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Risk, price volatility, and income instability in Makhana farming: A micro-econometric study from Bihar

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Abstract

Makhana (*Euryale ferox*) farming in Bihar is widely characterised as a high-value aquatic crop system, yet cultivators face pronounced income instability because production shocks (flood-water variability, labour bottlenecks, and post-harvest losses) interact with market shocks (grade-based price dispersion, buyer power, and delayed payments). This study provides a compact, evidence-based risk account and a defensible volatility measurement using a transparent institutional proxy price series when publicly available high-frequency mandi/farm-gate series are absent. Price risk is quantified using coefficient of variation, log-return volatility, seasonal indices, and downside semi-variance. Because publicly verifiable household microdata are not available for makhana in Bihar, the household econometric component is presented as an implementable identification design rather than as reported coefficient estimates. Results show economically meaningful inter-grade dispersion and variable seasonality, implying that liquidity, grading institutions, and processing/storage capacity are central to how volatility transmits into realised net returns. Policy options focus on grade-wise market information, standardised grading and quality assurance, producer-organisation working capital and processing/storage infrastructure, and flood-resilient waterbody management coordinated through the National Makhana Board framework.

Keywords: Makhana, Bihar, agricultural risk, price volatility, downside risk, semi-variance, income instability, value chain governance, risk management, micro-econometrics, floods

Introduction

Makhana in Bihar sits at the intersection of ecological dependence on waterbodies and a rapidly commercialising value chain. Institutional documentation highlights Bihar's centrality to the crop's production and the sector's policy focus on upgrading exports, processing, and organisation, but also notes that systematic records of arrivals and price trends remain limited, which constrains risk analytics and weakens price discovery in practice ^[1]. In such contexts, volatility is not only a statistical property of prices; it becomes a welfare mechanism because price movements interact with liquidity constraints and incomplete insurance, pushing households toward distress sales, high-cost borrowing, and safety-first production and marketing strategies ^[2].

The risk structure of makhana is distinctive. Production is exposed to covariate climatic and hydrological stress—especially floods and waterlogging, while harvesting is labour-intensive and time-sensitive, and post-harvest processing determines grade outcomes. Stakeholder-based field evidence from Bihar's major producing districts emphasises climate/water variability, harvesting labour constraints, and marketing/payment frictions as core drivers of instability ^[3]. Flood hazard documentation further supports treating north Bihar as a structurally flood-exposed environment, raising the likelihood that shocks are covariate

and therefore hard to smooth through local informal mechanisms alone ^[4].

Given these constraints, this study uses a transparent proxy approach for price volatility measurement and restricts causal claims accordingly. Grade-wise domestic price data reported in an APEDA study are used as a proxy series (not an official mandi/farm-gate series), and household-level econometrics is presented as a ready-to-run design for future microdata collection rather than as coefficient estimates ^[1]. Volatility measurement follows standard practice in food price volatility research by combining level-based and return-based measures and explicitly incorporating downside risk ^[2, 5].

