Integrated Export Pricing Framework Using N-HiTS Forecasting, Econometrics and Game Theory

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1. Project Background

Product pricing in any business is influenced by multiple interrelated factors, such as demand, competitor strategies, business priorities (e.g. revenue maximization vs. market share growth), customer behaviour, external conditions like government policies etc. Historical data capturing these factors, whether in time series or other forms is maintained at various sources and can be leveraged to gather valuable insights, build predictive models, and form data-driven pricing strategies for businesses.

This project aims to design an **integrated pricing framework** by using historical data, predictive modeling, and economic concepts such as price elasticity. The sector chosen for the project is 'agri-business and export' with a focus on HAFED, a Haryana based leading organization involved in processing, marketing, and export of agricultural products. Given that basmati rice is one of HAFED's primary export commodities, the framework has been developed around the export pricing of basmati rice for a selected international market. However, the approach and underlying methodology are generalizable and can be adapted by private exporters or other agri-based enterprises.

1.1 Problem Statement

The profitability of Haryana-based exporters, including HAFED, in international markets can be adversely affected by several factors, such as:

- Competition from both international and domestic players.
- Factors affecting cost of goods such as paddy prices, domestic taxation policies, and limited government subsidies.
- Changes in trade policies, particularly import tariffs imposed by foreign governments.

1.2 Project Objectives:

- Develop a predictive model to estimate future auction prices (modal rates) of basmati paddy.
- Develop a predictive model to evaluate how changes in export prices affect the market share of Indian and Haryana-based exporters in the U.S. basmati rice market.
- Evaluate exporter's profitability due to changes in price points and market shares.
- Use the previous analysis to estimate an optimal price range for exporters.

U.S. was selected as the target market as multiple reports indicate that it is expected to record one of the highest CAGRs for basmati rice consumption in the coming years. Furthermore, the new import tariff regime by the U.S. government has made it essential for exporters to re-evaluate their pricing strategies.

It is assumed that, unlike large brands, HAFED and other medium or small exporters may not possess the resources or infrastructure for inland distribution within the U.S. market. Consequently, their scope of responsibility would be limited to Free on Board (FOB) operations, up to the point of shipment loading. Therefore, the cost/profit modelling in this project is based on available FOB rates.

2. Paddy (Basmati) Auction Modal Rate Prediction

Historical date-wise data on mandi modal rates of basmati paddy were sourced from agmarknet.gov.in. The dataset was further developed by including co-variates representing multiple contributing factors, i.e., demand, supply, external shocks, economic indicators etc. The final dataset for prediction model included monthly averages of modal rates, from April 2019 to August 2025, along with co-variates data. The list of variables used in dataset are given below:

Variable type	Variables	Source
Time series indicators	Year/Month	agmarknet.gov.in
	Sin/Cos values of months	For model to interpret cyclical nature of months
Dependent var	Modal Price monthly avg (Rs./MT)	agmarknet.gov.in
Seasonality	No. of auctions in that month; auction month (0/1); no. of months since last auction; modal rate volatility in that month	agmarknet.gov.in
External shock	Covid lockdown month (0/1)	-

	Minimum export price status in current month: 0/1	News articles
Demand	Last 12 months export data since current month: – Export by India and Pakistan (Qty MT; Value in USD mil/INR Cr; Rate[USD/MT]) – India-Pak rate difference	DGCIS, REAP.com.pk
Supply	– Current year harvest (000 MT) – Current year yield (MT/ha)	Dept of Agriculture, GoI
Macroeconomic factors	INR to USD depreciation rate (YoY) in %	Finance and trade websites
	WPI change (YoY) in %	RBI

2.1 Time-Series Model Prediction Results:

Initially, an XGB regression model was used for prediction, however, it did not yield satisfactory results. Subsequently, time-series predictive model, Temporal Fusion Transformer **(TFT)** was implemented, achieving significantly better performance with an average test **accuracy of approx 95%** (results in Figure 1 below).

```
RMSE: 0.07367524734608594
MAE: 0.06088761979157916
Validation actual vs forecast:
                  actual      forecast
date
2024-10-01  33780.805687  36849.437993
2024-11-01  39628.553971  39287.683171
2024-12-01  38958.850575  39474.103135
2025-01-01  36224.605809  37138.162822
2025-02-01  35315.397490  38487.776680
2025-03-01  34637.175141  37071.444474
```

