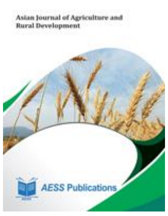

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Measurement of riskiness of agricultural income - evidence from India's agrarian economy

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ABSTRACT
Farmers in developing countries face significant challenges due to price and production fluctuations, which impact their income and well-being. This study focuses on potato and onion farmers in India to estimate the income variability experienced by them. This research applies the Autoregressive Distributed Lag (ARDL) approach to investigate how fluctuations in market prices influence agricultural supply, with an emphasis on both short- and long-term effects. The demand elasticity (ε) for potato is equal to -1.32, while for onion, it is 0.54. This study finds that income volatility is a significant issue for potato and onion farmers, which could impact the long-term well-being of the farmers in India. Price fluctuations in agricultural production, combined with lower market prices, pose serious threats to farmers' income. To reduce risks, the study recommends comprehensive strategies, such as improved price stabilization initiatives, agricultural income insurance, and financial tools like commodity derivatives. In particular, it suggests considering index-based income insurance that provides compensation based on specific indicators, such as regional yield and price changes. These measures can enhance financial security and resilience for Indian farmers facing market uncertainties.

Contribution/Originality: The farmers' income in India is affected by various factors such as price volatility in market prices, government policy changes, weather conditions, etc. This study uses the Autoregressive Distributed Lag (ARDL) model to examine the relationship between market price variability and agricultural supply, focusing on both short- and long-term effects for potato and onion farmers in India.

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1. INTRODUCTION

Modern technology has made India self-sufficient in food grain production, especially cereals. However, farmers often have low to moderate incomes due to various factors. While higher production can lower prices, natural disasters like droughts and floods lead to crop losses, negatively affecting farmers' incomes. Price volatility and crop losses continue to challenge producers. Farmers in developing countries face numerous challenges such as price volatility, harsh climatic conditions, uncertainty on the demand side, and changes in government policies, to name a few.

Price stability benefits buyers and producers, though its effects can vary based on whether the focus is on consumer or producer welfare (Gouel, 2013). Price volatility often dictates profit or loss outcomes. Stable prices generally favor producers (exporters), while consumers (importers) may suffer during periods of price instability due to supply disruptions. Consumers usually benefit from price stabilization efforts in economies with demand-side fluctuations, although the overall impact on producers, especially exporters, remains unclear (Gouel, 2013; International Monetary Fund (IMF), 2012).

An inflated average price and reduced supply can create optimal market distortion, mainly when demand is inelastic. Implementing market intervention strategies can lead to significant welfare gains (Antonaci, Demeke, & Vezzani, 2014; Hazell & Scandizzo, 1975). Empirical studies on agricultural price volatility show mixed trends (Mittal, Hariharan, & Subash, 2018). While price volatility is often seen as harmful, it can be beneficial since it leads to uncertain demand. Producers can make significant profits when prices rise, but this depends on their ability to adjust output in response to changing prices (Assouto, Houensou, & Semedo, 2020; Gouel, 2013). Conversely, price instability may hurt consumers, while declining prices could help them (Muflikh, Smith, Brown, & Aziz, 2021; Snell, 2022). As a welfare state, a government aims to stabilize prices for the benefit of its citizens (Lundberg & Abman, 2022).

On the supply side, using anticipated prices rather than actual market values complicates supply decisions, as unpredictable price changes affect how benefits are distributed between producers and consumers (El-Dukheri, Elamin, & Kherallah, 2012; Letta, Montalbano, & Pierre, 2022). Factors like commodity speculation also impact these expectations (Assouto et al., 2020). Policymakers face challenges in tackling the variable earnings of farmers in emerging countries, largely because of the erratic nature of crop pricing (Abokyi, Strijker, Asiedu, & Daams, 2020; Birthal, Negi, & Joshi, 2019). However, research on stabilization programs that could help reduce uncertainty for smallholder farmers, especially in countries like India, is lacking.

Indian farmers often struggle to forecast future prices accurately (Saini & Gulati, 2017). Price stabilization measures could enhance their forecasting skills and stabilize production decisions, resulting in a more consistent supply. Additionally, the Indian agrarian economy relies heavily on weather, especially the monsoon. Insufficient rainfall negatively affects production and profits. The farmers' income is affected by these factors. Thus, in such situations, crop insurance becomes essential for providing relief to farmers. This study analyzes the market dynamics of onions and potatoes in India, the two traditional crops grown widely in the country. The two crops (onions and potatoes) are crucial for daily caloric intake in Indian households. Price fluctuations occur regularly due to climate change, monsoon variations, pests, and supply-demand changes. These price changes affect the Consumer Price Index, contribute to inflation, and impact farmers' livelihoods and consumers' affordability of these staples. The study examines how price changes influence the market supply of these crops and the relationship between supply fluctuations and income variability. This study uses the Autoregressive Distributed Lag (ARDL) model to examine the relationship between market price variability and agricultural supply, focusing on both short- and long-term effects. Additionally, it looks at conditions where price stabilization could reduce income variability for farmers in a developing country like India.

The remaining sections of the paper are organized as follows: Section 2 provides a glimpse of government policies toward stabilizing farmers' income and critically evaluates the existing government policies in India. The third section outlines the methods and estimation strategy employed in this study. The fourth section presents the empirical results, while Section 5 concludes with alternative solutions to safeguard farmers' income.

