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RESEARCH ARTICLE

Impact of Farmer Producer Organizations on Price and Poverty Alleviation of Smallholder Dry Chillies Farmers in India

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Abstract: This study investigates the impact of Farmer Producer Organizations (FPOs) on smallholder dry chilli farmers in Guntur district, Andhra Pradesh, with a focus on price realization and poverty alleviation. Two specific FPOs, Red Chilli Farmer Producer Organisation and Spoorthi Chilli Producers Company Ltd., from the Guntur district of Andhra Pradesh were chosen for the study based on their substantial business turnover and comprehensive backward and forward linkages to their farmer-members. The smallholder farmers were stratified into two groups viz., treated (161) and untreated (n = 315) based on the FPO membership criterion. The Foster-Greer-Thorbecke model revealed that the poverty incidence among untreated farmers was recorded at 0.691, which was approximately 49 percent higher than the poverty incidence of treated farmers (0.352). The depth and severity of poverty were also greater among untreated farmers, with a poverty depth of 0.494 compared to the lower value of 0.126 observed among treated farmers. The results from Endogenous Switching Regression Model revealed a significant positive relationship between FPO membership and both price realization and poverty alleviation. Farmers with FPO membership experienced 2.11 percent higher prices and 39.14 percent higher annual agricultural income compared to untreated. Factors such as education, adherence to Good Agricultural Practices, farm experience, access to improved inputs, and credit significantly influenced FPO membership. The study concludes that FPO membership plays a crucial role in improving the standard of living for smallholder dry chilli farmers by increasing prices and income. So, this research sheds light on the significance of FPOs in enhancing the economic well-being of smallholder dry chilli farmers in Andhra Pradesh.

Keywords: Farmer producer organizations; Andhra Pradesh; Endogenous switching regression model; Impact assessment; Transitional heterogeneity

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1. Introduction

In India, the agriculture sector currently contributes approximately 13.39 percent to the Gross Domestic Product (GDP) while employing about 55 percent of the total workforce, indicating its significant role in the economy. As per the Agricultural Census of 2015-2016, there were over 145 million farm holdings in the country. Notably, marginal and small farm holdings constituted a substantial proportion, accounting for 86.21 percent of the total indicating the dominance of small-scale farmers in the agricultural landscape [1]. The share of small and marginal holdings has experienced a slight increase from 84.97 percent in 2010-2011 to 86.21 percent in 2015-2016, amounting to approximately 126 million holdings. This trend indicates a gradual decline in per capita land size over the past five years, primarily attributed to land subdivision and fragmentation. These have contributed to the persistence of poverty in the country leading to a decline in crop productivity, inefficient resource allocation, limited access to credit, the prevalence of subsistence farming, land disputes etc. [2]. The recent estimates revealed that approximately 10.2 percent of the population, or around 145.71 million people, were living Below Poverty Line (BPL) (www.scroll.in (10th June 2023)) and the percentage of the total population living BPL in Andhra Pradesh was 12.31 percent (https://www.newindianexpress.com, 10th June 2023). In view of these, alleviating poverty among farmers is crucial for ensuring food security, promoting rural development, stabilizing the economy, reducing overall poverty, fostering social stability, and pursuing sustainable development goals. The formation of Farmer Producer Organizations (FPOs) can significantly contribute to poverty alleviation among farmers by promoting collective action, enhancing market access, improving access to credit, fostering knowledge sharing, and advocating for policy reforms. Thus, they help farmers improve their income, enhance productivity, mitigate risks, and build sustainable agricultural enterprises, ultimately leading to improved living standards and reduced poverty among farming communities [3,4].

The XII Plan Working Group (formed as part of India's Five-Year Plans) associated with the policy of FPOs in India emphasized that small and marginal farmers encounter significant challenges in both production and marketing within the agri-business sector. These challenges include low output, limited marketable surplus, inadequate participation in price discovery mechanisms, weak vertical and horizontal linkages, restricted market access, lack of price information, insufficient training, and limited access to finance. Among these challenges, the issue of market access is particularly prominent among smallholder farmers [5]. Hence, the current imperative lies in optimizing benefits through effective and efficient aggregation models, especially by integrating these smallholders into agricultural markets. Such a transformation would lead to a more market-oriented agricultural production system, economies of scale, and higher income for smallholder farmers, ultimately resulting in more inclusive growth.

In this context, one of the significant interventions promoted by the Government of India is the Farmer Producer Company (FPC), which is registered under the Companies Act. FPCs have emerged as the most effective form of FPOs in providing various benefits to farmer-members compared to other aggregation formats such as cooperative societies and Farmer Interest Groups. Ministry of Agriculture and Farmers Welfare, Government of India, has identified FPOs registered under the special provisions of the Companies Act, 1956 (amended in 2002) and the Companies Act, 2013, as the most suitable institutional form for aggregating farmers. Forming a FPC under the Companies Act, 2013 facilitates capacity building among farmers, encourages them to work together, share knowledge and resources, and learn from each other's experiences. This will mobilize farmers towards member-owned FPOs to enhance production, productivity, and profitability across the country [6]. This initiative aims to empower farmers and enable them to access better market opportunities and improve their overall socio-economic well-being (Figure 1).

Dry chillies are a significant crop cultivated on 0.73 million hectares in India during 2020-2021 [1]. Among the States, Andhra Pradesh ranked first in dry chilli production during the same period [7]. Guntur, located in Andhra Pradesh, is renowned as Asia's largest market for dry chillies. The Agricultural Produce Market Committee (APMC) in Guntur receives dry chillies from various production regions in Andhra Pradesh as well as from Madhya Pradesh. Notably, the production trends in Madhya Pradesh significantly impact the prices of dry chillies in the Guntur market. Guntur district holds a comparative advantage over other districts due to factors like labor availability, specialization, mechanization, and irrigation facilities. Enhancing dry chilli productivity is crucial for promoting farmers' profitability and development in this region. To support this objective, the Government of Andhra Pradesh has facilitated the establishment of six FPOs that specifically focus on dry chillies in Guntur district. However, the production of dry chillies in Guntur predominantly relies on smallholder farmers, who constitute 92 percent of the total number of farmers in the region. These small-scale farms face challenges in both production and marketing of

