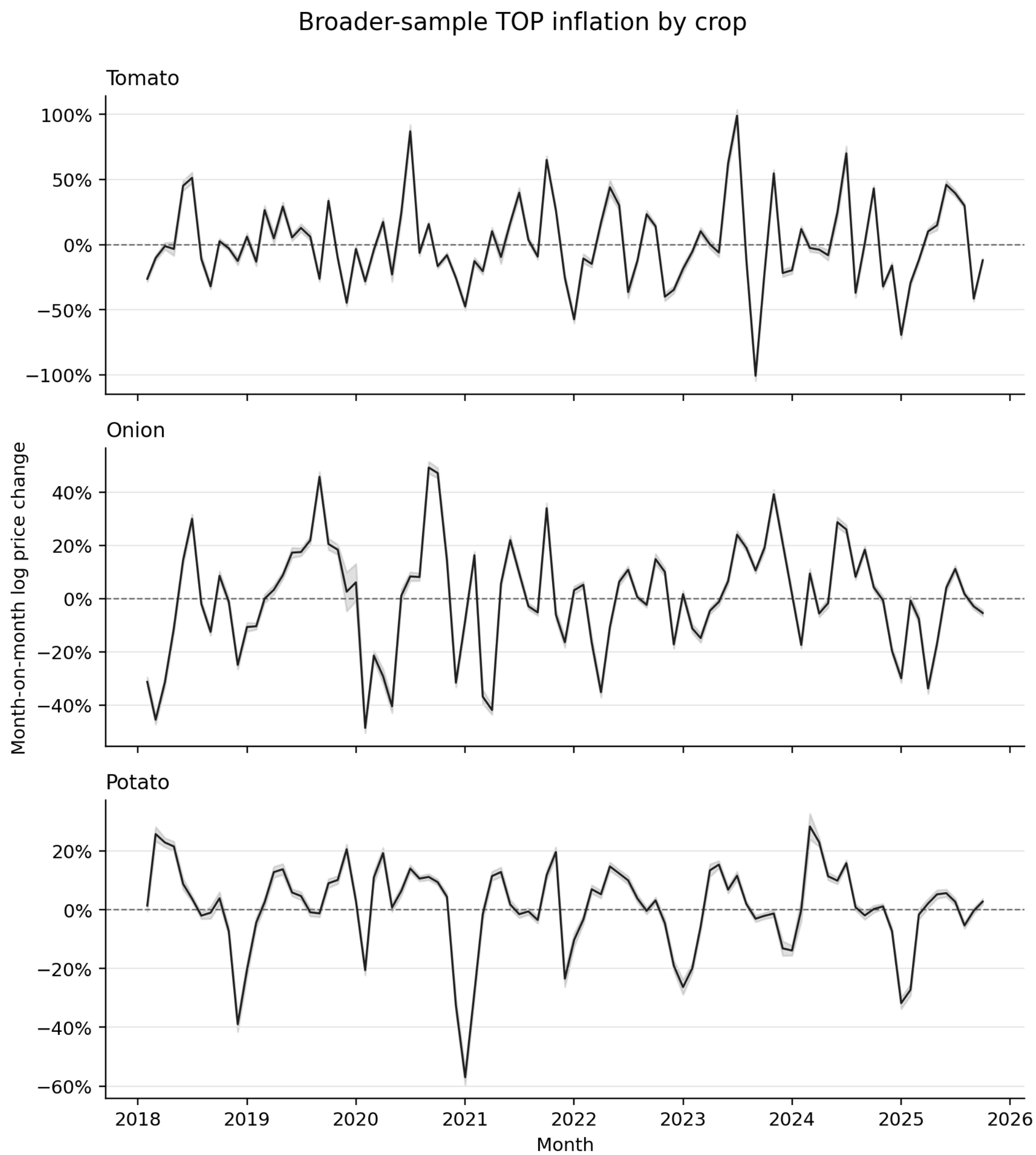

Figure 1. Broader-sample TOP inflation by crop. Each panel plots the cross-district mean month-on-month log price change for the eligible crop-specific sample.

Table 1. Summary Statistics

Variable	N	Mean	SD	Min	P25	P75	Max
TOP inflation (m-o-m log)	21341	0.008	0.206	-1.079	-0.115	0.128	1.167
Tomato inflation (m-o-m log)	22431	0.007	0.411	-2.308	-0.234	0.220	2.314
Onion inflation (m-o-m log)	21801	-0.001	0.249	-2.130	-0.138	0.143	2.126
Potato inflation (m-o-m log)	22557	0.009	0.198	-4.323	-0.061	0.113	4.899
Deficient rainfall indicator	17658	0.510	0.500	0.000	0.000	1.000	1.000
Excess rainfall indicator	17658	0.342	0.474	0.000	0.000	1.000	1.000
Monthly rainfall (mm)	17658	96.341	164.099	0.000	1.776	129.515	3074.698
Rainfall relative to LPA (District eNAM mandi count	23152	2.336	2.418	0.000	0.000	4.000	13.000
log(1 + mandi count)	23152	0.945	0.732	0.000	0.000	1.609	2.639
Cumulative agri-startup stock (state)	23152	255.878	333.038	0.000	42.000	359.000	2281.000
log(1 + startup stock)	23152	4.680	1.579	0.000	3.761	5.886	7.733

Notes: Broader queue-based district-month panel for 2018–2025. The TOP composite uses the 253 districts with at least 60 months of all-three-crop price coverage. Crop-specific regressions use larger crop-specific eligible samples. Inflation is month-on-month log price change.