2. CRITICAL EVALUATION OF GOVERNMENT POLICIES TOWARDS THE WELFARE OF THE INDIAN AGRARIAN ECONOMY

The government of India has instituted various agricultural price stabilization initiatives nationwide. Key programs include the Minimum Support Price (MSP), Price Stabilization Fund (PSF), Pradhan Mantri Annadata Aay Sanrakshan Abhiyan (PM-AASHA), and Market Intervention Scheme (MIS) (Das, 2020; GoI, 2015, 2016, 2023b).

On the other hand, crop insurance has been a risk management concept in India's agriculture since the beginning of the century. It has undergone occasional but continuous evolution in conception, execution, scope, methodology, and practices. In the 1972-1973 period, the Life Insurance Corporation of India's "General Insurance" Department initiated the inaugural crop insurance program specifically for H-4 cotton in the state of Gujarat. Later, the experimental program was transferred to the newly formed General Insurance Corporation of India, further expanding its coverage to include groundnut, wheat, and potatoes (Kaur, Raj, Singh, & Chattu, 2021; Raju & Chand, 2008).

The Comprehensive Crop Insurance Scheme succeeded the Pilot Crop Insurance Scheme, which was in place from 1979 to 1984. Between 1985 and 1999, the National Agriculture Insurance Scheme (NAIS) was launched and operated until 2016. Other important programs during this period included the Weather-based Crop Insurance Scheme, which ran from 2007 to 2016, and the Modified National Agriculture Insurance Scheme (MNAIS), which also operated from 2010 to 2016. Since 2016, the insurance landscape has evolved with the introduction of the Restructured Weather-based Crop Insurance Scheme and the Pradhan Mantri Fasal Bima Yojana (Bhattacharya & Biswas, 2018; Kaur et al., 2021; Raju & Chand, 2008). However, government schemes or policies may have little impact on the stabilization of farmers' income in the context of running a perfectly market-driven economy.

2.1. Evaluation of Price Stabilisation Schemes (MSP)

The government launches various schemes to benefit farmers; however, implementing effective pricing policies, particularly the Minimum Support Price (MSP), encounters several challenges. These include the need for improved agricultural market systems, inadequate infrastructure and storage capabilities, and ineffective mechanisms for price tracking and forecasting. An effective marketing strategy can help farmers secure fair prices for their products, while a poor strategy can lead to diminished earnings by driving prices down at the point of sale. Although many consider the MSP a successful tool for protecting farmers nationwide, various states face difficulties in its implementation, primarily due to a lack of awareness among stakeholders (Singh, Mehta, Shukla, & Singh, 2015). Furthermore, recent studies reveal that the ongoing elevation of the Minimum Support Price (MSP) over the years has played a role in diminishing the agricultural sector's contribution to the country's Gross Domestic Product (GDP). The share of nonagricultural Gross Domestic Product (GDP) has significantly risen compared to the national total. This shift is thought to be driven by persistent inflationary pressures and a significant drop in investments aimed at agriculture, which has ultimately led to a decrease in the overall economic health of the country (Deshpande & Naika, 2002; IRADe, 2007; Parikh, Ganesh-Kumar, & Darbha, 2003). The benefits that a farmer can achieve by locking in the price of a particular crop go beyond simple pricing strategies. Several elements play a role, such as the opportunity for diversifying crops, having multiple sources of income, the farmer's ability to sustain their harvest levels, and the possibility of engaging in speculative trading based on upcoming market trends (Kumar & Mittal, 2022).

India's agricultural price support program has faced significant criticism for its diminishing relevance. While it was designed to assist farmers by providing a safety net for crop prices, many farmers have reported that it has not substantially benefited them. A growing number of small farmers are experiencing increased financial strain and accumulating debt, making it difficult for them to obtain fair prices for their produce (Ramaswami, 2019). Despite years of implementing a floor-cost-based support system, the challenges within the agricultural sector continue to escalate, highlighting the need for a reevaluation of these support mechanisms.

2.2. Evaluation of Crop Insurance Schemes

The PMFBY crop insurance program was established to provide farmers with a comprehensive risk solution. It features a simple premium structure and quick settlement of claims for complete crop failure coverage on annual commercial and horticultural crops, aiming to stabilize farmers' income. However, challenges such as long-term tenders, access to coverage for all farmers, and the expansion of risk coverage and add-on options need to be addressed for the program to be effective. Solutions to these issues are essential to ensure the program meets the needs of all stakeholders and local agricultural conditions (GoI, 2023c).

Financial factors play a significant role in farmers' willingness to engage with the government's crop insurance program. Key issues include liquidity when purchasing insurance, overall wealth and earnings, limited credit access, and insurance premium costs (Biswal & Bahinipati, 2022). Most farmers in India are small or marginal and come from economically disadvantaged households, making it difficult for them to afford crop insurance (Biswal & Bahinipati, 2022; Rajeev & Nagendran, 2019). Additionally, credit constraints and a lack of information about insurance products hinder their ability to purchase insurance (Giné, Townsend, & Vickery, 2008). One of the major challenges that farmers encounter in securing institutional credit is the lack of adequate financial institutions in rural regions. By enabling timely access to formal financing, we can help farmers navigate liquidity challenges and promote the adoption of crop insurance (Dey & Maitra, 2017). Furthermore, there is a need for better-designed crop insurance policies grounded in agronomic principles. Instead of the typical isolated pricing strategies in the agricultural sector, adopting a portfolio approach for pricing similar to the empirical Bayes credibility theory would be more beneficial (Clarke, Clarke, Mahul, Rao, & Verma, 2012).