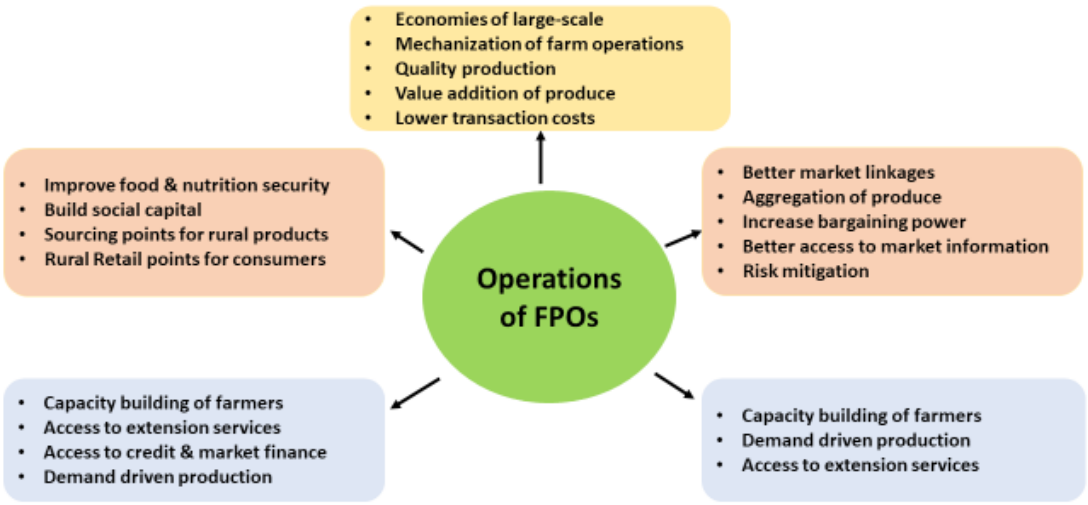

Figure 1. Operations of FPO.

their produce [7]. Previous studies on FPOs have primarily focused on aspects like the growth of farmer-members, establishment of linkages, transaction volumes, and prices realized for the produce [8-10]. However, these studies have not provided a comprehensive assessment of the overall impact of FPOs. Therefore, this study aims to contribute to the existing literature by delving into the factors that drive smallholder dry chillies farmers' decision to engage with FPOs. It seeks to examine socio-economic characteristics, resource accessibility, market linkages, and institutional support as determinants of farmers' participation. By analyzing these factors, the research can offer valuable insights into the factors influencing farmers' involvement in collective agricultural initiatives. Furthermore, the study seeks to assess the impact of FPOs on the achievement of remunerative prices and poverty alleviation among smallholder farmers. This analysis holds significance in the literature on collective marketing initiatives, providing insights into their role in improving farmers' income and overall economic well-being.

2. Review of Literature

The studies examined in the review collectively showcase the transformative potential of FPOs on farmers' livelihoods, productivity, and sustainability. These findings underscore the need for a comprehensive approach to agricultural development, integrating various interventions and leveraging diverse agricultural models.

Ranjit et al. (2022) [9] emphasized that FPOs offer substantial promise for small and marginal farmers in India. Through effective collective action, FPOs empower farmers, enhance market access, and reduce transaction costs. However, addressing the capital constraints faced by FPOs remains a significant challenge. Policy-makers must prioritize the development of enabling environments, including improved access to finance, capacity-building support, and institutional reforms, to fully unlock the potential of FPOs. This will pave the way for inclusive and sustainable agricultural development, elevating the livelihoods of small and marginal farmers and fostering overall rural prosperity.

In the study by Manaswi [11] et al. (2020), the benefits of FPOs in organic chilli production are underscored. FPO membership is associated with higher gross returns, reduced transaction costs, and increased technical efficiency. These findings highlight the importance of collective action, improved market linkages, and streamlined value chains through FPOs, enabling farmers to secure better prices and access to markets.

Barun and Sunil [12] (2019) shed light on the impact of improved agricultural practices on farm productivity. They emphasize the significance of public-private partnerships in promoting practices such as seed distribution, bio-fertilizer production, and capacity-building. These partnerships, which combine technical knowledge, resources, and infrastructure, facilitate the adoption of sustainable farming practices. As a result, farmers experience increased productivity and resilience in the face of challenges like climate change.

John et al. (2019) [13] explore the relationship between contract farming and chilli productivity in Ghana. Their study reveals that contract farming has a positive effect on productivity and gross margins. Educated farmers, larger farm sizes, and integrated soil fertility management are identified as factors influencing contract farming participation. This suggests the need to target and support educated farmers, enabling them to engage in contract farming and potentially improve productivity and market

access.

In the dairy sector, Anjani et al. (2018) [14] highlight the positive effects of cooperative membership on milk yield, net return, and adoption of food safety measures. Cooperative membership provides farmers with improved infrastructure, technology, and collective marketing opportunities. These benefits contribute to increased income and the adoption of practices that ensure food safety and quality.

Wondimagegn (2016) [15] explores the impact of improved storage innovations on food security and welfare. The study demonstrates that households using improved storage technologies enjoy higher dietary diversity scores, indicating improved access to a variety of nutritious foods. This underscores the significance of appropriate storage practices in preserving agricultural produce, reducing post-harvest losses, and enhancing food security.

Lastly, Tamer et al. (2015) [16] focus on the impact of zero tillage on the livelihoods of smallholder farmers. Their study highlights the benefits of conservative tillage, including increased net income and per capita wheat consumption. Conservative tillage practices improve soil health, water retention, and crop productivity while minimizing environmental degradation. Promoting these sustainable agricultural practices enhances farmers' livelihoods and contributes to broader ecological benefits.

Taken together, these studies demonstrate that a combination of approaches, including the formation of FPOs, adoption of improved agricultural practices, engagement in contract farming, participation in cooperatives, and implementation of innovative technologies, can significantly improve farmers' incomes, productivity, and sustainability. These findings underscore the importance of integrating multiple interventions tailored to the local context, addressing the complex challenges faced by farmers, and promoting inclusive and resilient agricultural systems.