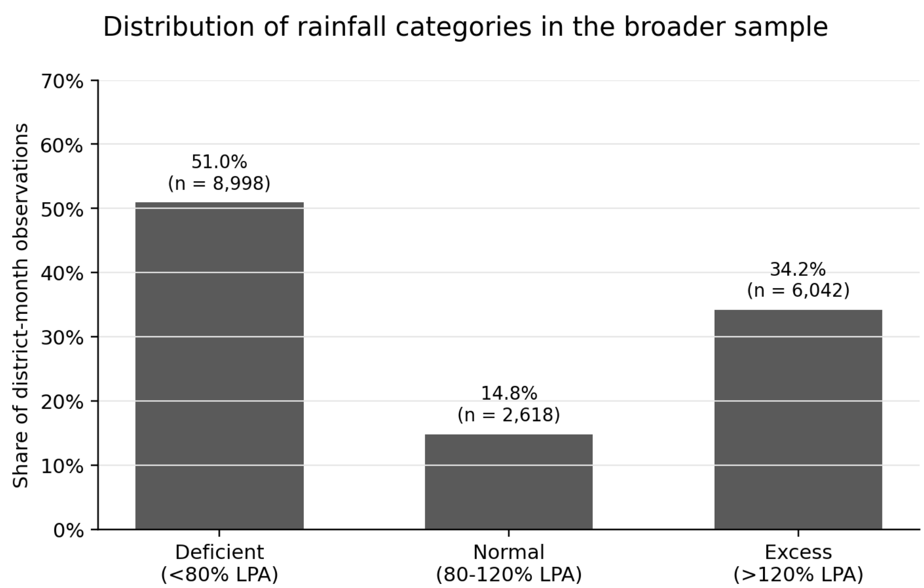

Figure 2. Distribution of monthly rainfall categories in the broader TOP sample.

3 Empirical Strategy

The baseline specification is a district fixed-effects, month-year fixed-effects panel:

$$
\begin{aligned}
\pi_{dt} = {} & \beta_1 \pi_{d,t-1} + \beta_2 \pi_{d,t-2} + \gamma_1 \text{Deficient}_{dt} + \gamma_2 \text{Excess}_{dt} \\
& + \gamma_3 \text{Deficient}_{d,t-1} + \gamma_4 \text{Excess}_{d,t-1} \\
& + \delta_1 \text{Deficient}_{dt} \times \log(1 + M_d) \\
& + \delta_2 \text{Excess}_{dt} \times \log(1 + M_d) + \alpha_d + \lambda_t + \varepsilon_{dt}.
\end{aligned} \tag{4}
$$

The paper then estimates three classes of extensions. First, it replaces the threshold dummies with continuous rainfall relative to normal. Second, it examines whether rainfall sensitivity changes over time. Third, it interacts rainfall with state-level reform and startup variables. District-level rainfall and mandi specifications are clustered at the district level. Specifications driven by state-level moderators are clustered at the state level because the treatment varies at the state or state-year level[4] (Moulton, 1990).

4 Results

4.1 Baseline Rainfall Effects

Table 2 reports the main broader-sample threshold specification. The central TOP-index result is straightforward: excess rainfall raises short-run TOP inflation. The contemporaneous coefficient is 0.0110** and the one-month lag is 0.0100***. By contrast, deficient rainfall is small and imprecisely estimated for the composite index. At the crop level, potato shows the clearest positive excess-rain response, while onion and tomato are more heterogeneous.

The mandi result is more convincing when the evidence is read across complementary specifications rather than from a single interaction coefficient. In Table 2, the TOP excess-

[4] The AMFFRI variable is constant within state, while the startup-stock measure varies at the state-year level and is then assigned to all districts in that state-year. Clustering below the level at which these regressors vary would overstate precision by treating mechanically shared variation as independent.

rainfall interaction with mandi density is negative in sign but imprecisely estimated. In the continuous rainfall specification (Appendix Table 5), however, the interaction between rainfall intensity and mandi density is negative and statistically significant for the TOP composite. The marginal-effects calculations in Table 3 reinforce the same economic pattern: the TOP excess-rainfall effect is 0.0076^{***} in districts with one mandi, falls to 0.0056^{**} with two mandis, to 0.0030 with four mandis, and is essentially zero in districts with nine mandis.

Onion provides the strongest crop-level evidence for this channel. In the threshold specification, the deficient-rainfall interaction is -0.0119^{***} and the excess-rainfall interaction is negative at conventional marginal significance. This is consistent with thicker mandi networks making local onion inflation less sensitive to rainfall shocks.

Appendix Table 6 shows why we do not want to overstate the baseline interaction. The negative TOP excess-rainfall interaction remains essentially unchanged when district trends are added, but it becomes smaller under state-by-time fixed effects and disappears when district seasonality is absorbed. At the same time, the interaction becomes much stronger when mandi depth is measured using TOP-trading mandis only. We therefore interpret the mandi result as a pattern supported by several related exercises, with the strongest evidence coming from TOP-relevant market depth measures and from the onion and continuous-rainfall specifications.