We now discuss the methodology and build a model to assess the income variability of farmers.

3. METHODOLOGY

Agriculture plays a vital role in promoting economic growth and reducing poverty in developing economies. By diversifying into higher-value crops, farmers can increase their income and improve their risk management, which offers two significant benefits of agricultural expansion (Neogi & Ghosh, 2022; Pandey & Kumari, 2021; Zhang, Mishra, & Hirsch, 2021). At the same time, the Government of India is actively working towards doubling farmers' incomes (GoI, 2017). Farmers can integrate these two priorities into their agricultural practices. However, as previously discussed, they may encounter challenges due to government and market failures.

This study aims to identify the conditions that can reduce income variability in India's agrarian economy. Before conducting empirical estimation, it employs time series econometric analysis to assess the impact of market price variability on supply in the market. This analysis is especially relevant given that Indian farmers face a dual challenge of price variability and crop failure.

3.1. Theoretical Background: Condition of the Income Variability of Farmers'

Assessing the fluctuation of revenue from agriculture is critical. This research adheres to the methodology described by Newbery and Stiglitz (1981). This study expands upon the income stabilization hypothesis in the Indian context, emphasizing its relevance to the global economy. A significant component of India's agricultural sector comprises marginal and small-scale growers who often have little information regarding international market dynamics yet are impacted by fluctuations in prices. Consequently, it is imperative to synchronize India's crop production with global output to stabilize farmers' income, represented as the product of price (r) and quantity (k).

$$y = r_i k_i \qquad (1)$$

Where i ranges from 1 to n crop.

To measure income instability through the variance of the logarithm of income, it can be expressed as:

$$\log y = \log (r_i k_i)$$

$$\Rightarrow \qquad Var\,(\log y) = Var\{\log(r_i k_i)\}$$

$$\Rightarrow \qquad Var\,(\log y) = Var(\log r_i) + Var\,(\log k_i) + 2 * Cov(\log r_i\,, \log k_i) \qquad (2)$$

The initial hypothesis asserts that the demand function will exhibit an elasticity that remains constant from (1), namely,

$$k_i = r^{\frac{1}{\varepsilon}} \qquad (3)$$

The inverse demand schedule will be,

$$r_i = k^{-\frac{1}{\varepsilon}} \quad (4)$$

Thus, the income of the farmer will be,

$$y = r_i k_i \Rightarrow y = k^{-\frac{1}{\varepsilon}}$$

$$\Rightarrow \quad \log k_i = \left(1 - \frac{1}{\varepsilon}\right) \log k_i$$

$$\Rightarrow \quad Var(\log y) = (1 - \frac{1}{\varepsilon})^2 Var(\log k_i)$$

After stabilisation, it yields

$$Var(\log y) = Var(\log k_i) \quad (5)$$

Here, ε denotes the elasticity of demand, which must equal 1/2 for the stabilization requirement to be met. The degree of stabilization is contingent upon the value of ε, which could vary approximately greater than or less than 1/2. Utilizing a demand schedule characterized by constant elasticity (from Equation 4).

$$Var(\log r_i) = ({}^{1}/_{\varepsilon})^2 Var(\log k_i)$$

It becomes

$$Var(\log k_i) = [Var(\log k_i) + ({}^{1}/_{\varepsilon})^2] Var(\log k_i) + 2\, cov(\log r_i, \log k_i)$$

$$Var(\log k_i) = [1 + ({}^{1}/_{\varepsilon})^2] Var(\log k_i) + 2\, cov(\log r_i, \log k_i) \quad (6)$$

Since the conditions for farmers' income stabilization are already derived, the following two conditions must be satisfied.

First proposition:

$$[1 + ({}^{1}/_{\varepsilon})^2] = 1 \quad (7)$$

$$\Rightarrow \quad \varepsilon \to \infty \quad (8)$$

$$\Rightarrow \quad \lim_{\varepsilon \to \infty} \left(\frac{1}{\varepsilon}\right) \to \infty \quad (9)$$

A consequence of the initial proposition: If ε approaches infinity, then

$$\frac{\partial q_i / q_i}{\partial p_i / p_i} = \infty \quad (10)$$

Thus transpires as ε signifies that the elasticity of demand nears zero (0).

Second proposition:

$$2cov\,(\log r_i, \log k_i) = 0$$

$$\Rightarrow \; cov(\log r_i, \log k_i) = 0 \quad (11)$$

The first condition implies infinite elasticity of demand, indicating perfectly elastic demand, where the equilibrium price remains unaffected by changes in supply. The second criterion indicates an absence of correlation between price (r) and quantity (k). Despite their theoretical plausibility, both possibilities are practically impossible to achieve. Consequently, the farming community consistently experiences income fluctuations.

Before exploring the empirical evidence of income variation for selected crops, it is essential to assess whether the quantity of supply of any crop is directly linked to its long- and short-term relationship with market price, particularly in relation to the price stabilization scheme. Thus, before proceeding with the data analysis and description for the selected crop, we outline the estimation procedure to evaluate the impact of price changes on crop supply.