Figure 1: TFT prediction results

While the TFT model delivered reliable results, it involves additional complexity of defining past and future covariates. To simplify the modeling process, **N-HiTS** (Neural hierarchal interpolation of times series) model was subsequently used, which also showed high predictive accuracy, **achieving 96.5%** on the test data (as shown in Figure 2).

```
RMSE: 0.06698529208471315
MAE: 0.0551987324090669
Validation actual vs forecast:
                  actual      forecast
date
2023-10-01  38200.135135  37330.500688
2023-11-01  44643.046512  41026.046733
2023-12-01  47285.818182  45023.408957
2024-01-01  44401.036585  45398.601442
2024-02-01  43681.714286  45077.319397
2024-03-01  42874.054054  42547.205940
```

Figure 2: N-HiTS prediction results

The trained N-HiTS model was then used to forecast average mandi modal rates from September 2025 to March 2026. The month-wise forecast results are shown below.

Month/Year	**Avg Modal rate forecast (INR/quintal)**
Sep 2025	2,868.1
Oct 2025	3,102.8
Nov 2025	3,439.5
Dec 2025	3,442
Jan 2026	3,303.1
Feb 2026	3,375.2
Mar 2026	3,339.6

```
       forecast
0  28681.130162
1  31028.068419
2  34395.767494
3  34420.114337
4  33031.432753
5  33752.205890
6  33396.930838
```

N-HiTS prediction results for Sep 25-Mar 26

Interestingly, the actual modal rates for basmati paddy auctioned in September and October 2025 were available at the time of this report, recorded at INR 2,933 and INR 2,990 per quintal, respectively (source: agmarknet.gov.in). For comparison, the model's **predicted value of INR 2,889.6 for Sep 2025 differs by only 2.2%** from the actual figure, whereas the **predicted value of INR 3,102.8 for Oct 2025 differs by 3.7%** which further validates the model's accuracy and reliability.

3. Profitability Analysis

A profitability analysis was conducted using the prevailing FOB rates to estimate the per kg profit margin %, which will **subsequently serve for assessing profitability across different price points and market share percentages.**

- On the cost side, the average auction modal rate over seven months (INR 3,372.97 per quintal) was used to determine the raw material cost. Assuming a recovery rate of 65%, the final cost was calculated as INR 5,189.18 per quintal.
- Other costs such as commission rates, taxes, processing, logistics, and financial expenses were obtained from multiple sources such as news articles, government or finance websites etc.
- The analysis resulted in profit margin % and the estimated cost to the U.S. importer after accounting for a 40% import tariff. A snapshot of the results is given below for reference:

Total Operating Expense (TOE)	Value in Rs
Avg mandi modal rates for paddy (Rs/quintal)	3372.97
Rate of recovered rice at 65% (Rs/quintal)	5189.18
Rate of recovered rice (Rs/kg)	51.89
Commission charges per kg (rs 55/quintal)	0.55
Mandi fee @2%	0.67
Cess @2%	0.67
Processing cost (milling, polishing, grading, storage, packaging) Rs per kg	12
Transport cost(mandi->mill->port) Rs/kg	3
Port handling charges Rs/kg	0.5
US compliance certification cost Rs/kg	1
Overheads Rs/kg	1
Total per kg cost	**71.29**

Financial Expenses	Value in Rs
Short-term working capital interests (@10%p.a.)	2.14
Exchange rate hedge cost (0.63% of transaction value)	0.60
Total	**2.74**

Profit	Medium exp
Operating profit (Rs)	26.71
Operating Margin (on TOE) %	37%
Net profit (Rs)	17.29
Profit margin%	17.64%

Taxes	Values
Corporate tax rate	25%
GST	nil

FOB rates for US export	Values in Rs/kg
Medium exporter	98
freight	11.136
insurance	0.49
Medium exporter CIF	109.626
Medium CIF in $	1.24575
Cost of Goods for US importers at 40% tariff (USD)	1.74405

Figure 3: Profitability Analysis For India Basmati Rice

Similarly, a profitability analysis for Pakistan's exporters was conducted based on their current FOB rate (Pkr 358.9/kg) for Basmati rice. The results indicated a profit margin of 19.5%, with the per kg cost to the U.S. importer estimated at USD 1.81.

4. Regression-Based Price Elasticity of Demand Analysis

The optimal price for Indian exporters relative to an international competitor depends on price-demand elasticity. Specifically, how changes in export rates affect Indian exporters' market share. Accordingly, regression models were developed to project India's market share percentage based on varying export rates.