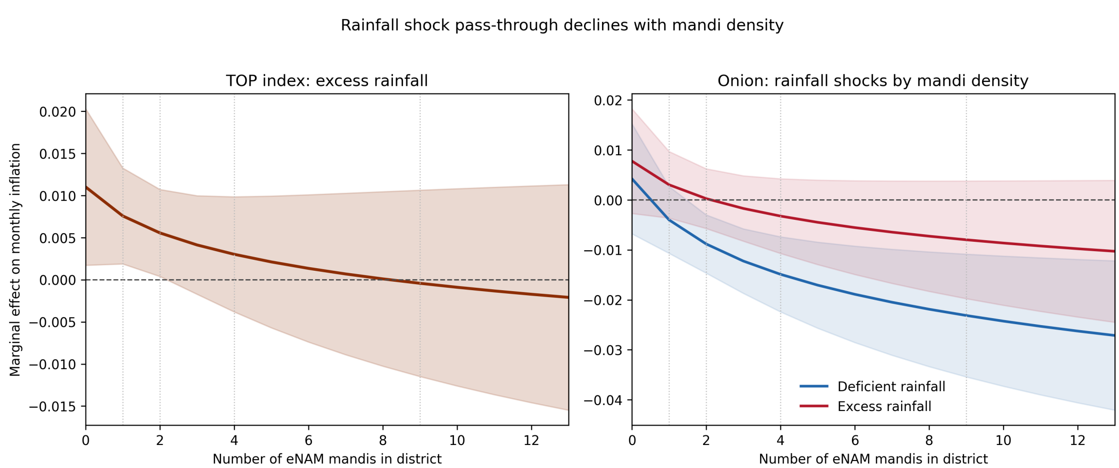

Figure 3. Marginal effects of rainfall shocks by mandi density for the TOP index and onion.

Table 2. Mandi Density and Rainfall Shocks: Baseline Threshold Specification

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0384***	-0.2296***	-0.0673***	-0.0671***
	(0.0136)	(0.0226)	(0.0224)	(0.0179)
Inflation $(t-2)$	-0.2748***	-0.1884***	-0.1112***	-0.2352***
	(0.0113)	(0.0089)	(0.0110)	(0.0110)
Deficient rainfall (t)	0.0025	0.0042	0.0049	0.0049
	(0.0105)	(0.0056)	(0.0045)	(0.0047)
Excess rainfall (t)	0.0126	0.0078	0.0163***	0.0110**
	(0.0105)	(0.0053)	(0.0044)	(0.0047)
Deficient rainfall $(t-1)$	-0.0044	-0.0051	-0.0032	-0.0046
	(0.0070)	(0.0032)	(0.0030)	(0.0032)
Excess rainfall $(t-1)$	0.0149**	0.0041	0.0099***	0.0100***
	(0.0060)	(0.0030)	(0.0031)	(0.0029)
Deficient $\times$ $\log(1+\text{mandis})$	0.0008	-0.0119***	-0.0028	-0.0038
	(0.0088)	(0.0045)	(0.0040)	(0.0041)
Excess $\times$ $\log(1+\text{mandis})$	-0.0065	-0.0068*	-0.0039	-0.0050
	(0.0087)	(0.0042)	(0.0036)	(0.0039)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17910	17740	18038	15216

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Dependent variable is month-on-month log price inflation. Columns (1)–(3) report crop-specific samples; column (4) uses the 253-district TOP composite sample. All regressions include district and month-year fixed effects. Standard errors are clustered at the district level and reported in parentheses.

Table 3. Marginal Effects of Rainfall Shocks at Different Mandi Densities

Scenario	Tomato	Onion	Potato	TOP index
Deficient rainfall, 1 mandi	0.0030	-0.0040	0.0029	0.0023
	(0.0064)	(0.0034)	(0.0030)	(0.0030)
Deficient rainfall, 2 mandis	0.0033	-0.0088***	0.0018	0.0007
	(0.0059)	(0.0030)	(0.0030)	(0.0029)
Deficient rainfall, 4 mandis	0.0037	-0.0149***	0.0004	-0.0012
	(0.0079)	(0.0038)	(0.0041)	(0.0039)
Deficient rainfall, 9 mandis	0.0043	-0.0231***	-0.0016	-0.0039
	(0.0128)	(0.0063)	(0.0063)	(0.0062)
Excess rainfall, 1 mandi	0.0082	0.0030	0.0136***	0.0076***
	(0.0065)	(0.0034)	(0.0028)	(0.0029)
Excess rainfall, 2 mandis	0.0055	0.0003	0.0120***	0.0056**
	(0.0059)	(0.0030)	(0.0026)	(0.0026)
Excess rainfall, 4 mandis	0.0022	-0.0032	0.0100***	0.0030
	(0.0079)	(0.0038)	(0.0035)	(0.0035)
Excess rainfall, 9 mandis	-0.0023	-0.0080	0.0073	-0.0004
	(0.0127)	(0.0060)	(0.0055)	(0.0056)

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Entries report marginal effects implied by the threshold specification at different district mandi counts. The TOP composite effect of excess rainfall falls from 0.0076*** at one mandi to 0.0056** at two mandis, 0.0030 at four mandis, and essentially zero at nine mandis.

4.2 Time Variation and State-Level Moderators

The broader sample provides little evidence of a monotone decline in rainfall sensitivity over time. In the TOP composite, the year-trend interaction terms are near zero, and the year-specific coefficient plot in Figure 4 shows a noisy pattern rather than a clean downward trajectory. This suggests that the perceived attenuation of TOP shocks after 2023 is not well captured by a simple linear trend.

The state-level moderator results point in different directions. The continuous AMFFRI interaction is negative and statistically significant for excess rainfall in the TOP composite. In the state-clustered joint specification, the excess-rainfall interaction with AMFFRI is -0.0005^{***}, implying smaller inflationary pass-through in higher-reform states. The high-versus-low reform split points in the same direction, but with wider confidence intervals and less precision.

By contrast, the time-varying startup-stock channel is weak in the broader sample once the regressions are clustered at the state level. In Specification A, the interaction between excess rainfall and log startup stock is essentially zero for the TOP index. In the joint specification, the reform interaction remains informative while the startup interaction remains imprecise. The broader sample therefore shifts the paper's interpretation away from startup resilience and toward a more defensible emphasis on market depth and reform heterogeneity.