3.2. Estimation Procedure

3.2.1. Assumptions of the Estimation Procedure

To measure income changes, we make the assumptions mentioned below:

a. Farmers will grow only one type of crop.
b. There is no non-farm income earned by farmers.
c. Farmers and producers will not be affected by global market changes.

3.2.2. Econometric Approach

To determine income volatility, we follow these essential steps:

1. Evaluate the importance of our determined method to understand the previously defined parameters.
2. Determine with precision the elasticity of demand, the covariance between logarithmic price and quantity, and the variance of logarithmic price. The subsequent steps to establish the credibility of our model are as follows.

- The study uses daily prices and quantities of arrivals in the agricultural market.
- We examine the existence of a linear relationship between the time series variables.

$$k_t = \beta_1 + \beta_2 r_t + \varepsilon_t \quad (12)$$

The two variables, price and quantity, are defined as follows: r denotes price, k represents quantity, ε denotes random disturbance, β stands for the coefficients, and t denotes time.

The ordinary least squares (OLS) method for examining long-term relationships between price and quantity should be used carefully, as time series data can be nonstationary and lead to spurious regression results.

Nonstationarity can lead to inaccurate conclusions about causality. Thus, this study integrates cointegration theory with dynamic econometrics to address the limitations associated with the OLS method and to effectively manage nonstationary time series. The study delves into the short-term dynamics and long-term relationships between the daily pricing and quantities of potatoes and onions. The first stage in cointegration theory is to ascertain the order of integration of time series variables. This conclusion is derived from multiple tests. The study utilizes the correlogram, the Augmented Dickey-Fuller test, and the Phillips-Perron test to evaluate the existence of a unit root in the model (Fuller, 1996). Furthermore, the differing orders of integration of both variables—specifically, the logarithms of price and quantity—are analyzed using multiple techniques. The Autoregressive Distributed Lag (ARDL) Bounds test is applied to estimate both short-term and long-term parameters concurrently. Additionally, a Vector Error Correction Model (VECM) is utilized to analyze the behavior of price and quantity across both the short and long run. The term 'error correction' refers to how deviations from a long-term equilibrium in the previous period influence the short-run dynamics of the model.

3.3. Choice of Product and Market

This study examines the markets for two agricultural products: potatoes and onions. Both crops exhibit significant price volatility due to consistent year-round demand and variable supply. We have selected two agricultural markets for the analysis: the Burdwan Agricultural Produce Market Committee (APMC) in the East Burdwan district of West Bengal, focusing on potatoes, and the Lashalgao APMC in the Nashik district of Maharashtra, for onions. This choice is based on the steady demand for both crops over the years, and both markets are among the largest for their respective products. Maharashtra is the leading state in India for onion production, contributing 43% of the total, with Nashik being the top district for onion production nationwide (GoI, 2023a). In contrast, West Bengal ranks second in potato production, accounting for 23% of the total, while Uttar Pradesh is the highest, with 30% (GoI, 2023a). East Burdwan is the highest-producing district for potatoes among all districts in both Uttar Pradesh and West Bengal.

3.4. Data Source

The daily prices and quantities of potatoes and onions were collated from the Agriculture Marketing Information Network (AGMARKNET). Since 2014, the Government of India has implemented significant transformations in the agricultural sector. Therefore, this study uses daily prices and quantities of potatoes and onions from 2015 to 2020. This extensive data set provides valuable insights for modeling and understanding the factors that influence market behaviors. Additionally, the decision to focus on this period is based on the absence of major economic or environmental disasters during those years.

4. DATA ANALYSIS

The empirical analysis has two main components. First, it involves estimating the model to examine both short- and long-term relationships between price and quantity. Second, it includes validating the fundamental assumption regarding the income risk associated with crop cultivation in India.

4.1. Relationship Between the Quantity of Supply and Market Price

Table 1 summarizes key statistics on pricing and quantity arrivals of potatoes and onions in their respective markets.

Table 1. Descriptive Statistics - potatoes and onions in APMC(West Bengal) and APMC (Maharshtra).

Statistics	Potatoes		Onion	
	Price (Rs./Quintal)	Arrivals (Quintals)	Price (Rs./Quintal)	Quantity arrivals (Quintals)
Mean	1142	6679	1562	12974
Standard deviation	671	32940	1297	9544
Minimum	290	65	130	10
Maximum	3930	453540	8625	437000
N	2192	2192	2192	2192

In the Burdwan APMC (West Bengal), the typical daily price for potatoes is approximately Rs. 1,142 per quintal, with an average arrival quantity of about 6,679 quintals. In contrast, the Lasalgaon APMC (Maharashtra) reports an average daily price for onions at Rs. 1,562 per quintal, with a quantity arrival of 12,974 quintals. Notably, the range between the lowest and highest values for both the price and quantity arrivals of onions is significantly greater than that of potatoes. Additionally, the fluctuations in both the price and quantity of onions are much more pronounced compared to those of potatoes. Figure 1 (A, B) illustrates the changes in two indicators, namely price and quantity of potatoes and onions (after applying a logarithmic transformation). The supply price and quantity of potatoes in the Burdwan APMC of West Bengal show significant fluctuations. Notably, for potatoes, price and quantity are inversely correlated. In contrast, the onion market in the Lasalgaon APMC of Nashik, Maharashtra, also exhibits considerable volatility in price and quantity. However, the quantity supplied in this market remains nearly constant during normal periods. Unexpected weather events, market conditions, and other factors also influence the quantity supplied. As a result, the quantity supplied experiences downward volatility, while the highest quantity supplied remains relatively stable throughout the study period.