For this, year-wise U.S. import data was sourced from the World Integrated Trade Solution (WITS) database (https://wits.worldbank.org/). Since Pakistan is India's primary competitor in basmati export, the dataset was prepared by including annual quantity and value of rice imported by U.S. from India, Pakistan, and total imports during 2007–2023. By using this information, several variables were constructed, such as India and Pakistan's unit rates (USD/kg), India's quantity share % (ISQ) in U.S market, India – Pakistan rate difference, annual rate changes for both countries etc.

These variables were then used in **Ordinary Least Squares (OLS) regression models** to derive predictive functions for **Pakistan's unit rate** and **India's share in quantity (ISQ)**, whereas **India's unit rate** was treated as a known variable for the forecast year.

Accordingly, **two separate regression models** were developed, their results and variable details are given below.

4.1 Pakistan's unit rate projection (Model 1)

Pakistan's rates are estimated by using a model which uses two explanatory variables, Pakistan's previous year rate and India's (YoY) rate change (i.e., current year rate minus previous year rate). Model results show a high adj. R-squared value, indicating model has a high variance explainability. A very small Prob (F-statistic) value confirms that the model is statistically significant.

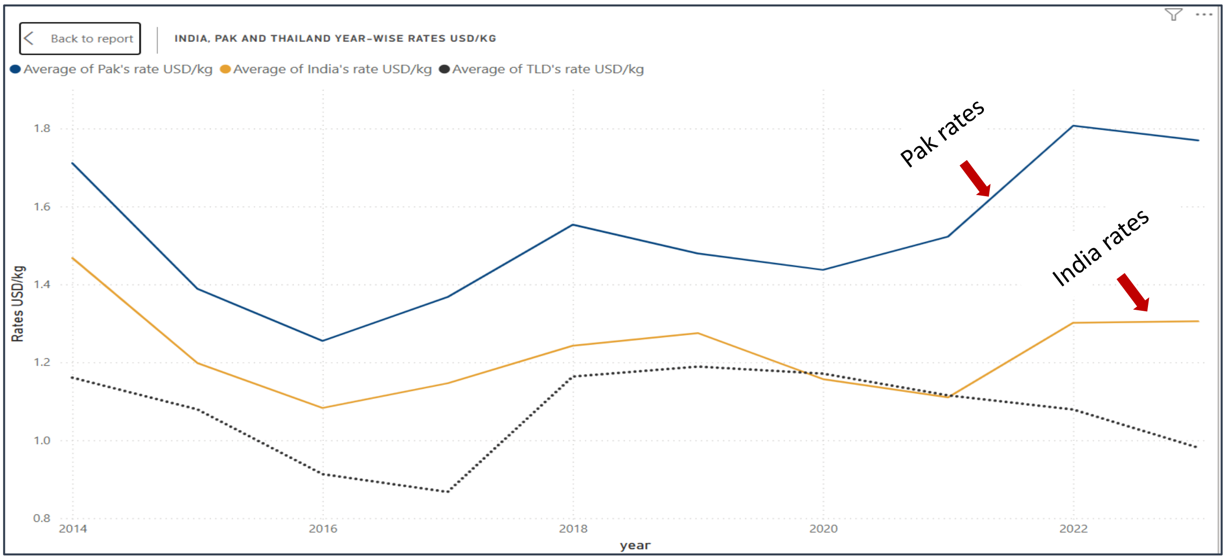
– The 'lagged Pakistan rate' variable has a very low p-value, indicating it is a significant predictor for current year's Pakistan rate. Its coefficient value 0.74 suggests that approximately 74% of the previous year's Pakistan rate carries forward into the current year.
– Likewise, the India YoY rate change variable also has a low p-value, and its coefficient value 0.86 implies that Pakistan's rate tends to change by nearly 86% of the variation observed in India's rate.

```
Pak rate regression:
                            OLS Regression Results
==============================================================================
Dep. Variable:      Pak's rate USD/kg   R-squared:                       0.836
Model:                            OLS   Adj. R-squared:                  0.813
Method:                 Least Squares   F-statistic:                     35.80
[redacted]                              Prob (F-statistic):           3.13e-06
                                        Log-Likelihood:                 18.698
No. Observations:                  17   AIC:                            -31.40
Df Residuals:                      14   BIC:                            -28.90
Df Model:                           2
Covariance Type:            nonrobust
================================================================================
                   coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------
const            0.3954      0.152      2.606      0.021       0.070       0.721
Pak rate lag     0.7425      0.105      7.077      0.000       0.517       0.968
India RC         0.8609      0.119      7.210      0.000       0.605       1.117
==============================================================================
Omnibus:                        1.069   Durbin-Watson:                   1.197
Prob(Omnibus):                  0.586   Jarque-Bera (JB):                0.923
Skew:                           0.493   Prob(JB):                        0.630
Kurtosis:                       2.424   Cond. No.                         15.8
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
Pak rate parameters:
{'const': 0.3954135720542853, 'Pak rate lag': 0.7424992024144105, 'India RC': 0.8609300492114627}
                 const  Pak rate lag  India RC
const         0.023029     -0.015758 -0.007931
Pak rate lag -0.015758      0.011007  0.005335
India RC     -0.007931      0.005335  0.014259
```