5 Robustness

The robustness exercises support the main interpretation, but they also clarify its scope. First, Appendix Table 5 confirms that more rainfall relative to normal is associated with higher TOP inflation and that the interaction with mandi density is negative for the TOP composite. Second, Appendix Table 6 shows that the threshold interaction is not equally strong under every absorbed fixed-effects design. It becomes small with state-by-time fixed effects and is not negative once district-by-calendar-month effects are absorbed, but it re-

Table 4. Joint Startup Stock and Reform Moderators

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0350	-0.2341***	-0.0768***	-0.0665
	(0.0295)	(0.0342)	(0.0285)	(0.0453)
Inflation $(t-2)$	-0.2743***	-0.1904***	-0.1086***	-0.2348***
	(0.0266)	(0.0120)	(0.0133)	(0.0179)
Deficient rainfall (t)	0.0164	-0.0143	0.0130	-0.0004
	(0.0365)	(0.0176)	(0.0185)	(0.0189)
Excess rainfall (t)	0.0126	-0.0158	0.0149	0.0019
	(0.0362)	(0.0116)	(0.0166)	(0.0160)
Deficient rainfall $(t-1)$	-0.0059	-0.0047*	-0.0058	-0.0048
	(0.0120)	(0.0026)	(0.0045)	(0.0060)
Excess rainfall $(t-1)$	0.0150*	0.0038	0.0082***	0.0098***
	(0.0082)	(0.0033)	(0.0024)	(0.0030)
Deficient $\times$ log$(1 + \text{mandis})$	0.0019	-0.0121***	-0.0040	-0.0029
	(0.0087)	(0.0032)	(0.0057)	(0.0054)
Excess $\times$ log$(1 + \text{mandis})$	-0.0042	-0.0070**	-0.0038	-0.0036
	(0.0080)	(0.0035)	(0.0033)	(0.0041)
Deficient $\times$ log(startup stock)	-0.0024	0.0048	-0.0021	0.0017
	(0.0091)	(0.0033)	(0.0034)	(0.0042)
Excess $\times$ log(startup stock)	0.0032	0.0063**	0.0008	0.0039
	(0.0070)	(0.0030)	(0.0033)	(0.0028)
Deficient $\times$ AMFFRI	-0.0002	-0.0002	0.0002	-0.0002
	(0.0008)	(0.0002)	(0.0003)	(0.0004)
Excess $\times$ AMFFRI	-0.0009**	-0.0004	-0.0001	-0.0005***
	(0.0004)	(0.0002)	(0.0002)	(0.0002)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17657	17445	17594	15157

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: State-level moderators are clustered at the state level. In the broader sample, the AMFFRI excess-rainfall interaction remains negative for the TOP composite, while the startup-stock interaction is not precisely estimated.

mains negative with district trends and becomes substantially larger when mandi depth is measured using TOP-trading mandis only. Third, the extreme-years-only subsample reduces precision but still points to onion as the crop with the clearest mandi-buffering pattern, while the annual drought/excess classification preserves the positive excess-rainfall effect for the TOP composite.

Two caveats remain. First, the broader sample greatly improves district-level power, but state-level moderators are still repeated across districts within a state and should be interpreted with care. Second, the cereal placebo and wild-cluster bootstrap exercises have not yet been reproduced for the broader sample.

6 Discussion and Conclusion

The broader queue-based panel changes the paper's message in a useful way. Excess rainfall does not lower TOP inflation in the broader sample; it raises it. The central evidence instead suggests that deeper market networks moderate that pass-through, especially for onion, in the continuous-rainfall results, and when mandi depth is measured using TOP-relevant trading networks.

The paper's strongest results concern mandi depth and reform quality, not startup accumulation. That is the more credible and policy-relevant interpretation. A plausible reading is that agriculture startups have not yet reached the scale or spatial penetration needed to buffer district-level TOP shocks. The broader district panel improves external validity, the signs are more consistent with the economics of perishability, and the state-level startup channel no longer carries the main burden of interpretation, although the absence of district-level startup and reform measures means that these moderator results should still be interpreted with caution.

Taken together, the results suggest that agricultural price stability in perishable crops depends not only on production conditions but also on the density and quality of the marketing network through which local shocks are absorbed. In that sense, market infrastructure appears to have deepened enough to shape how supply shocks pass through into prices. Strengthening mandi connectivity and broader agricultural marketing reforms therefore appears more promising as a stabilisation margin than relying on startup growth alone.

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Appendix

Table 5. Continuous Rainfall Specification

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation ($t-1$)	-0.0401***	-0.2288***	-0.0706***	-0.0685***
	(0.0136)	(0.0226)	(0.0221)	(0.0179)
Inflation ($t-2$)	-0.2748***	-0.1879***	-0.1126***	-0.2370***
	(0.0113)	(0.0089)	(0.0110)	(0.0110)
Rainfall / LPA (t)	0.0068***	-0.0002	0.0088***	0.0044***
	(0.0021)	(0.0012)	(0.0012)	(0.0010)
Rainfall / LPA ($t-1$)	0.0057***	0.0014*	0.0029***	0.0044***
	(0.0013)	(0.0008)	(0.0007)	(0.0007)
Rainfall / LPA × log(1 + mandis)	-0.0022	0.0003	-0.0034***	-0.0014*
	(0.0015)	(0.0009)	(0.0008)	(0.0008)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17885	17721	18038	15216

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Rainfall enters as monthly rainfall relative to the district's calendar-month long-period average. The TOP interaction with mandi density is negative and statistically significant in this continuous specification.