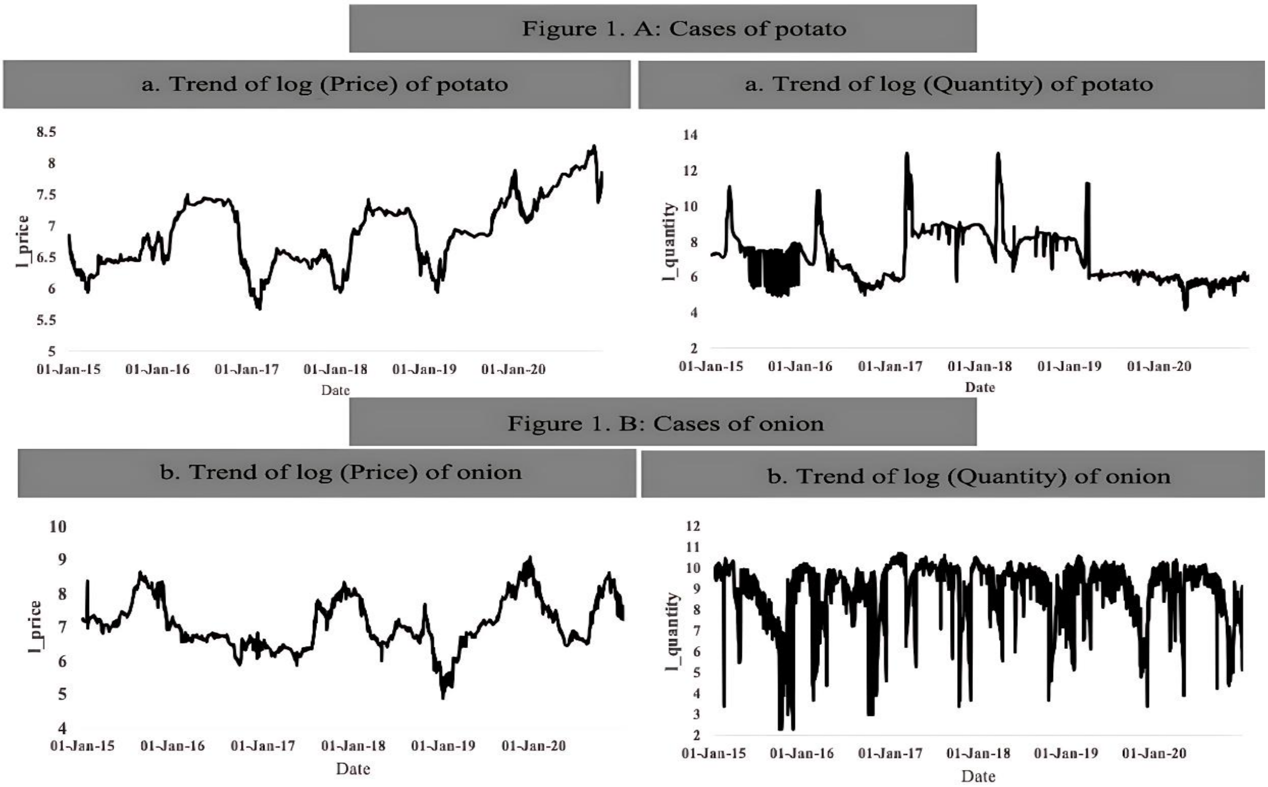

Figure 1. Trend of price and quantity of potatoes and onions.

The correlogram test evaluates the randomness of a dataset concerning specific variables, i.e., $\log r_i$, and $\log k_i$. A strong positive autocorrelation is found between prices and quantities for potatoes and onions. The correlogram for autocorrelation shows a gradually decreasing trend for both potatoes and onions. High correlations between the variables at various time intervals suggest potential trends and seasonal components within the data. Notably, applying first differencing can help mitigate the impact of the trend, while seasonal differencing can effectively address seasonality. Additionally, a unit root test is employed to determine the stationarity of the variables.

4.1.1. ADF and Phillips-Perron test

We verify the integration order of the dataset using the Augmented Dickey-Fuller and Phillips-Perron tests, with the results presented in Table 2. The ARDL Bounds testing method is suitable regardless of whether the independent variables are integrated of order one, I(1), or order zero, I(0), as long as the dependent variable is I(1). Our analysis indicates that the prices of both potatoes and onions are stationary at order I(1). The test statistics for the logarithmic levels of quantity show significance for both potatoes and onions at order zero, I(0), and order one, I(1).

Table 2. Results - ADF and Phillips-Perron test.