3. Materials and Methods

3.1 Data and Research Method

In the initial stage of the study, the state of Andhra Pradesh and Guntur district were purposefully chosen based on their potential for dry chillies production and the presence of a significant number of functioning FPOs involved in its production and marketing (Figure 2). In the second stage, two specific FPOs, namely Red Chilli Farmer Producer Organisation located in Machavaram mandal and Spoorthi Chilli Producers Company Ltd located in Edlapadu mandal, were purposively selected. These FPOs were chosen due to their substantial business turnover and their ability to provide comprehensive backward and forward linkages to their farmer-members. Two sampling frames were created, one consisting of the lists of farmer-members from the two selected FPOs (treated group) and the other consisting of non-members (untreated group). So, farmers in the study area were then stratified into treated and untreated groups based on their FPO membership status. In the third stage, smallholder dry chilli farmers were selected in proportion to the number of farmers in each stratum based on probability proportional to the number sampling technique. This ensured that the selected sample of farmers in Guntur was representative and included both treated (n = 161) and untreated (n = 315) categories based on the FPO membership criterion. A structured schedule was employed to gather the required cross-section data from sample farmers on covariates and outcome variables, as shown in Table 1, specifically related to the Kharif season of 2022-2023. Prior to the actual survey, the schedule underwent a pre-testing phase in non-sampled villages to assess the suitability and effectiveness of the schedule in gathering the required data and to evaluate the proficiency of the enumerators in conducting the survey. The collected comprehensive data sought to provide a holistic understanding of the farmers' socio-economic context and their engagement in various agricultural practices. Further, to analyze the impact of FPO membership on poverty alleviation, only farmers who derived their annual income solely from agricultural sources were included in the sample. This criterion ensured that the analysis focused on smallholder chilli farmers whose livelihoods primarily relied on agriculture. This sampling approach and data collection process allowed for a comprehensive examination of the impact of FPO membership on poverty alleviation among smallholder chilli farmers in the study area.

3.2 Tools of Analysis

a. Descriptive statistics: Descriptive statistics viz., mean and Standard Deviation (SD) are employed to analyze and compare the selected variables between treated and untreated farmers.

b. Estimation of Poverty Profile (Foster-Greer–Thorbecke (FGT) Model): As per the FGT model [17], the poverty profile of the sample farmers is represented below:

$$P_{(\alpha)} = (1/n) \sum_{i=1}^{q} \{(y_p - y_i)/y_p\}^{\alpha} \quad (1)$$

where 'n' is the number of sample farmers (households), 'y_i' is the income of the i^{th} household, 'y_p' represents the poverty line indicated by the income limit for households qualifying as a beneficiary under the BPL (ie., ≤ Rs.1,20 lakh per year for rural households in Andhra Pradesh (https://www.business-standard.com), 'q' is the number

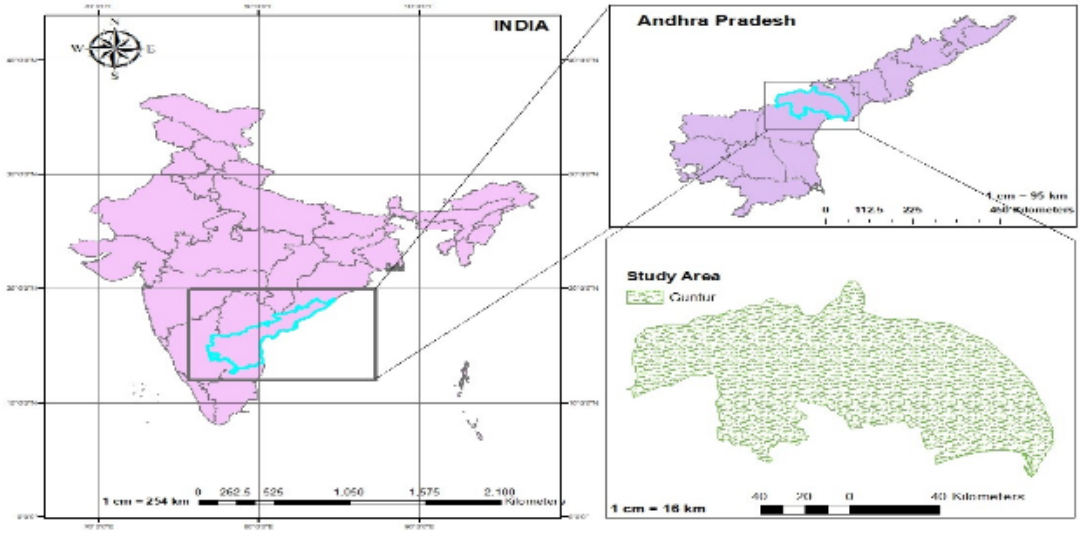

Figure 2. Selection of Guntur district, Andhra Pradesh.

Table 1. Variable types and definitions.

Variable type	Abbreviation	Variables definition
Outcome Variables	Price	Price realized for dry chillies (Rs./quintal of produce transacted)
	Poverty	BPL is indicated by the income limit for households ie., ≤ Rs.1,20,000/year for rural households in Andhra Pradesh* - Primary data regarding annual income derived by both treated and untreated farmers from dry chillies transactions are considered.
Treatment variable	FPO membership decision	FPO membership/Dummy (1 = Member, 0 = Non-member)
Instrumental Variable (IV)	MOTIV	Motivation of farmers to join in FPOs/Dummy (1 = Yes, 0 = No)
Covariates	GND	Gender/Dummy (1 = Male, 0 = Female)
	LHS	Landholding size (Acres)
	EDU	Education of the farmer/Dummy (1 = Yes if > 10th class, 0 = No, if < 10th class)
	GAP	Good Agricultural Practices/Dummy (1 = Yes, 0 = No)
	FE	Farming Experience (years)
	DTF	Distance to FPO from village (kilometers)
	AMI	Access to market information/Dummy(1 = Yes, 0 = No)
	AII	Access to improved inputs at right time/Dummy (1 = Own land, 0 = No)
	ATE	Access to extension services/Dummy (1 = Yes, 0 = No)
	ATIV	Access to improved dry chillies varieties/Dummy (1 = Yes, 0 = No)
	ATIC	Access to institutional credit/Dummy (1 = Yes, 0 = No)

* https://www.thehindu.com/news/national/andhra-pradesh/andhra-pradesh-to-raise-incomelimit-for-bpl-category/article30098727.ece

of households BPL, and 'α' is the poverty parameter (incidence, gap and severity) which takes the values of 0 (P measures poverty head count ratio), 1 (P measures the depth of poverty), and 2 (P measures severity or intensity of poverty).

c. ESRM approach: In this study, the potential endogeneity issue of FPO membership influencing farmer participation is addressed using the ESRM [18]. To verify the exogeneity of the endogenous variable (FPO membership), both the Durbin score test and Wu-Hausman test for endogeneity are conducted. To account for self-selection bias in the decision to join FPOs, the study incorporates a selection equation with MOTIV (a relevant variable) as an instrumental variable for FPO membership. This approach helps address the endogeneity concern by using an instrumental variable that affects FPO membership but is not directly related to the outcome variable of interest. The selection equation used in this study follows the framework [19] as specified below:

$$e_i^* = X_{ia} + \delta_i \text{ with } M = \{1 \text{ if } M^* > 0; = 0 \text{ otherwise}\} \quad (2)$$