Table 6. Alternative Fixed Effects and Mandi Definitions

Dependent variable:	TOP inflation				
Model:	(1)	(2)	(3)	(4)	(5)
Specification	Baseline	State× Time FE	District seasonality	District trends	TOP mandis only
Variables					
Deficient rainfall (t)	0.0049	0.0002	-0.0008	0.0051	0.0091***
	(0.0047)	(0.0032)	(0.0043)	(0.0048)	(0.0034)
Excess rainfall (t)	0.0110**	0.0043	0.0037	0.0111**	0.0126***
	(0.0047)	(0.0033)	(0.0037)	(0.0047)	(0.0033)
Deficient rainfall ($t-1$)	-0.0046	0.0005	-0.0059**	-0.0050	-0.0046
	(0.0032)	(0.0021)	(0.0024)	(0.0032)	(0.0032)
Excess rainfall ($t-1$)	0.0100***	0.0005	0.0064***	0.0101***	0.0099***
	(0.0028)	(0.0021)	(0.0022)	(0.0029)	(0.0028)
Deficient $\times$ $\log(1 + \text{mandis})$	-0.0038	-0.0007	-0.0004	-0.0044	-0.0181***
	(0.0040)	(0.0026)	(0.0030)	(0.0041)	(0.0045)
Excess $\times$ $\log(1 + \text{mandis})$	-0.0050	-0.0010	0.0029	-0.0050	-0.0147***
	(0.0039)	(0.0027)	(0.0030)	(0.0039)	(0.0041)
Fixed-effects					
District FE	Yes	Yes	No	Yes	Yes
Month-Year FE	Yes	No	Yes	Yes	Yes
State×Month-Year FE	No	Yes	No	No	No
District×Calendar-Month FE	No	No	Yes	No	No
District Linear Trends	No	No	No	Yes	No
Fit statistics					
Mandi Measure	All eNAM	All eNAM	All eNAM	All eNAM	TOP only
Observations	15216	15216	15216	15216	15216

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: All columns use the 253-district TOP composite sample. The table shows how the excess-rainfall interaction with mandi density changes under alternative absorbed fixed-effects structures and when mandi depth is measured using only mandis that trade TOP crops. The negative interaction is strongest under the TOP-trading-mandi measure.

Table 7. Monthly Threshold Specification, Extreme Years Only

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0386**	-0.2147***	-0.0459**	-0.0722***
	(0.0165)	(0.0178)	(0.0209)	(0.0217)
Inflation $(t-2)$	-0.2857***	-0.1927***	-0.1167***	-0.2327***
	(0.0158)	(0.0108)	(0.0154)	(0.0145)
Deficient rainfall (t)	0.0012	0.0086	0.0053	0.0065
	(0.0147)	(0.0071)	(0.0065)	(0.0074)
Excess rainfall (t)	0.0091	0.0114	0.0130**	0.0102
	(0.0141)	(0.0074)	(0.0066)	(0.0069)
Deficient rainfall $(t-1)$	-0.0001	-0.0091*	-0.0022	-0.0025
	(0.0093)	(0.0049)	(0.0039)	(0.0044)
Excess rainfall $(t-1)$	0.0072	0.0026	0.0092**	0.0077*
	(0.0086)	(0.0048)	(0.0039)	(0.0042)
Deficient $\times$ $\log(1 + \text{mandis})$	0.0028	-0.0157***	-0.0058	-0.0045
	(0.0128)	(0.0060)	(0.0055)	(0.0064)
Excess $\times$ $\log(1 + \text{mandis})$	-0.0095	-0.0072	-0.0033	-0.0063
	(0.0122)	(0.0061)	(0.0052)	(0.0057)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	9476	9501	9480	7984

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Sample restricted to district-years classified as annual drought or annual excess years using district-level annual rainfall relative to annual LPA.

Table 8. Annual Drought and Excess Dummies

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0382***	-0.2286***	-0.0659***	-0.0659***
	(0.0137)	(0.0226)	(0.0224)	(0.0182)
Inflation $(t-2)$	-0.2752***	-0.1882***	-0.1111***	-0.2359***
	(0.0113)	(0.0089)	(0.0111)	(0.0110)
Annual drought year	0.0044	-0.0023	0.0025	0.0013
	(0.0048)	(0.0037)	(0.0035)	(0.0026)
Annual excess year	0.0109**	0.0041	0.0085**	0.0080***
	(0.0043)	(0.0043)	(0.0033)	(0.0029)
Drought year $\times$ log$(1+\text{mandis})$	0.0036	0.0024	0.0015	0.0022
	(0.0043)	(0.0031)	(0.0030)	(0.0020)
Excess year $\times$ log$(1+\text{mandis})$	-0.0059*	0.0006	-0.0052**	-0.0029
	(0.0031)	(0.0030)	(0.0026)	(0.0021)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17910	17740	18038	15216

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Replaces monthly rainfall thresholds with annual drought and annual excess indicators, still estimated in monthly regressions with district and month-year fixed effects.

Table 9. Year-Trend Interactions

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0388***	-0.2297***	-0.0676***	-0.0673***
	(0.0136)	(0.0225)	(0.0224)	(0.0178)
Inflation $(t-2)$	-0.2747***	-0.1886***	-0.1107***	-0.2353***
	(0.0113)	(0.0089)	(0.0110)	(0.0110)
Deficient rainfall (t)	0.0132	-0.0090	0.0205***	0.0058
	(0.0134)	(0.0081)	(0.0077)	(0.0066)
Excess rainfall (t)	0.0021	-0.0041	0.0229***	0.0056
	(0.0124)	(0.0072)	(0.0066)	(0.0058)
Deficient rainfall $(t-1)$	-0.0041	-0.0050	-0.0031	-0.0045
	(0.0070)	(0.0032)	(0.0030)	(0.0032)
Excess rainfall $(t-1)$	0.0151**	0.0040	0.0100***	0.0100***
	(0.0060)	(0.0030)	(0.0031)	(0.0029)
Deficient $\times$ $\log(1+\text{mandis})$	0.0006	-0.0118***	-0.0031	-0.0038
	(0.0087)	(0.0045)	(0.0040)	(0.0041)
Excess $\times$ $\log(1+\text{mandis})$	-0.0067	-0.0069*	-0.0041	-0.0050
	(0.0087)	(0.0042)	(0.0036)	(0.0039)
Deficient $\times$ year trend	-0.0032	0.0038***	-0.0044***	-0.0003
	(0.0025)	(0.0014)	(0.0015)	(0.0012)
Excess $\times$ year trend	0.0030	0.0034**	-0.0018	0.0016
	(0.0025)	(0.0014)	(0.0013)	(0.0012)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17910	17740	18038	15216

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Adds rainfall-by-year-trend interactions to the baseline specification. The TOP composite interactions are not statistically distinguishable from zero in the broader sample.