Figure 4: Pakistan's Rate Regression model summary

It is reasonable that Pakistan's rate can be explained just by using its previous year's rate and India's rate change, since both countries exhibit a closely aligned annual price trajectory, as illustrated in the trend chart below.



4.2 India's market share projections (Model 2)

Next, the regression model for projecting India's market share in quantity (ISQ) was developed by using previous year's ISQ, current year rate difference between India and Pakistan, and Pakistan's rate change in the preceding year (Pak RC+).

The model results indicate a very high adj. R-squared value, indicating high variance explainability by the model. The extremely low Prob (F-statistic) further confirms that the selected variables collectively have significant explanatory power.

- Std. errors were computed using **HC3** covariance estimator to prevent heteroskedasticity and ensure reliable p-values.
- ISQ_lag has coefficient value of 0.52, indicating that 52% of the previous year's market share (ISQ) is retained in the current year.
- The second most significant variable is the rate difference between India and Pakistan. The coefficient value -0.10 indicates that India's market share declines notably when its export rates exceed those of Pakistan.
- Pakistan's previous year rate change (Pak RC+) also have minor but noticeable effects on the ISQ projection.
- A **Leave-One-Out Cross-Validation (LOOCV)** test was conducted to evaluate the model's ability to generalize on unseen data. The results showed that, on average, the model's predictions were approximately 94% consistent with the actual market share values, indicating a strong predictive fit. Along with very low p-values for the independent variables, this suggests that the chosen predictors exhibit a statistically significant and stable linear relationship with the dependent variable, making the model reliable for projecting market share % across years.

```
ISQ regression:
                            OLS Regression Results
==============================================================================
Dep. Variable:                    ISQ   R-squared:                       0.938
Model:                            OLS   Adj. R-squared:                  0.924
Method:                 Least Squares   F-statistic:                     143.7
[redacted]                              Prob (F-statistic):           3.23e-10
                                        Log-Likelihood:                 54.861
No. Observations:                  17   AIC:                            -101.7
Df Residuals:                      13   BIC:                            -98.39
Df Model:                           3
Covariance Type:                  HC3
================================================================================
                  coef    std err          z      P>|z|      [0.025      0.975]
--------------------------------------------------------------------------------
const           0.0659      0.015      4.301      0.000       0.036       0.096
ISQ_lag         0.5281      0.115      4.572      0.000       0.302       0.754
Rate diff IP   -0.1024      0.030     -3.427      0.001      -0.161      -0.044
Pak RC+        -0.0346      0.008     -4.434      0.000      -0.050      -0.019
==============================================================================
Omnibus:                        2.733   Durbin-Watson:                   2.573
Prob(Omnibus):                  0.255   Jarque-Bera (JB):                1.522
Skew:                           0.732   Prob(JB):                        0.467
Kurtosis:                       3.057   Cond. No.                         45.0
==============================================================================

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)
ISQ parameters:
{'const': 0.06589139923360421, 'ISQ_lag': 0.5280782471804797, 'Rate diff IP': -0.10240493303223376, 'Pak RC+': -0.03457782436526597}
```

Figure 5: ISQ Regression model summary

The variable types and their coefficients were then used to create regression functions for Pak unit rate and ISQ.
e.g. ISQ = 0.5281*ISQ_lag + (-0.1024*Rate diff IP) + (-0.0346*Pak RC+)

4.3 Estimations of 2024 & 2025 values

In order to estimate Pakistan's unit rate and India's share in quantity (ISQ) for 2026, past data from 2025 and 2024 is also required. However, these values were not available on WITS, hence **Vector Error Correction Model (VECM)** was trained on past data (2007-2023) to generate estimated figures for India and Pakistan's rates, for the years 2024 and 2025.

```
Eigenvalues: [0.95500539 0.68629798 0.55731974 0.35546349]
Trace stats: [82.71983374 36.20164608 18.81197029  6.58835718]
Critcial values (90%, 95%, 99%): [[44.4929 47.8545 54.6815]
 [27.0669 29.7961 35.4628]
 [13.4294 15.4943 19.9349]
 [ 2.7055  3.8415  6.6349]]
```