For a farmer-member of FPO (M = 1), if M∗ > 0, where M∗ represents the expected benefits of participating in FPO (treated) compared to untreated. The analysis of the impact of FPO membership on the outcome variables (prices and poverty) under the ESRM framework proceeds in two stages. In the first stage, a probit model (Equation 3a) is used to analyze the determinants of the decision to join FPO. In the second stage, an OLS regression with selectivity correction is employed to study the relationship between the outcome variables and a set of explanatory variables, conditional on the FPO membership decision (Equation 3b). The two outcome regression equations, conditional on FPO membership, can be expressed as [16]:

Regime 1 (Treated): $y_{1i} = x_{1i}\beta_1 + \varepsilon_{1i}$ if, M = 1 (3a)

Regime 2 (Untreated): $y_{0i} = x_{0i}\beta_0 + \varepsilon_{0i}$ if, M = 0 (3b)

where, y_{1i} and y_{0i} are the outcome variable(s) with and without FPO membership respectively, x_{1i} and x_{0i} are vectors of exogenous covariates; β_1 and β_0 are vectors of parameters; and ε_{1i} and ε_{0i} are random disturbance terms. The error terms are assumed to have the following covariance matrix:

$$cov(\varepsilon, \epsilon_1, \epsilon_0) = \begin{bmatrix} \sigma_{\epsilon 0}^2 & \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 0 \varepsilon} \\ \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 1}^2 & \sigma_{\epsilon 1 \varepsilon} \\ \sigma_{\epsilon 0 \varepsilon} & \sigma_{\epsilon 1 \varepsilon} & \sigma_{\varepsilon}^2 \end{bmatrix} \quad (4)$$

where σ_{ε}^2 is the variance of the selection equation (Equation 4), $\sigma_{\epsilon 0}^2$ and $\sigma_{\epsilon 1}^2$ are the variances of the outcome equations for untreated and treated, while $\sigma_{\epsilon 0 \varepsilon}$ and $\sigma_{\epsilon 1 \varepsilon}$ represent the covariance between, ϵ_1 and ϵ_0 [20]. If ε is correlated with ϵ_1, and ϵ_0, the expected values of ϵ_1, and ϵ_0 conditional on the sample selection are non-zero:

$$E(\epsilon_1 | \mathrm{M} = 1) = \sigma_{\epsilon 1 \varepsilon} \frac{\phi(Z_i \beta_i)}{\Phi(Z_i \beta_i)} = \sigma_{\epsilon 1 \varepsilon} \lambda_1 \quad (5)$$

$$E(\epsilon_0 | \mathrm{M} = 0) = \sigma_{\epsilon 0 \varepsilon} \frac{-\phi(Z_i \beta_i)}{1 - \Phi(Z_i \beta_i)} = \sigma_{\epsilon 0 \varepsilon} \lambda_0 \quad (6)$$

where, ϕ and Φ are the probability density and the cumulative distribution function of the standard normal distribution, respectively. The Full Information Maximum Likelihood (FILM) estimator is used to fit an ESRM to compare the actual expected outcomes of treated (Equation 7) and untreated (Equation 8), and to investigate the counter factual hypothetical cases that the untreated did participate in FPO (treated) (Equation 9) and the treated did not participate in FPO i.e., untreated (Equation 10) as follows:

$$E(y_1 | \mathrm{M} = 1) = X_1 \beta_1 + \sigma_{\epsilon 1 \varepsilon} \lambda_1 \quad \text{-----} \rightarrow \text{(a)} \quad (7)$$

$$E(y_0 | \mathrm{M} = 0) = X_0 \beta_0 + \sigma_{\epsilon 0 \varepsilon} \lambda_0 \quad \text{-----} \rightarrow \text{(b)} \quad (8)$$

$$E(y_0 | \mathrm{M} = 1) = X_1 \beta_0 + \sigma_{\epsilon 0 \varepsilon} \lambda_1 \quad \text{-----} \rightarrow \text{(c)} \quad (9)$$

$$E(y_1 | \mathrm{M} = 0) = X_0 \beta_1 + \sigma_{\epsilon 1 \varepsilon} \lambda_0 \quad \text{-----} \rightarrow \text{(d)} \quad (10)$$

In the above equations and Table 2, cases (a) and (b) represent the actual expectations observed in the sample, and cases (c) and (d) represent the counter factual expectations with respect to prices and poverty alleviation.

Following [21-23], the ATT and ATU are calculated as below:

$$ATT = \mathrm{E}(y_{1i} | \mathrm{M} = 1; x) - \mathrm{E}(y_{0i} | \mathrm{M} = 1; x), = x_{1i}(\beta_1 - \beta_0) + \lambda_{1i}(\sigma_{\varepsilon 1} - \sigma_{\varepsilon 0}) \quad (11)$$

$$ATU = \mathrm{E}(y_{1i} | \mathrm{M} = 0; x) - \mathrm{E}(y_{oi} | \mathrm{M} = 0; x), = x_{2i}(\beta_1 - \beta_0) + \lambda_{2i}(\sigma_{\varepsilon 1} - \sigma_{\varepsilon 0}) \quad (12)$$

$$\mathrm{BH}_1 = \mathrm{E}(y_{1i} | \mathrm{M} = 1; x) - \mathrm{E}(y_{1i} | \mathrm{M} = 0; x) = (x_{1i} - x_{2i})\beta_{1i} + \sigma_{\varepsilon 1}(\lambda_{1i} - \lambda_{2i}) \quad (13)$$

$$\mathrm{BH}_2 = \mathrm{E}(y_{2i} | \mathrm{M} = 1; x) - \mathrm{E}(y_{2i} | \mathrm{M} = 0; x) = (x_{1i} - x_{2i})\beta_{2i} + \sigma_{\varepsilon 2}(\lambda_{1i} - \lambda_{2i}) \quad (14)$$

Conditions in Equations (11) to (14) can be described as follows:

- The treatment on treated (A*TT*) is the difference between (7) and (9), which is given by Equation (11).
- The effect of the treatment on untreated (A*TU*) is the difference between (10) and (8), which is given by Equation (12).
- The effect of heterogeneity of treated (BH_1) is the difference between (7) and (10).
- The effect of base heterogeneity (BH_2) of untreated is the difference between (9) and (8).