Table 10. AMFFRI Continuous Moderator

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0372***	-0.2293***	-0.0702***	-0.0665***
	(0.0136)	(0.0226)	(0.0224)	(0.0178)
Inflation $(t-2)$	-0.2753***	-0.1880***	-0.1133***	-0.2349***
	(0.0113)	(0.0090)	(0.0109)	(0.0111)
Deficient rainfall (t)	0.0065	0.0055	0.0055	0.0069
	(0.0126)	(0.0059)	(0.0050)	(0.0059)
Excess rainfall (t)	0.0282**	0.0105*	0.0204***	0.0186***
	(0.0122)	(0.0057)	(0.0047)	(0.0052)
Deficient rainfall $(t-1)$	-0.0044	-0.0051	-0.0037	-0.0048
	(0.0070)	(0.0032)	(0.0030)	(0.0032)
Excess rainfall $(t-1)$	0.0150**	0.0041	0.0097***	0.0099***
	(0.0061)	(0.0030)	(0.0031)	(0.0029)
Deficient × $\log(1 + \text{mandis})$	0.0023	-0.0114**	-0.0032	-0.0033
	(0.0086)	(0.0045)	(0.0040)	(0.0039)
Excess × $\log(1 + \text{mandis})$	-0.0046	-0.0063	-0.0036	-0.0041
	(0.0084)	(0.0042)	(0.0037)	(0.0037)
Deficient × AMFFRI	-0.0003	-0.0001	0.0000	-0.0001
	(0.0003)	(0.0001)	(0.0001)	(0.0001)
Excess × AMFFRI	-0.0008***	-0.0002	-0.0002*	-0.0004***
	(0.0003)	(0.0001)	(0.0001)	(0.0001)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17846	17681	17974	15157

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: The AMFFRI moderator is centred at the sample mean. Negative excess-rainfall interactions imply lower pass-through in higher-reform states.

Table 11. Startup Stock Moderator

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0364	-0.2344***	-0.0737***	-0.0670
	(0.0294)	(0.0342)	(0.0282)	(0.0455)
Inflation $(t-2)$	-0.2740***	-0.1911***	-0.1066***	-0.2351***
	(0.0265)	(0.0120)	(0.0134)	(0.0178)
Deficient rainfall (t)	0.0175	-0.0088	0.0024	0.0000
	(0.0361)	(0.0205)	(0.0197)	(0.0187)
Excess rainfall (t)	0.0264	-0.0079	0.0135	0.0103
	(0.0305)	(0.0101)	(0.0168)	(0.0138)
Deficient rainfall $(t-1)$	-0.0060	-0.0047*	-0.0054	-0.0046
	(0.0120)	(0.0026)	(0.0045)	(0.0060)
Excess rainfall $(t-1)$	0.0149*	0.0039	0.0083***	0.0100***
	(0.0081)	(0.0033)	(0.0024)	(0.0030)
Deficient $\times$ $\log(1 + \text{mandis})$	0.0006	-0.0132***	-0.0030	-0.0038
	(0.0098)	(0.0040)	(0.0054)	(0.0060)
Excess $\times$ $\log(1 + \text{mandis})$	-0.0062	-0.0083*	-0.0037	-0.0050
	(0.0092)	(0.0044)	(0.0032)	(0.0049)
Deficient $\times$ log(startup stock)	-0.0031	0.0030	0.0005	0.0010
	(0.0068)	(0.0037)	(0.0034)	(0.0029)
Excess $\times$ log(startup stock)	-0.0032	0.0034*	0.0003	0.0002
	(0.0052)	(0.0020)	(0.0032)	(0.0025)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17721	17504	17658	15216

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Uses the time-varying cumulative agriculture-startup stock built from DPIIT registrations and clusters standard errors at the state level. The TOP interaction is economically small and statistically imprecise in the broader sample.

Table 12. High-Reform Split

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0370***	-0.2294***	-0.0701***	-0.0662***
	(0.0136)	(0.0226)	(0.0224)	(0.0179)
Inflation $(t-2)$	-0.2755***	-0.1884***	-0.1133***	-0.2353***
	(0.0112)	(0.0089)	(0.0109)	(0.0110)
Deficient rainfall (t)	0.0037	0.0054	0.0050	0.0050
	(0.0134)	(0.0060)	(0.0057)	(0.0063)
Excess rainfall (t)	0.0228	0.0082	0.0181***	0.0154***
	(0.0139)	(0.0058)	(0.0053)	(0.0059)
Deficient rainfall $(t-1)$	-0.0044	-0.0051	-0.0037	-0.0049
	(0.0070)	(0.0032)	(0.0030)	(0.0032)
Excess rainfall $(t-1)$	0.0151**	0.0041	0.0097***	0.0099***
	(0.0061)	(0.0030)	(0.0031)	(0.0029)
Deficient $\times$ $\log(1+\text{mandis})$	0.0006	-0.0120***	-0.0032	-0.0040
	(0.0089)	(0.0044)	(0.0039)	(0.0041)
Excess $\times$ $\log(1+\text{mandis})$	-0.0082	-0.0069*	-0.0044	-0.0057
	(0.0089)	(0.0042)	(0.0036)	(0.0040)
Deficient $\times$ high reform	-0.0030	-0.0023	0.0021	0.0003
	(0.0122)	(0.0063)	(0.0054)	(0.0058)
Excess $\times$ high reform	-0.0178	-0.0010	-0.0017	-0.0076
	(0.0120)	(0.0062)	(0.0048)	(0.0054)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17846	17681	17974	15157

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Interacts rainfall shocks with an indicator for states with AMFFRI scores of at least 70. Point estimates imply weaker excess-rainfall pass-through in higher-reform states, but the intervals are wide.