Data and Risk Measurement

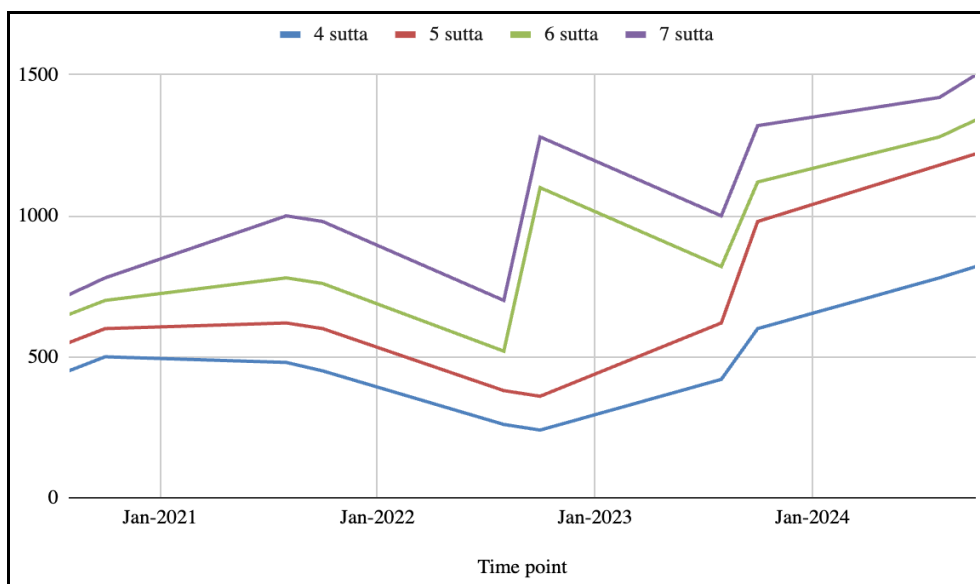
Price proxy series and construction

Publicly accessible, high-frequency official makhana prices with consistent grade reporting are not readily available for Bihar, and the APEDA study explicitly discusses the sector's limited systematic records for arrivals and price trends ^[1]. We therefore use APEDA's grade-wise domestic price figure (4/5/6/7 sutta; Aug and Oct points, 2020-2024) as a proxy for price dynamics. These values are digitised and rounded to the nearest ₹10 and should be interpreted as an approximation of the institutional proxy series rather than administrative price data ^[1].

Table 1: Grade-wise proxy prices for makhana (₹/kg), Aug/Oct 2020-2024

Time point	4 sutta	5 sutta	6 sutta	7 sutta
Aug-2020	450	550	650	720
Oct-2020	500	600	700	780
Aug-2021	480	620	780	1000
Oct-2021	450	600	760	980
Aug-2022	260	380	520	700
Oct-2022	240	360	1100	1280
Aug-2023	420	620	820	1000
Oct-2023	600	980	1120	1320
Aug-2024	780	1180	1280	1420
Oct-2024	820	1220	1340	1500

Digitised from the APEDA proxy series; proxy nature and limitations apply ^[1].

**Fig 1:** Grade-wise proxy prices for makhana (₹/kg), Aug/Oct 2020-2024

The proxy series indicates large inter-grade spreads and sharp movements across years and marketing points. Even without the official mandi series, the magnitude of swings is sufficient to motivate a downside-risk perspective and to treat processing/grading and liquidity as central mediators of realised farm-gate risk ^[1, 3].

Volatility metrics (including downside risk)

Let P_t be the price at time t . Volatility is measured using:

$$CV = \frac{\sigma(P)}{\mu(P)}$$

$$r_t = \ln(P_t) - \ln(P_{t-1})$$

$$\sigma_r = \sqrt{\text{Var}(r_t)}$$

$$SI = \frac{P_{Oct}}{P_{Aug}}$$

Downside risk is captured by semi-variance of log returns relative to the mean return $\bar{r}$:

$$SV = \mathbb{E}[(\min(0, r_t - \bar{r}))^2]$$

This set follows established food price volatility measurement principles and explicitly avoids parametric ARCH/GARCH modelling because the proxy series is short ^[2, 5].

Table 2: Volatility diagnostics by grade (proxy series)

Grade	Mean (₹/kg)	SD (₹/kg)	CV	σ_r	SV (downside semi-variance)
4 sutta	520	200	0.38	0.43	0.083
5 sutta	710	310	0.44	0.33	0.050
6 sutta	907	290	0.32	0.26	0.030
7 sutta	1098	300	0.27	0.22	0.020

Computed from Table 1; volatility framing consistent with ^[2, 5].

Relative volatility (CV) is higher for lower grades in this proxy, consistent with a risk stratification mechanism in which households that cannot consistently achieve higher grades face more unstable price realisation. Downside semi-variance indicates that negative-return episodes are non-trivial, which is the relevant object for safety-first behaviour and distress coping ^[2, 3].

Micro-econometric identification framework

Because publicly verifiable household microdata for

makhana risk outcomes are not available, the econometric component is stated as an implementable design consistent with the risk environment described above ^[1, 3]. The goal is to estimate how volatility exposure and production/market risk indicators map into welfare-relevant outcomes such as net-income downside risk, distress borrowing/sales, and diversification.