By comparing the results of Equations (13) and (14) or (11) and (12), the Transitional Heterogeneity (TH) is estimated [24]. TH represents the heterogeneity in the effect of FPO participation, indicating whether the effect is larger or smaller for the farmers who actually participated compared to the counter factual scenario where non-participants hypothetically participated. This analysis allows for a deeper understanding of the nuanced impacts of FPO participation, considering the differential effects treated and untreated. It sheds light on the potential variations in outcomes and helps identify factors that may influence the differential effects of FPO participation among farmers.

4. Results and Discussion

4.1 Descriptive Statistics of the Variables

According to the results presented in Table 3, both treated and untreated farmers, with respect to FPO membership, exhibit similar averages in terms of variables such as LHS, FE, and DTF. However, when it comes to other covariates, treated farmers demonstrate statistically significant advantages over untreated farmers. Specifically, treated farmers who are members of the FPO benefit in terms of both prices and annual income compared to their untreated counterparts, and these differences are statisti-

Table 2. Treatment and heterogeneity effects.

TH	Decision stage		Treatment effects
	Treated	Untreated	
Treated	$E(y1i\|M = 1)$ = (a)	$E(y0i\|M = 1)$ = (c)	ATT (a – c)
Untreated	$E(y1i\|M = 0)$ = (d)	$E(y0i\|M = 0)$ = (b)	ATU (d – b)
Heterogeneity effects	BH1 (a – d)	BH2 (c – b)	TH (ATT – ATU)

Notes: (a) and (b) represent observed expected outcome indicators, (c) and (d) represent counter factual expected outcome indicators; M = 1 if farmers participate in FPO and M = 0, otherwise; y_{1i}: Outcome indicators if farmers participate in FPO, y_{0i}: Outcome indicators if farmers do not participate in FPO; ATT: effect of the treatment (i.e., FPO membership) on the treated, ATU: Effect of the treatment (i.e., FPO membership) on the untreated; BH_1: The effect of base heterogeneity for farmers enjoying membership in FPO (M = 1), BH_2: The effect of base heterogeneity for farmers not having membership in FPO (M = 0), TH = (ATT – ATU) [14].

cally significant. The advantages enjoyed by treated farmers can be attributed to various factors facilitated by FPO membership, such as economies of large-scale production, reduced transaction costs, and better market linkages. These factors contribute to higher prices obtained by treated farmers, which in turn leads to higher annual income compared to untreated farmers. These results suggest that FPO membership provides tangible benefits to farmers, including improved prices for their produce and increased annual income, as a result of factors associated with FPOs such as economies of scale, reduced transaction costs, and enhanced market connections [25,26].

4.2 Poverty Analysis—Estimation of Poverty Status among Smallholder Dry Chilli Farming Households

The Below Poverty Line (BPL) classification is a recognized benchmark used to indicate economic disadvantage and identify households in need of Government assistance and aid. In the Indian context, the poverty line is determined based on household income rather than the level of prices. Recently, the Government of Andhra Pradesh has revised the income limit for the BPL category, setting it at an annual income below Rs. 1.20 lakh

Table 3. Descriptive statistics of the variables across Treated vis-à-vis Untreated.

Variables	Pooled (n = 476)		Treated (n = 161)		Untreated (n = 315)		'Z' test (Treated – Untreated)
	Mean	SD	Mean	SD	Mean	SD	
Price (Rs/qtl)	8221.73	271.87	8943.72	150.82	7457.56	149.05	7.23**
Income (Rs/year)	125092.60	54985.57	141068.8	46120.05	96482.62	32589.32	11.94**
FPO membership	0.3382	0.4736	--	--	--	--	--
GND	0.3634	0.4815	0.8634	0.3445	0.1079	0.3108	23.93**
LHS	3.3277	0.9877	3.6273	0.8520	3.1746	1.0180	1.82
EDU	0.3866	0.4875	0.6460	0.4797	0.2540	0.4360	7.66**
GAP	0.5609	0.6074	0.7019	0.4589	0.4889	0.6598	3.41*
FE	24.3466	11.6288	23.9068	11.6075	24.5714	11.6517	0.83
DTF	25.0231	15.1344	25.5031	14.8409	24.7778	15.2998	0.2459
AMI	0.3971	0.4898	0.9441	0.2304	0.1175	0.3225	9.4502**
AII	0.3761	0.4849	0.6534	0.4994	0.2365	0.4733	2.6102**
ATE	0.2311	0.4220	0.9621	0.2421	0.3175	0.4662	9.4907**
ATIV	0.4223	0.4944	0.8261	0.3802	0.2159	0.4121	19.58**
ATIC	0.5609	0.4968	0.7516	0.4335	0.3635	0.4995	2.09*

Note: ** and * denote significance levels at 1% and 5% levels respectively.

Raw data source: Field survey, 2022-2023.

for rural families. In the study's context, smallholder dry chilli farmers whose household income falls below this BPL threshold are considered to be living in poverty. This classification enables the identification of farmers who are economically disadvantaged and require targeted support and interventions. By considering the BPL category, the study aims to assess the impact of FPO membership on poverty alleviation among these smallholder farmers.

The findings from Table 4 reveal significant insights into the extent and severity of poverty among smallholder dry chilli farmers in the study area. The calculated poverty indicators shed light on the challenges faced by these farmers and emphasize the importance of targeted interventions and policies to improve their economic well-being. Firstly, the study area's poverty incidence (P0) of 0.521 indicates that approximately 52 percent of the sample farmers are living in BPL. This high percentage highlights the prevalence of poverty in the region and the urgent need to address this issue. Secondly, the poverty depth or gap (P1) of 0.23 indicates that, on average, the income of poor households falls short by 23 percent of the poverty line. This statistic demonstrates the extent of income inadequacy faced by poor farmers and the magnitude of the challenge in lifting them out of poverty. Figure 2 visually represents the proportion of the poverty line that needs to be bridged to uplift these poor farmers' incomes above the poverty line. Moreover, the poverty severity (P2) rate of 16.6 percent highlights the existence of a subgroup among the poor population that experiences particularly severe poverty. These farmers are in dire need of attention from policy-makers, and measures such as income redistribution and livelihood improvement initiatives should be prioritized to uplift their standard of living. These poverty indicators provided by this study offer valuable data for policy-makers to develop targeted interventions and policies that address the economic challenges faced by smallholder dry chilli farmers in the study area. FPO membership has been identified as a significant positive factor in improving the farmers' standard of living by increasing prices and income [27,28].

Table 4. Estimates of poverty incidence, depth and severity among smallholder dry chilli farmers.