Table 13. Cross-Sectional Startup-Density Moderator

Dependent variable:	Month-on-month log price inflation			
Model:	(1)	(2)	(3)	(4)
Crop	Tomato	Onion	Potato	TOP index
Variables				
Inflation $(t-1)$	-0.0368***	-0.2295***	-0.0702***	-0.0662***
	(0.0136)	(0.0226)	(0.0224)	(0.0179)
Inflation $(t-2)$	-0.2755***	-0.1885***	-0.1133***	-0.2354***
	(0.0113)	(0.0090)	(0.0109)	(0.0111)
Deficient rainfall (t)	0.0096	0.0140	0.0006	0.0053
	(0.0201)	(0.0123)	(0.0105)	(0.0117)
Excess rainfall (t)	0.0813***	0.0068	0.0274***	0.0359***
	(0.0230)	(0.0125)	(0.0103)	(0.0088)
Deficient rainfall $(t-1)$	-0.0044	-0.0051	-0.0037	-0.0048
	(0.0070)	(0.0032)	(0.0030)	(0.0032)
Excess rainfall $(t-1)$	0.0151**	0.0040	0.0098***	0.0100***
	(0.0060)	(0.0030)	(0.0031)	(0.0029)
Deficient $\times$ $\log(1+\text{mandis})$	0.0013	-0.0116***	-0.0037	-0.0039
	(0.0087)	(0.0045)	(0.0039)	(0.0040)
Excess $\times$ $\log(1+\text{mandis})$	-0.0058	-0.0066	-0.0041	-0.0047
	(0.0084)	(0.0042)	(0.0037)	(0.0038)
Deficient $\times$ log(startup count)	-0.0016	-0.0019	0.0011	-0.0001
	(0.0035)	(0.0024)	(0.0019)	(0.0020)
Excess $\times$ log(startup count)	-0.0133***	0.0001	-0.0020	-0.0048***
	(0.0038)	(0.0025)	(0.0019)	(0.0015)
Fixed-effects				
District FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Fit statistics				
Observations	17846	17681	17974	15157

Standard errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Uses the cross-sectional startup count embedded in the reform file. This is distinct from the time-varying cumulative startup-stock panel used in Specification A.

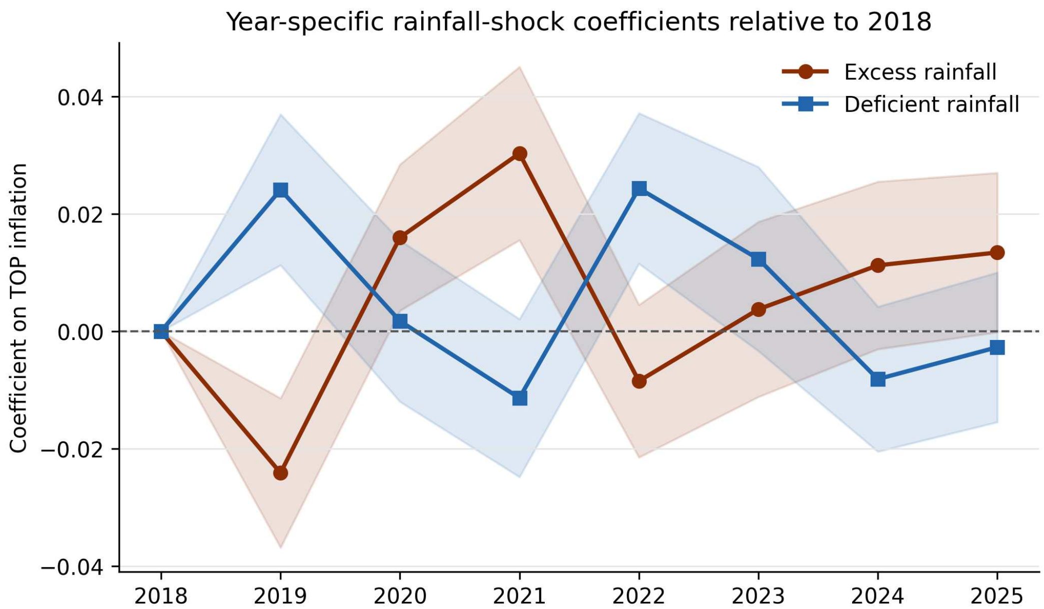

Figure 4. Year-specific rainfall-shock coefficients for the TOP composite relative to 2018. The broader sample does not reveal a monotone decline in rainfall sensitivity.