	India_rate	Pak_rate	ISQ	ISV
2024-12-31	1.342652	1.647104	0.200333	0.264423
2025-12-31	1.254466	1.457440	0.195380	0.254575

Figure 5: VECM results

From the VECM results, only the estimated value of India's 2024 rate was used as input to the Pakistan unit rate function to project Pakistan's rate. The resulting India and Pakistan rates represent CIF (Cost, Insurance, Freight) values. These rates were then adjusted by the applicable U.S. import tariffs for the respective year and used in the ISQ regression function to estimate India's market share for 2024 and 2025.

4.4 India's market share and profitability in 2026

India's current CIF rate, adjusted for 40% U.S. import tariff, was used to estimate India's market share in 2026. In 2024 (year before the new import tariff regime) India's market share was 22.53%, and the projected share declines to 17.5% in 2026. Leading to an estimated reduction of 5 percentage points, or ~22% reduction overall, primarily due to Pakistan's price advantage under the prevailing U.S. import tariffs.

2026												
Pak rate w/o tariff	1.683937651				**ISQ**	17.58%				**ISV**	22.42%	
var	coeff	value			var	coeff	value			var	coeff	value
const	0.3954				const	0.0659				const	0.0148	
India RC w/o tariff	0.8609	0.11			ISQ_lag	0.5281	20.27%			ISV_lag	0.3958	24.30%
Pak rate lag	0.7425	1.612965133			Rate diff IP	-0.1024	-0.05			ISQ	0.6259	17.58%
					Pak RC+	-0.0346	0.06			India RC	0.0575	0.06
2026 India rate with tariff (40%)	1.89		2025 India RC with tariff	0.26								
2026 Pak rate with tariff (15%)	1.936528299		2025 Pak RC with tariff	0.14								

Figure 6: India's projected market share% in 2026

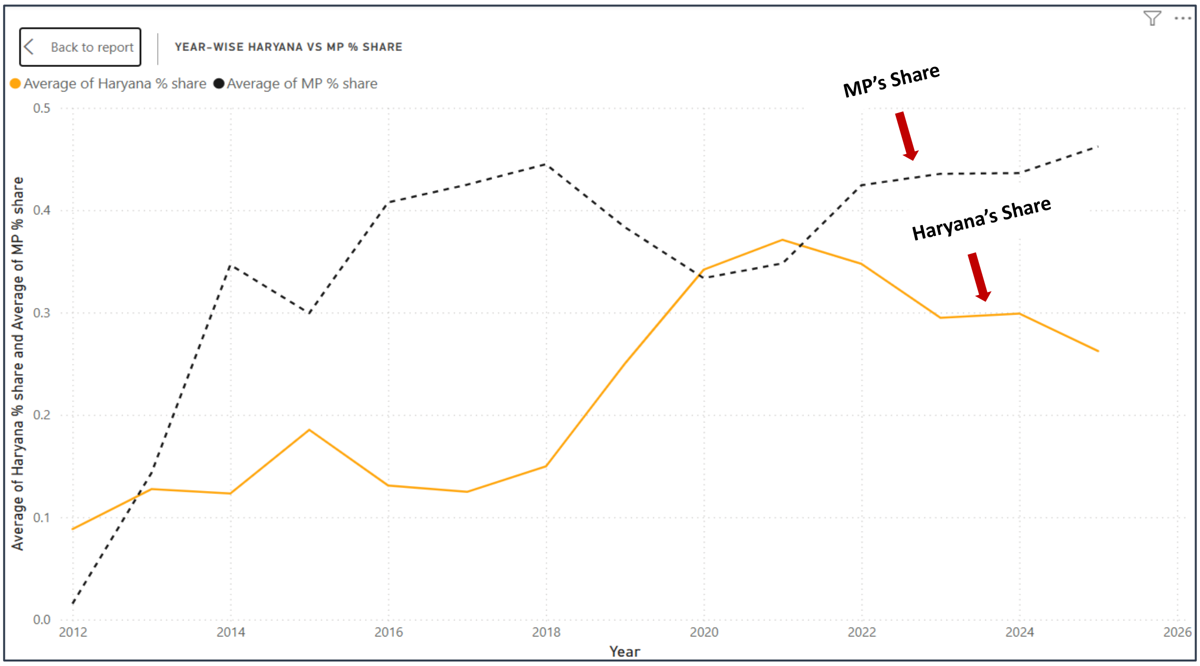
- The following equation was used for profitability assessment for the Indian exporters:
  Overall Profit = (Estimated rice import by U.S. in 2026)* 17.58% (market share) * profit margin% * fob rate.
- Profitability and market share percentages were evaluated across varying price points. The analysis revealed that the gain in market share resulting from a reduction in FOB rates is very small compared to the corresponding decline in profit margins. For instance, when FOB rates decrease from INR 98/kg to INR 90/kg, the profit margin falls by approximately 4–5%, while the increase in market share is just 0.6%.
- This unfavourable price-demand elasticity can mainly be attributed to the price disadvantage for Indian exporters due to current import tariff regime. Attempting to counter Pakistan based exporters by substantially lowering prices would severely hurt profitability, while protecting only a small percentage of market share. Therefore, adopting this strategy under the present conditions cannot be recommended.