Let household net income from makhana be

$$RiskY_i = \alpha + \beta_1 VolPrice_{m(g),t} + \beta_2 FloodExp_i + \beta_3 BuyerConc_i + \beta_4 PayDelay_i + \beta_5 ProcStore_i + \beta_6 CreditFormal_i + \gamma' X_i + \delta_d + \varepsilon_i,$$

where $VolPrice_{m(g),t}$ is grade-adjusted price volatility exposure, $FloodExp_i$ is flood hazard exposure (e.g., hazard atlas class), $BuyerConc_i$ captures buyer concentration/market power, $PayDelay_i$ is delayed payment incidence, $ProcStore_i$ indicates processing/storage access, $CreditFormal_i$ indicates formal credit access, X_i includes household and farm controls, and δ_d are district fixed effects. Identification

$$\Delta \ln(PQ) \approx \Delta \ln P + \Delta \ln Q, \quad \text{Var}(\ln(PQ)) \approx \text{Var}(\ln P) + \text{Var}(\ln Q) + 2 \text{Cov}(\ln P, \ln Q)$$

For makhana, this is crucial because flood exposure can shift both Q and harvesting difficulty, while market frictions can shift PPP, making covariance terms potentially important drivers of downside risk ^[1, 3, 4].

Results and interpretation

The proxy evidence supports three compact conclusions. First, price risk is large and grade-differentiated, implying that “average high price” narratives are not sufficient for welfare analysis because downside episodes and relative volatility matter for safety-first households ^[2]. Second, the risk environment is compounded: production shocks are covariate in a flood-prone region and interact with labour constraints and post-harvest quality, which then map into grade outcomes and price realisation ^[3, 4]. Third, institutions that affect liquidity and grading, processing/storage capacity, collective marketing, and enforceable payment terms are likely first-order protective factors because they reduce forced sales during low-price windows and lower the variance of realised farm-gate prices at a given reference price ^[1, 3].

To illustrate seasonality in a minimal way, the two-point seasonal index $SI = P_{Oct}/P_{Aug}$ varies considerably across years in the proxy series, which is consistent with unstable seasonal patterns and suggests that inter-temporal marketing ability (storage/working capital) can be a risk-management tool rather than merely a margin-improving tactic ^[1, 2].

Policy options for risk management

Risk management should be layered because risks are layered. A first priority is grade-wise market information and standardised grading protocols to reduce information asymmetry and bargaining noise—directly addressing the

$\pi_{it} = P_{it}Q_{it} - C_{it}$. A tractable downside-risk outcome is the lower partial moment of income relative to a threshold π^* :

$$LPM_i = \mathbb{E} [\max(0, \pi^* - \pi_{it})],$$

or alternatively an income semi-variance. The baseline estimable equation for a survey/panel dataset is:

relies on within-district variation in buyer structure, payment terms, processing/storage adoption, and credit access, while flood exposure and district fixed effects absorb major spatial hydrology differences ^[3, 4]. Quantile regression is recommended when the dependent variable is a lower-tail outcomes and robust standard errors are required under heteroskedasticity typical of income data ^[2].

A decomposition useful for interpretation separates gross revenue variability into price and yield components under a log approximation:

documented weakness of systematic price records and supporting more credible price discovery for grade-specific transactions ^[1]. A second priority is processing/grading and storage infrastructure financed through producer organisations with working capital for procurement and timely payment; this directly targets forced sales and delayed payment risk and improves grade realisation, thereby reducing both level volatility and downside outcomes ^[1, 3]. The institutional logic for storage-linked risk reduction is consistent with established policy discussions on storage/receipts and structured marketing finance, which can be adapted for makhana inventories at the producer-organisation level ^[6].

A third priority is flood-resilient waterbody management because flood exposure is structural. Interventions that reduce siltation, stabilise pond/chaar conditions, and improve water quality can reduce covariate yield shocks and lower the covariance between yield shocks and cost shocks that drives left-tail income risk ^[4]. A fourth priority is risk transfer for catastrophic events using insurance principles; while makhana-specific implementation requires tailoring, national crop insurance guidelines provide the operational architecture for transferring tail risk and reducing welfare collapses after extreme shocks ^[7]. Finally, coordination is essential; the National Makhana Board framework is an institutional vehicle for bundling market information, grading/quality infrastructure, finance, and resilience under one sector strategy rather than dispersing interventions across disconnected schemes ^[8].

Conclusion

Makhana farming in Bihar exhibits a compounded risk structure: floodwater variability and labour-intensive harvesting generate production risk, while grade-based price dispersion, information frictions, and payment delays

generate market risk. Using a transparent institutional proxy series, this study documents economically meaningful volatility and non-trivial downside risk, especially for lower grades, and provides an implementable micro-econometric identification design to link volatility exposure to welfare-relevant downside outcomes once microdata are collected. The most credible stabilisation strategy is risk layering—grade-wise information and grading standards, producer-level processing/storage and working capital, flood-resilient waterbody management, and tailored risk transfer—coordinated through the National Makhana Board framework.

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