Variable	Level		First difference		Order of integration
	Intercept	Intercept and trend	Intercept	Intercept and trend	
A. Cases of Potatoes					
Augmented Dickey-Fuller test					
$\log r_i$	-1.9	-2.5	-8.1*	-8.147*	I(1)
$\log k_i$	-3.3*	-3.7*	-12.4*	-12.4*	I(0) and I(1)
Phillips-Perron test					
$\log r_i$	-1.7	-2.4	-41.8*	-41.8*	I(1)
$\log k_i$	-6.2*	-6.8*	-69.3*	-69.3*	I(0) and I(1)
B. Case of onions					
Augmented Dickey-Fuller test					
$\log r_i$	-2.9*	-2.9	-7.5*	-7.5*	I(1)
$\log k_i$	-5.3*	-5.3*	-11.9*	-11.9*	I(0) and I(1)
Phillips-Perron test					
$\log r_i$	-2.5#	-2.6	-52.5*	-52.5*	I(1)
$\log k_i$	-20.9*	-20.9*	-100.5*	-100.5*	I(0) and I(1)

Note: *Significant at the 5% level. #significant at the 10% level.

4.1.2. Cointegration Test

The ARDL bounds estimation technique is used to assess cointegration and analyze the relationships among the specified variables. Unlike traditional methods, which do not allow for cointegration tests with variables that have mixed or uncertain integration orders such as I(0) or I(1), the bounds testing approach effectively addresses these evaluations (Pesaran, Shin, & Smith, 2001; Sam, McNown, & Goh, 2019). This methodology can accommodate a combination of I(1) and I(0) variables; however, this only applies to the independent variables, while the dependent variable must be I(1).

In this context, I(1) indicates that the best lag length for the logarithm of the price, following an analysis of the order of integration, acts as an independent variable. Meanwhile, the logarithm of quantity, regarded as the dependent variable, is also optimal at I(1). Therefore, the ARDL Bounds estimation is utilized to investigate cointegration and determine the relationship between the log of quantity and the prices of potatoes and onions. The findings from the Bounds tests conducted for potatoes and onions using ARDL models are presented in Table 3. The hypothesis for the Bounds test is as follows:

H0: There is no cointegration.

H_1: There is cointegration.

The Bounds test evaluated the F-test results for the coefficients related to the prices of potatoes and onions, considering one differentiation period, as well as the quantity supplied. The calculated F-statistics for potatoes and onions were 10.3 and 44.7, respectively. Both values exceed the critical upper limit for F-statistics. This indicates that we may disregard the null hypothesis, which posits the absence of cointegration. Consequently, we can ascertain that a long-term correlation exists between the price and quantity of potatoes and onions.

Table 3. Results - Bounds test for onions and potatoes.

Category		**F-statistic**		**t-statistic**
Potatoes		10.3		-4.4
Onions		44.7		-9.4
Significance	**Critical values (0.1-0.01), F-statistics, Case 3**			
	10%	**5%**	**2.5%**	**1%**
Lower bound	4.0	4.9	5.7	6.8
Upper bound	4.7	5.7	6.6	7.8
Significance	**Critical values (0.1-0.01), t-statistic, Case 3**			
	10%	**5%**	**2.5%**	**1%**
Lower bound	-2.5	-2.8	-3.1	-3.4
Upper bound	-2.9	-3.2	-3.5	-3.8

Table 4. Selection of optimal lag-length criteria for price and quantity in the cases of potatoes and onions.

Lag	First difference in the log of price						log of quantity					
	Log likelihood (LL)	Liklihood Ration (LR)	Final prediction error (FPE)	Akaike's information criterion (AIC)	Schwarz's Bayesian information criterion (SBIC)	Hannan and Quinn Information Criterion (HQIC)	Log likelihood (LL)	Liklihood ration (LR)	Final prediction error (FPE)	Akaike's information criterion (AIC)	Schwarz's Bayesian information criterion (SBIC)	Hannan and Quinn information criterion (HQIC)
A. Case of potatoes												
0	4367		0.001	-3.9	-3.9	-3.9	-3890.3		2.053	3.5	3.5	3.5
1	4393.8	53.5	0.001	-4.0	-4.0	-4.0	-1144.5	5491.6	0.167	1.0	1.05	1.0
2	4397.6	7.5	0.001	-4.0	-4.0	-4.0	-1048.1	192.8	0.153	0.96	0.96	0.96
3	4402.5	9.7*	0.001*	-4.0*	-4.0*	-4.0*	-1039.3	17.6*	0.152*	0.95*	0.95*	0.96*
4	4402.5	0.003	0.001	-4.0	-4.0	-4.0	-1039.2	0.21	0.152	0.95	0.95	0.96
B. Case of onions												
0	2199.9		0.008	-2.01	-2.01	-2.0	-4007.3		2.2	3.6	3.6	3.6
1	2214.5	29.3*	0.008*	-2.02*	-2.02*	-2.0*	-2963.1	2088.4	0.880	2.7	2.7	2.7
2	2214.9	0.8	0.008	-2.02	-2.02	-2.0	-2904.4	117.3	0.83	2.6	2.6	2.6
3	2215.0	0.1	0.008	-2.02	-2.01	-2.0	-2888.6	31.6	0.82	2.6	2.6	2.6
4	2216.5	2.8	0.008	-2.02	-2.01	-2.0	-2884.5	8.1*	0.82*	2.6*	2.6*	2.7*

Note: * Optimal lag.

4.1.3. Vector Error Correction Model

Cointegration indicates that specific variables preserve a consistent long-term equilibrium relationship. This equilibrium signifies an optimal state; yet, transient fluctuations may still arise. Consequently, it is essential to examine whether these variations ultimately converge with the long-term equilibrium. The Vector Error Correction Model (VECM) is employed to examine the short-term and long-term relationships among the variables. The error-correcting mechanism rectifies imbalances in subsequent periods, aligning short-term dynamics with long-term trends.