5. Price elasticity in context of domestic competition

Exporters from a particular state need to optimize their FOB rates according to the prices set by competitors from other states. To develop regression models for estimating state-wise market shares at different price points, a year-wise basmati export dataset for Indian states was compiled using information from 'APEDA's AgriExchange portal'. Historical trends indicate that the three major basmati-exporting states to the U.S. market are Madhya Pradesh (MP), Haryana, and Punjab. MP has maintained the highest market share since 2014. Market shares of Haryana and Punjab remained comparable until 2018. Post-2018 Haryana recorded a significant gain in 2019, largely at the expense of MP. A snapshot of the market shares of the three states over the last 14 years is shown below for reference.

Year	Total	Avg rates	Haryana export value (mil USD)	Haryana rate	Haryana % share	Punjab export value (mil USD)	Punjab rate	Punjab % share	MP export value (mil USD)	MP rate	MP % share
2012	105.09	1.14	11.68	1.44	8.84%	1.37	1.10	1.36%	2.23	1.57	1.55%
2013	103.17	1.13	13.71	1.18	12.74%	12.94	1.22	11.55%	14.20	1.08	14.31%
2014	143.87	1.39	17.28	1.36	12.32%	21.84	1.41	15.01%	48.72	1.36	34.66%
2015	132.30	1.48	24.95	1.51	18.53%	15.93	1.48	12.07%	38.17	1.43	29.93%
2016	131.51	1.09	17.27	1.09	13.08%	17.99	1.11	13.48%	51.40	1.04	40.76%
2017	112.39	1.03	12.99	0.96	12.47%	14.39	0.98	13.41%	47.04	1.02	42.49%
2018	148.97	1.17	23.37	1.23	14.97%	16.56	1.21	10.77%	61.49	1.09	44.49%
2019	169.18	1.25	43.37	1.28	24.99%	25.21	1.28	14.51%	63.01	1.21	38.34%
2020	179.66	1.21	61.07	1.20	34.18%	29.46	1.21	16.40%	59.22	1.20	33.36%
2021	194.58	1.08	75.95	1.13	37.10%	23.07	1.12	11.43%	62.62	0.99	34.80%
2022	183.93	1.14	65.81	1.18	34.76%	24.46	1.15	13.17%	75.29	1.10	42.44%
2023	239.33	1.17	76.02	1.26	29.48%	33.64	1.25	13.24%	94.07	1.06	43.55%
2024	304.78	1.30	93.33	1.33	29.90%	39.78	1.35	12.55%	128.61	1.26	43.62%
2025	337.12	1.23	91.15	1.27	26.23%	48.07	1.29	13.63%	152.19	1.20	46.22%

This dataset was further used to derive key variables for regression analysis, including year-on-year rate change, lagged market share, and annual change in market share. Madhya Pradesh (MP) was identified as the primary influencing factor for Haryana's market share, given the strong negative correlation observed between their market share trends over the past decade (see graph below).



5.1 Regression models for Haryana and MP's market share

Regression models were developed to project market shares of Haryana and Madhya Pradesh (MP) at specific price points using the following variables:

- For Haryana market share (%) - Previous year's Haryana share (Haryana share lag), price difference between Haryana and MP, price difference between Haryana and Punjab, and Haryana's YoY change in share in previous year (HS diff lag).
- For MP market share (%) - Previous year's MP share (MP share lag), change in Haryana's share (%), and MP's YoY change in share in previous year (MPS diff lag).