Category	Incidence (P0)	Depth (P1)	Severity (P2)
Treated	0.352	0.126	0.059
Untreated	0.691	0.494	0.281
Overall	0.521	0.226	0.166

Raw data source: Field survey, 2022-2023.

According to Figure 3, the poverty profile analysis highlights the stark disparities between untreated and treated farmer-households, indicating that FPO membership has a significant impact on poverty and economic conditions. The study reveals that untreated farmer-households had a substantially higher poverty incidence of 0.691 compared to treated farmer-households, where the poverty incidence was significantly lower at 0.352. This 49 percent difference in poverty incidence suggests that a larger proportion of untreated farmers were living below the poverty line compared to their treated counterparts. Moreover, the depth and severity of poverty were also found to be greater among untreated farmers. The poverty depth for untreated farmers was measured at 0.494, indicating a larger income shortfall below the poverty line for this group. In contrast, treated farmers had a lower poverty depth of 0.126, implying a comparatively smaller income deficit. Similarly, the severity of poverty was 0.281 for untreated farmers, while treated farmers experienced a much lower severity of poverty at 0.059. This significant difference indicates higher levels of inequality and deprivation among untreated farmers. The study's findings are consistent with previous research [27,29]. In the context of the current study, these results strongly suggest that membership in FPOs and the associated benefits, such as economies of scale, reduced transaction costs, and improved market linkages, play a vital role in poverty reduction and decreased income inequality among smallholder dry chilli farmers in the study area.

4.3 ESRM Approach

Before proceeding with the ESRM, the variables were tested for the presence of multicollinearity. The estimated Variance Inflation Factor (VIF) values for all the variables in both the price and poverty models were found to be less than the critical value of 10 (Appendix 1). This indicates that multicollinearity was not a problem [30-32]. The absence of multicollinearity suggests that the variables are not highly correlated with each other, and their independent contributions can be effectively assessed. To test for heteroskedasticity, the Breusch-Pagan/Cook-Weisberg test was conducted on both models. The findings indicated the absence of heteroskedasticity, indicating that the variances of the error terms in the models were constant (Appendix 2). The overall test of possible endogeneity of the 'FPO membership' variable produced significant results in both the price and poverty models (Table 5). The findings of both the Durbin (score) χ^2 (1) test and the Wu-Hausman F (1,462) test were significant, implying that the treatment variable, 'FPO membership' is highly endogenous in both models. This means that the decision to join FPO is influenced by other factors, and endogeneity needs to be

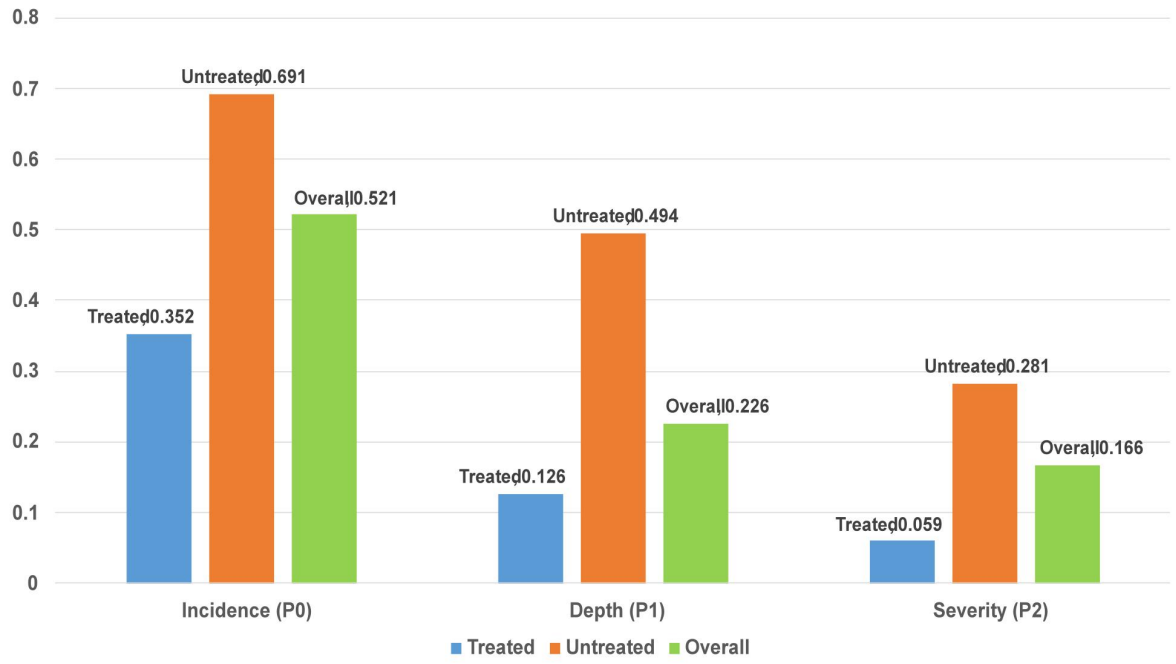

Figure 3. Poverty incidence, depth and severity among smallholder (dry) farmers.

controlled for in the estimation process to obtain unbiased results. These tests and findings help ensure the reliability and validity of the estimation process in addressing the impact of FPO membership on both prices and poverty outcomes among smallholder dry chilli farmers.

Table 5. Tests for the endogeneity of 'FPO membership' variable in price and poverty models.

S.No	Models	Durbin (score) χ^2 (1)	Wu-Hausman F (1,462)
1	Price	13.5524 (0.0002)	13.5393 (0.0003)
2	Poverty	16.3384 (0.0001)	16.4215 (0.0001)

Raw data source: Field survey, 2022-2023.