When a long-term relationship or cointegration exists, the error correction model (ECM) can be defined as follows:

$$\Delta \log k_i = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \log k_{(t-i)} + \sum_{i=1}^{p} \alpha_{2i} \log k_{(t-i)} + \lambda ECT_{(t-1)} + e_t \quad (13)$$

where,

i. The coefficients α_{1i}, and α_{2i} represent short-term adjustments toward long-term equilibrium. $\lambda = (1 - \sum_{i=1}^{p} \delta_i)$ si
ii. Gnifies that the parameter is represented with a negative sign, implying a reduction in speed.
iii. $ECT = (logq_{(t-i)} - \theta X_t)$ implies the error correction term, where $\theta = \frac{\sum_{i=1}^{q} \beta_i}{\alpha}$ represents the long-term parameter.
iv. e_t represents the residual, which is the stochastic error term, often called impulses, innovations, or shocks.
v. The r lags and k-lags indicate the dependent variable and independent variable, accordingly

When estimating a Vector Error Correction Model (VECM), it is crucial to select the appropriate lag length. The Akaike Information Criterion (AIC) suggests that a lag length of three is optimal for analyzing the changes in the logarithms of prices and potato quantities (see Table 4.A). Additionally, for the changes in the logarithm of prices, a lag length of one is deemed ideal, while four lags are recommended for the logarithms of onion quantities (see Table 4.B).

Before evaluating the ARDL error correction model, we first assess the significance of the ARDL model itself by examining the F-statistic to determine its validity (see Table 5).

Table 5. Empirical estimation of the price-quantity nexus with the ARDL framework.

Varriables	Potato	Onions
	l_quantity	**l_quantity**
l_quantity		
L1.	0.64*** (0.021)	0.57*** (0.021)
L2.	0.23*** (0.025)	0.14*** (0.025)
L3.	0.091*** (0.021)	0.084*** (0.025)
d1_l_price		
---	-0.77** (0.257)	0.061** (0.022)
L1.	-0.323 (0.260)	-0.104 (0.221)
L2.	0.325 (0.260)	0.0771 (0.222)
L3.	0.375 (0.258)	0.303 (0.221)
Constant	0.189*** (0.043)	1.208*** (0.129)
	N = 2188 F(7, 2180) = 3934.67 Prob > F = 0.0000 R-sq = 0.927 adj. R-sq = 0.926 rmse = 0.389	N = 2188 F(7, 2180) = 558.52 Prob > F = 0.0000 R-sq = 0.642 adj. R-sq = 0.641 rmse = 0.906

Note: Standard errors in parentheses **p<0.01, ***p<0.001.

The ARDL error correction model serves to assess the long-term association between potato and onion prices and their corresponding quantities. The coefficients derived from the cointegration equation demonstrate this enduring relationship, while the coefficients from the error correction model (ECM) highlight how fluctuations from this relationship affect changes in the variables in the following period. In this framework, errors from the prior period are rectified in the subsequent period. Notably, the error correction coefficient for potatoes stands at -0.026, which is statistically significant at the 1% threshold. In the same vein, the error correction coefficient for onions is -0.13, also statistically significant at the 1% level. These negative and statistically significant adjustment coefficients suggest that discrepancies from equilibrium are corrected over time. Furthermore, the adjustment speed is considerably greater for onions (-0.13) than for potatoes (-0.026), implying that the onion market adjusts at a faster pace (see Table 6).

Table 6. Empirical assessment of the price-quantity dynamics through the error correction model (ECM).

Variables		Potatoes	Onions
		D.l_quantity	D.l_quantity
ADJ			
	l_quantity L.	-0.026*** (0.006)	-0.13*** (0.014)
LR			
	d1_l_price	-14.99 (16.73)	-0.490 (2.424)
SR			
	l_quantity LD.	-0.32*** (0.022)	-0.29*** (0.023)
	L2D.	-0.091*** (0.021)	-0.14*** (0.023)
d1_l_price			
	D.	-0.377 (0.397)	
	LD.	-0.700* (0.339)	
	L2D.	-0.375 (0.258)	
l_quantity			
	L3D.		-0.0610** (0.022)
D.d1_l_price			-0.0430 (0.221)
Constant		0.18*** (0.043)	1.20*** (0.129)
		N = 2188 R-sq= 0.116 adj. R-sq = 0.113 rmse = 0.389	N = 2188 R-sq = 0.169 adj. R-sq 0.167 rmse = 0.906

Note: Standard errors in parentheses *p<0.05, **p<0.01, ***p<0.001.

The long-run price elasticity for potatoes and onions is statistically insignificant, indicating that prices do not strongly influence long-term quantity adjustments. In the short run, the negative and significant coefficients of lagged quantities (l_quantities) for both potatoes and onions suggest that past quantities negatively impact current adjustments. This may be due to supply rigidities, storage effects, or demand constraints (Birthal et al., 2019; Roy, Gupta, & Wardhan, 2024).

In the short run, price changes have a minimal impact on the quantities of potatoes, except for the variable d1_l_price in the potato category. The significant negative coefficient for d1_l_price indicates that changes in price do indeed significantly influence adjustments in the quantity of potatoes. The negative sign indicates that as prices rise, the quantity decreases, highlighting demand-side sensitivity or short-run supply.