Regression results for both models are given below for reference:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:          Haryana % share   R-squared:                       0.940
Model:                              OLS   Adj. R-squared:                  0.915
Method:                   Least Squares   F-statistic:                     13.91
[redacted]                                Prob (F-statistic):            0.00246
                                          Log-Likelihood:                 26.895
No. Observations:                    11   AIC:                            -45.79
Df Residuals:                         7   BIC:                            -44.20
Df Model:                             3
Covariance Type:                    HC3
=====================================================================================
                       coef    std err          z      P>|z|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                0.0773      0.028      2.728      0.006       0.022       0.133
Haryana share lag    0.6869      0.120      5.714      0.000       0.451       0.922
PR                  -0.3467      0.139     -2.503      0.012      -0.618      -0.075
HS diff lag          0.8944      0.172      5.205      0.000       0.558       1.231
==============================================================================
Omnibus:                          0.920   Durbin-Watson:                   3.090
Prob(Omnibus):                    0.631   Jarque-Bera (JB):                0.753
Skew:                            -0.519   Prob(JB):                        0.686
Kurtosis:                         2.248   Cond. No.                         25.4
==============================================================================

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)
```

Figure 6: Haryana export share regression results

```
                            OLS Regression Results
==============================================================================
Dep. Variable:               MP % share   R-squared:                       0.831
Model:                              OLS   Adj. R-squared:                  0.789
Method:                   Least Squares   F-statistic:                     10.43
[redacted]                                Prob (F-statistic):            0.00590
                                          Log-Likelihood:                 27.172
No. Observations:                    11   AIC:                            -48.34
Df Residuals:                         8   BIC:                            -47.15
Df Model:                             2
Covariance Type:                    HC3
================================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
--------------------------------------------------------------------------------
const          0.1629      0.074      2.195      0.028       0.017       0.308
MP share lag   0.6327      0.189      3.356      0.001       0.263       1.002
HSC           -0.7419      0.183     -4.061      0.000      -1.100      -0.384
==============================================================================
Omnibus:                          0.714   Durbin-Watson:                   2.202
Prob(Omnibus):                    0.700   Jarque-Bera (JB):                0.506
Skew:                            -0.454   Prob(JB):                        0.777
Kurtosis:                         2.472   Cond. No.                         25.0
==============================================================================

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)
```

Figure 7: MP export share regression results

5.2 Haryana vs MP payoff matrix

- Regression functions for Haryana and MP's market shares were created using coefficient values from their regression results.
- Three price points were selected for each state:
  - **Haryana:** Ongoing FOB rate – INR 98 (17.64% profit margin), Lower rate – INR 86.5 (10% margin), Higher rate – INR 102 (19.9% margin).
  - **Madhya Pradesh (MP):** Ongoing FOB rate – INR 79.3 (4.12% profit margin), Higher rate – INR 83.3 (7.52% margin), Higher rate 2 – INR 86.5 (10% margin).
- India's total export volume to the U.S. in 2026 was estimated at **19.5 million tons** (estimated U.S. import in 2026) x **16.8%** (India's projected market share). Profitability and market share for both states were calculated using their regression functions.
- The state-wise profit and market share percentages were placed in a payoff matrix as shown below.

	Pay-Off Matrix (Profit in INR Cr, Market share in %)			
		MP		
H	**Details**	**Ongoing Rate** **Rate:** 79.3 INR **Margin:** 4.12%	**Increased Rate** **Rate:** 83.3 INR **Margin:** 7.52%	**Increased Rate 2** **Rate:** 86.5 INR **Margin:** 10%
	Ongoing Rate **Rate:** 98 INR **Margin:** 17.64%	MP: 51.52, 48.14% H: 118.49, 20.92%	MP: 96.89, 47.22% H: 125.60, 22.18%	MP: 131, 46.46% H: 131.41, 23.20%
	Lower Rate **Rate:** 86.5 INR **Margin:** 10%	MP: 51.16, 47.81% H: 60.57, 21.37%	MP: 96.21, 46.88% H: 64.12, 22.63%	MP: 130, 46.13% H: 67.03, 23.66%
	Higher Rate **Rate:** 102 INR **Margin:** 19.9%	MP: 51.65, 48.26% H: 138.07, 20.76%	MP: 97.14, 47.34% H: 146.31, 22.01%	MP: 132, 46.58% H: 153.19, 23.04%

- The results show that if Haryana exporters reduce their ongoing FOB rate from INR 98 to INR 86.5, the gain in market share (from 20.92% to 21.37%) is small, while the decline in profitability is substantial. This outcome can be attributed to the highly competitive pricing set by MP exporters and the inherent characteristics of the agricultural sector, where changes in market share occur gradually in response to price variations.
- The only scenario where Haryana exporters can retain a portion of their declining market share is when MP exporters raise their FOB rate, as shown in **column 3**. If MP exporters increase their rate (e.g., to INR 86.5), Haryana exporters can also raise their rate slightly to enhance profitability, even at the cost of a minor reduction in market share. This scenario (in column 3, row 3) represents an **equilibrium state**, where the overall profitability for both states' exporters is maximized, and any further downward adjustment in price by either side may yield marginal market share gains but would result in a sharp decline in ROI.
- The same outcome can be derived by applying the Nash equilibrium function in Python. For this, the profit and market share (%) values were first normalized using a MinMax scaler and then combined into a weighted composite score (weights of 0.5:0.5 for MP and 0.7:0.3 for Haryana), giving higher priority to market share in the latter case.