Tables 6 and 7 present the Wald χ^2 test statistics for the price and poverty models, respectively, indicating that both models exhibit a good fit for the ESRM. This suggests that the ESRM framework is appropriate for addressing the endogeneity problem and obtaining reliable estimates for the study. To further investigate the endogeneity issue, the researchers conducted a Likelihood Ratio (LR) test to test the independence of the outcome and selection equations. The LR test results show that the null hypothesis (HO) of 'no correlation between FPO membership and price/income across both the price and poverty models' was rejected, as evidenced by the test statistics of 19.27** and 17.66** respectively. This rejection indicates that there is a positive correlation between FPO membership and price/income in both the outcome and selection equations, and thus, these equations are dependent on each other. The positive correlation between FPO membership and price/income in both outcome and selection equations is a strong indication of endogeneity, meaning that FPO membership is not randomly assigned but influenced by other factors. This highlights the need to account for endogeneity in the model specification for both the price and poverty models to obtain more accurate and unbiased estimates. By identifying and addressing the endogeneity issue through the ESRM approach, the study ensures that the estimated impact of FPO membership on price realization and poverty alleviation is more reliable and robust. It allows policy-makers and researchers to have confidence in the findings and better understand the true relationship between FPO membership and the economic well-being of smallholder dry chilli farmers in the study area. The Full Information Maximum Likelihood (FIML) approach is a powerful statistical method used in this study to jointly estimate both the outcome and selection equations. This approach allows the researchers to account for the endogeneity issue and obtain reliable estimates of the impact of FPO membership on prices and poverty outcomes for smallholder dry chilli farmers. In Tables 6 and 7, the outcome equations are presented in columns 2 and 3, respectively. These equations represent the estimated impact of FPO membership on price realization and poverty for

both the treated and untreated categories of farmers. By analyzing these outcome equations, the study can quantify the specific effects of FPO membership on prices and poverty levels, taking into consideration the FPO membership status of the farmers. Column 4 in Tables 6 and 7 presents the selection equation. This equation identifies the determinants of FPO membership, allowing the researchers to understand the factors influencing farmers' decisions to join or not join the FPOs. The estimated impact of FPO membership based on the coefficients of the OLS regression is presented in the last column (column 5) of Tables 6 and 7. To provide a comprehensive understanding of the impact of FPO membership, the study employs the ESRM framework, which simultaneously estimates the

Table 6. ESRM-Impact of FPO membership on price realization of smallholder dry chilli farmers.

Dependent Variable ------→	Endogenous switching regression			OLS
	Treated (Price)	Untreated (Price)	FPO membership (Treated = 1 Untreated = 0)	Price
1	2	3	4	5
FPO membership				0.0283** (0.0061)
MOTIV	--	--	0.3879** (0.1088)	--
GND	0.0046 (0.0030)	0.0002 (0.0140)	0.0257 (0.0652)	–0.0079 (0.0047)
LHS	0.0297** (0.0076)	0.0004 (0.0034)	0.2647** (0.1043)	0.0095* (0.0045)
EDU	0.0125* (0.0059)	0.0027 (0.0084)	0.2170* (0.1009)	0.0029 (0.0021)
GAP	0.0128** (0.0048)	0.0056 (0.0056)	0.0309** (0.0115)	0.0052 (0.0034)
FE	0.0151** (0.0053)	0.0001 (0.0002)	0.0244* (0.0112)	9.79E-06 (0.0002)
DTF	–0.0101** (0.0032)	–0.0074** (0.0022)	–0.2751** (0.1043)	–0.0209** (0.0047)
AMI	0.0490** (0.0095)	0.0653** (0.0132)	0.3032** (0.1021)	0.0497** (0.0062)
AII	0.0064** (0.0016)	0.0027 (0.0038)	0.0448** (0.0161)	0.0002 (0.0048)
ATE	0.0118** (0.0021)	0.0533** (0.0096)	0.3689** (0.1389)	0.0154** (0.0056)
ATIV	0.0266** (0.0066)	0.0115** (0.0028)	0.4458** (0.1887)	–0.0002 (0.0001)
ATIC	0.0181** (0.0066)	–0.0139 (0.0081)	0.1721 (0.0963)	–0.0006 (0.0046)
Constant	3.1927 (0.0192)	3.2348 (0.0157)	0.5922 (0.3167)	3.2353 (0.0099)
σ_i	0.0639** (0.0031)	0.0561** (0.0066)		
ρ_j	–0.4897** (0.2025)	0.8987 (0.8705)		
n	476			476
Wald χ^2 (11)	194.67** (0.0000)			
LR test of independent equations: χ^2 (1)	19.27** (0.0000)			

Note: Robust standard errors in parentheses; ** & * indicate 1 and 5 percent probability levels respectively.
Raw data source: Field survey, 2022-2023.

outcome and selection equations, accounting for the endogeneity problem. This approach takes into account the interdependencies between the decision of farmers to join the FPO and the resulting outcomes on prices and poverty levels [33-35]. These estimates allow the researchers to draw meaningful conclusions about how FPO membership affects price realization and poverty alleviation among smallholder dry chilli farmers.

In the price model (Table 6), the covariance term of FPO membership for the treated category is statistically significant (–0.4897**), indicating that self-selection occurs in FPO membership. This means that treated farmers

Table 7. ESRM-impact of FPO membership on poverty alleviation of smallholder dry chilli farmers.

Dependent Variable ------→	**Endogenous switching regression**			**OLS**
	Treated (Poverty)	**Untreated (Poverty)**	**FPO membership (Treated = 1 Untreated = 0)**	**Poverty**
1	**2**	**3**	**4**	**5**
FPO membership				0.4897** (0.0251)
MOTIV			0.3956** (0.1290)	
GND	–0.0288 (0.0221)	–0.0063 (0.0221)	0.1352 (0.7812)	0.0280 (0.0187)
LHS	0.2815** (0.0119)	0.3555** (0.0307)	0.2234** (0.0366)	0.3363** (0.0061)
EDU	0.0713* (0.0335)	–0.0195 (0.0158)	0.6835** (0.2794)	0.0221 (0.0132)
GAP	0.0163** (0.0052)	0.0144 (0.0105)	0.3079* (0.1504)	0.0139 (0.0098)
FE	0.0021** (0.0006)	0.0003 (0.0009)	0.0108** (0.0013)	0.0032** (0.0005)
DTF	–0.0033** (0.0007)	–0.0025** (0.0004)	–0.0193* (0.0091)	–0.0006 (0.0004)
AMI	0.0208** (0.0047)	0.0613** (0.0266)	0.4349** (0.0406)	0.0067** (0.0006)
AII	0.0347** (0.0015)	0.0205 (0.0231)	0.3330** (0.0914)	0.0112 (0.0138)
ATE	0.0399** (0.0148)	0.0411* (0.0203)	0.0587** (0.0195)	0.0406** (0.0163)
ATIV	0.0256** (0.0083)	0.1111** (0.0179)	0.3835** (0.1129)	0.0063 (0.0146)
ATIC	0.0580* (0.0279)	–0.0054 (0.0146)	0.7203* (0.3305)	0.0073 (0.0146)
Constant	11.0260 (0.0951)	10.2932 (0.0318)	4.3691 (0.7417)	10.3616 (0.0288)
σ_i	0.1235** (0.0075)	0.1182** (0.0047)		
ρ_j	–0.4661* (0.2309)	0.2262 (0.2416)		
n	476			476
Wald χ^2 (11)	618.73** (0.0000)			
LR test of independent equations: χ^2 (1)	17.66** (0.0000)			