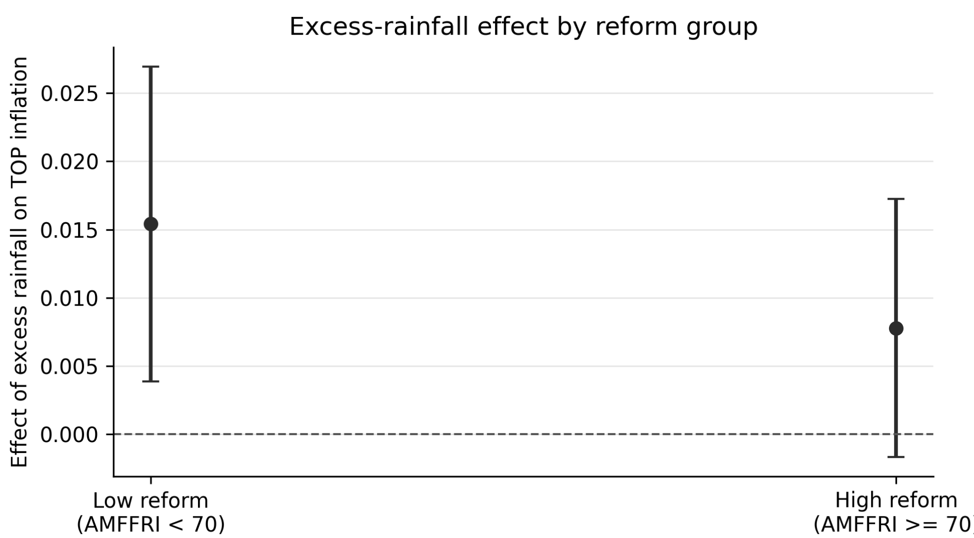

Figure 5. Estimated excess-rainfall effect by reform group. High-reform states show a smaller point estimate, but the interval is wide.

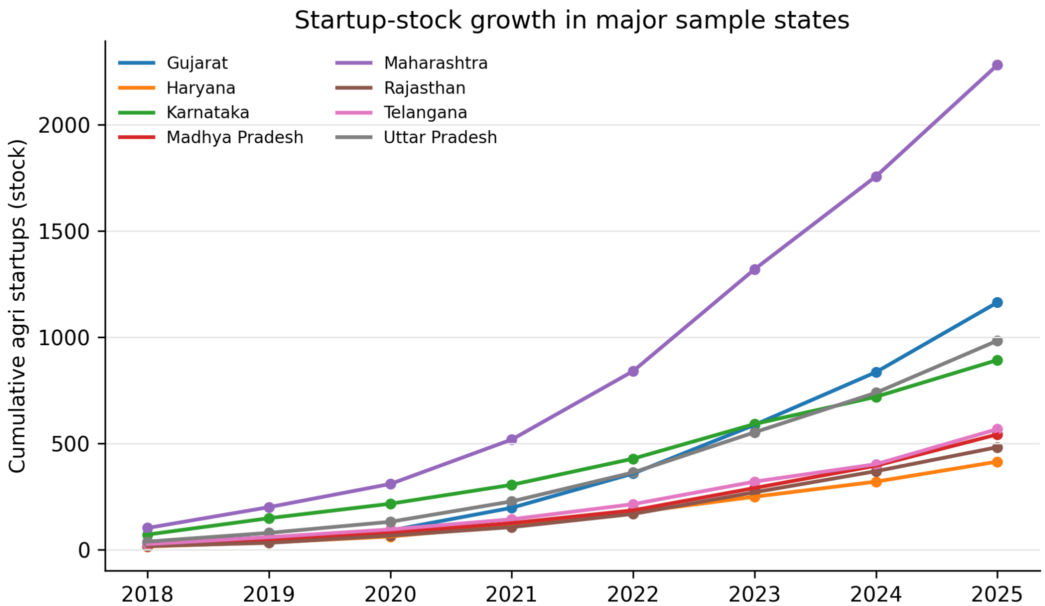

Figure 6. Cumulative agriculture-startup stock in major sample states, 2018–2025.

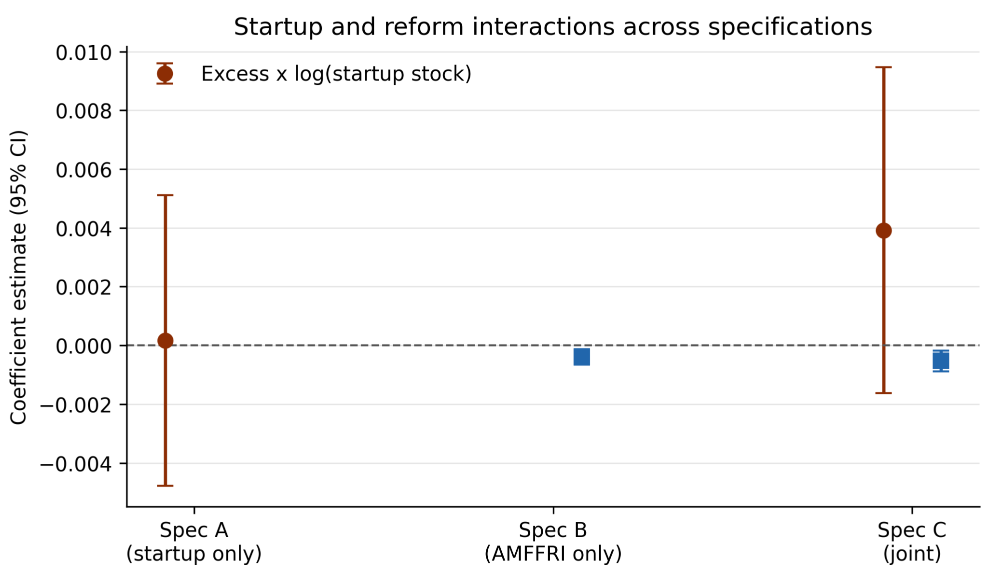

Figure 7. Comparison of startup and reform interactions across specifications. The broader sample provides stronger support for the reform interaction than for the time-varying startup-stock interaction.