```
Bi matrix game with payoff matrices:

Row player:
[[0.38 0.73 1.01]
 [0.31 0.64 0.92]
 [0.41 0.75 1.04]]

Column player:
[[0.47 0.54 0.57]
 [0.39 0.45 0.49]
 [0.5  0.57 0.61]]

Nash Equilibria:
(array([0., 0., 1.]), array([0., 0., 1.]))
```

	Pay-Off Matrix FOB Rates			
	MP			
	Details	**Ongoing Rate** **Rate:** 79.3 INR **Margin:** 4.12%	**Increased Rate** **Rate:** 83.3 INR **Margin:** 7.52%	**Increased Rate 2** **Rate:** 86.5 INR **Margin:** 10%
H	**Ongoing Rate** **Rate:** 98 INR **Margin:** 17.64%	MP: 0.47 H: 0.38	MP: 0.54 H: 0.73	MP: 0.57 H: 1.01
	Lower Rate **Rate:** 86.5 INR **Margin:** 10%	MP: 0.39 H: 0.31	MP: 0.45 H: 0.64	MP: 0.49 H: 0.92
	Higher Rate **Rate:** 102 INR **Margin:** 19.9%	MP: 0.50 H: 0.41	MP: 0.57 H: 0.75	MP: 0.61 H: 1.04

Figure 8: Nash results

- The most favourable outcome for both players occurs when Haryana maintains or slightly increases its current rates, while MP also raises its rates but keeps them below Haryana's level.
- The pricing threshold can be set by using next major competitor's rates (Punjab) as a reference point. Given that Punjab's current FOB rate is INR 103/kg, **the optimal FOB price range for Haryana exporters would be between INR 98 and INR 102 per kg.**

6. Results

- Time-series machine learning models such as N-HiTS and TFT proved highly effective in predicting future auction prices of basmati paddy, achieving an average **accuracy of ~95%**.
- The price elasticity of demand, derived using regression analysis, indicates an unfavourable trend for Haryana-based exporters in context of both domestic and international competitors. Which results from price disadvantages in current conditions.
- For Haryana-based exporters, reducing FOB rates to gain market share is not recommended currently, as the steep decline in profitability combined with only marginal gains in market share renders this strategy financially sub-optimal.
- The optimal FOB price range for Haryana-based exporters (including HAFED) under the current market conditions is estimated as between **INR 98 and INR 102 per kg**.
- However, if MP exporters raise their rates in the future and the price gap between Haryana and MP narrows, Haryana exporters may consider reducing their rates slightly to retain more share of the market, keeping in mind the long-term advantage of a larger customer portfolio.
- Governments can also use such profitability and market share analyses to design indirect subsidies that can support exporters in maintaining their market position.

7. Next steps for further improvements

- Indian rice exporters also compete with countries such as Thailand and China. However, since their rice serves as a substitute rather than a direct competitor, India's relationship with their FOB/CIF prices and market shares is strongly non-linear. Advanced machine learning models like N-HiTS or TFT can be used to capture these non-linear dynamics and develop a more comprehensive framework for assessing how changes in other countries' prices impact India's market share.
- Including other competing states such as Punjab and Gujarat in the framework can improve the predictive models and the depth of game theory analysis.
- Data from market intelligence agencies can be leveraged to improve profitability analysis and assess price–demand elasticity more accurately.
- Market intelligence data integrated with ML models, can help analyze importer and domestic buyer behavior. Enabling estimation of customer lifetime value, churn/retention probability, and segmentation based on customer frequency or price/product preference. This in turn can enhance strategy formulation, e.g. by estimating long-term opportunity cost associated with current loss in market share, exporters can make more informed decisions regarding pricing strategies and target market selection.