The relationship between price and quantity in the Indian economy is unpredictable, with only a weak connection in the short term. This weak relationship suggests that fundamental issues, such as production cycles, input costs, and market access, often hinder farmers' ability to respond to price changes effectively (Agrawal, Hirons, & Gathorne-Hardy, 2021). Additionally, income variability among farmers plays a significant role in this setup. Many small and marginal farmers lack the financial resources to quickly adjust their production in response to price shifts (Ceballos, Kannan, & Kramer, 2020; Touch et al., 2024). As a result, even when prices fluctuate, the supply may not change proportionally in the short run, leading to inefficiencies and unstable incomes within the agricultural sector.

4.2. Validation of the Condition of Income Riskiness of Crop Cultivation in India

The dynamics of agricultural markets involve complex interactions between price and quantity, which are significantly influenced by factors such as demand sensitivity, supply constraints, and various external influences. Understanding these interactions is crucial for farmers as they adapt to price changes, particularly for essential crops like potatoes and onions. However, the inherent unpredictability of these markets presents significant challenges for farmers aiming for consistent income. The previous subsection examined the prerequisites for achieving income stability. This section builds on that discussion by providing deeper insights into how markets respond and the economic factors influencing this responsiveness.

The study finds that the elasticity of demand (ε) is -1.32 for potatoes and 0.54 for onions. This indicates that price changes are not negligible over the observed period. The price variations for potatoes and onions are recorded at 0.30

and 0.54, respectively. Furthermore, the covariance of the logarithm of quantity, denoted as cov($\log r_i$ $\log k_i$), is not equal to zero. For potatoes, the covariance is -0.40, and for onions, it is -0.28. This negative covariance suggests that the prices and quantities of these products are moving in opposite directions. Several factors contribute to this situation, including asymmetric information in the market accessed by farmers and producers, market distortions, and the potential cartelization by market participants, such as agents or traders (Briones & Rakotoarisoa, 2013; Paul, Das, Das, & Mathur, 2021). Therefore, achieving the market stabilization condition, which requires that $Var(\log y) = Var\ (\log k_i)$, is nearly impossible. Thus, the findings suggest that income unpredictability is faced by Indian farmers over time. India has introduced several price stabilization schemes to tackle the issue of agricultural income stability, but the effectiveness of these measures on a national scale needs improvement (Kumar & Mittal, 2022). Additionally, climate irregularities continually threaten the yields of Indian farmers. This widespread concern about production variability highlights the necessity for protective mechanisms for farmers, leading to the emergence of crop insurance as a potential solution. However, as previously mentioned, crop insurance does not effectively protect farmers from income variability (Biswal & Bahinipati, 2022).

5. CONCLUSION AND POLICY RECOMMENDATION

This study shows that potato and onion farmers face significant income volatility, threatening their long-term well-being. Price fluctuations and lower market prices directly impact their earnings, while weather events and natural disasters increase these challenges.

To effectively manage risks, it is essential to understand the sources and impacts of different types of risks in agriculture. The main goal of risk management is to maintain farm profitability and ensure financial stability. Despite implementing various measures to stabilize income, farmers still struggle with income fluctuations. To protect farmers' income, we should introduce supportive programs and use financial tools from the derivatives market through commodity exchanges. Additionally, purchasing insurance policies is essential. Establishing agricultural income or farm revenue insurance schemes in India is crucial, especially given the ineffective use of current government policies.

In this context, numerous governments worldwide have initiated income insurance programs. The United States and Canada, for instance, have implemented income insurance programs (Li & Ker, 2013; Meuwissen & Huirne, 1998). Canada provides coverage for farmers' total income under the "Farm Income Protection Act" (GoC, 1991). Brazil has introduced agricultural insurance aimed at safeguarding farmers' revenues or incomes, shielding them from fluctuations in market prices. This policy encompasses productivity protection, featuring a price guarantee provided by private insurance companies (Loyola, Moreira, & Pereira, 2016). Furthermore, six countries in the European Union, namely Denmark, France, Germany, Greece, Italy, and the Netherlands, have initiated a pilot program for income insurance (Meuwissen & Huirne, 1998).

This study suggests that the government consider implementing income or revenue insurance based on specific indices. Index insurance is an innovative method of providing insurance that delivers benefits according to a predetermined index, such as farmers' income or farm revenue, to compensate for losses in assets and investments—particularly working capital—due to income or revenue fluctuations in agriculture.

This approach, known as area revenue index insurance, calculates indemnities by evaluating reductions in average crop yields and prices within a designated area. It can be customized for specific products or applied to cover an entire farm.

The primary advantage of this income or revenue insurance scheme is its direct approach to addressing income variability. Unlike commodity price stabilization programs, which focus solely on prices and may inadvertently increase income variability, the effectiveness of this scheme relies on its capacity to mitigate the costs associated with income fluctuations, the average yields, and prices of crops in a given area. This insurance can be tailored to specific products or cover the entire farm.

The advantage of this income or revenue insurance scheme lies in its direct approach to addressing the problem of income variability. Unlike commodity price stabilization schemes, which solely affect prices and may increase income variability, the effectiveness of this scheme depends on its ability to reduce the costs associated with income variability.

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