Note: Robust standard errors in parentheses; ** & * indicate at 1 and 5 percent probability levels respectively.
Raw data source: Field survey, 2022-2023.

who choose to have FPO membership may have different effects compared to untreated farmers. The negative and significant sign of ρ_j for the treated category suggests a positive bias. This means that farmers with above-average prices have a higher probability of enjoying FPO membership. On the other hand, the insignificant covariance estimate for the untreated category (0.8987^{NS}) suggests that, in the absence of FPO membership, there would be no significant difference in the average price realized between the treated and untreated categories due to unobservable factors. These estimates are consistent since $\rho_1 < \rho_2$. Therefore, farmers who are members of FPOs are able to obtain higher prices compared to their untreated counterparts, as reported in studies [12-14]. Similar findings are observed in the poverty model (Table 7), where the covariance term of the treated category is statistically significant (–0.4661**), indicating a positive bias. The covariance estimate for the untreated category is insignificant (0.2262^{NS}). This suggests that treated farmers realize higher incomes than they would if they did not have FPO membership [36]. The estimated coefficient of correlation (ρ_j) is statistically significant for the treated category in both models, indicating the presence of sample selectivity bias in both equations. So, the H_O that *sample selectivity bias was absent in both equations* can be rejected [37]. Moreover, there is a significant difference in σ_i across the treated and untreated categories, indicating the presence of heterogeneity in the sample. In both models, ρ_1 and ρ_2 have alternative signs, with ρ_1 being statistically significant and negative, while ρ_2 is statistically non-significant and positive. This suggests that farmers decide whether to join FPOs based on comparative advantages. The significance of ρ_1 indicates that self-selection matters and farmers with above-average price and income levels have higher chances of enjoying FPO membership. Therefore, treated farmers experience better or higher prices and incomes than they would without FPO membership. Furthermore, the positive value of ($\sigma_1 - \sigma_2$) term (i.e., between treated and untreated) across both models demonstrates that participating in FPO membership ensures higher prices and incomes under self-selection than under random assignment. These results confirm that the ESRM is an appropriate model controlling for self-selection and inherent differences between the treated and untreated categories, as discussed by Seng [20].

The differences in the significance of coefficients of the key explanatory variables in both ESRMs (Tables 6 and 7) provide valuable insights into the presence of heterogeneity [21]. In the price model (Table 6), for the treated category (column 2), an increase in EDU and adherence to GAPs in dry chilli cultivation significantly increase the price of the produce. However, for the untreated category (column 3), these variables do not show a correlation with price, and even their magnitudes are lower compared to the treated category. This pattern is similarly observed in the poverty model concerning the realization of higher income across the treated and untreated categories. The results indicate that a higher level of education plays a significant role in influencing prices and incomes among smallholder dry chilli farmers who are members of FPOs. Education facilitates better access to local extension networks, leading to FPO membership, and subsequently, access to backward and forward linkages, higher productivity, increased output, and substantial benefits compared to the untreated category. Hence, EDU and GAPs together contribute to higher prices and incomes in the Guntur district. Importantly, the coefficients in Tables 6 and 7 represent unconditional effects, and the observed differences are not solely due to FPO membership. Additionally, it is evident that EDU and GAPs play a joint role in determining the likelihood of participating in FPOs and influencing the outcome variables (price and income). These findings align with previous works [12,16,23,15,20]. Factors such as FE, AII, and ATIC also exhibit heterogeneous effects between the treated and untreated categories across both price and poverty models. This variation is expected as long-term farm experience influences farmers' membership in FPOs and their access to quality inputs for dry chilli production. Regarding ATIC, the untreated category primarily relies on non-institutional loans from local wholesalers, millers, and private money lenders, resulting in the sale of their produce in local markets, unlike the treated farmers. In contrast, treated farmers, benefiting from higher prices and prompt payment of sales proceeds, are considered more creditworthy by institutional sources. Hence, FPO membership plays a crucial role in enhancing the repayment capacity of treated farmers, highlighting the link between credit and marketing through FPO membership. Furthermore, the variable "LHS" is found to significantly increase both price and income for the treated farmers and significantly influence income for the untreated category. On the other hand, "DTF" negatively and significantly influences price and income, as the remoteness of farms discourages farmers' membership in FPOs, leaving them deprived of remunerative prices compared to the treated category. These findings reveal the presence of heterogeneity in the effects of key explanatory variables between treated and untreated categories in the price and poverty models.

In the selection equations (column 4), the major drivers

for farmers' membership in FPOs include MOTIV, LHS, EDU, GAP, FE, AII, AMI, ATE, and ATIV. The instrumental variable "MOTIV" stands out as having a positive and significant influence on both the price (0.3879**) and poverty (0.3956**) models. This result is not surprising, as farmers who have strong linkages with research and extension networks are motivated to join FPOs. This finding is in line with earlier research [14] and thus, provides valuable evidence that MOTIV plays a crucial role in influencing FPO membership and contributes to poverty alleviation by increasing income above the poverty line of Rs. 1.20 lakh per year. Consistent with theoretical expectations, several other factors also show significant effects on FPO membership and subsequent outcomes. Farmers with more farm experience, access to improved inputs, extension agents, improved dry chilli varieties, and market information achieve significant increases in prices and income. However, it is noteworthy that "DTF" has a significant negative influence on farmers' membership in FPOs. This implies that the remoteness of farms discourages farmers from joining FPOs, potentially limiting their access to benefits such as higher prices and improved income that FPO members enjoy. On the other hand, the variable "GND" does not show a significant influence on the outcome variables, in line with the findings from previous studies [38,39].

The last column (OLS approach) of Tables 6 and 7 focuses on examining the effects of FPO membership on price and poverty alleviation. The results indicate a significant difference in the prices and incomes realized between the treated and untreated categories of FPO membership. However, it is crucial to acknowledge that the OLS approach assumes that "FPO membership" is exogenously determined, whereas in reality, it is endogenously determined, as demonstrated in Table 5. The endogeneity of FPO membership can introduce bias in the OLS estimates, as there might be unobservable factors that simultaneously influence both FPO membership and the outcome variables (price and income). Consequently, the OLS estimates may not provide accurate and reliable estimates of the true causal effects of FPO membership on the outcomes. To address this endogeneity issue and obtain unbiased and consistent estimates, the study employed ESRM in the second, third, and fourth columns of Tables 6 and 7. This model allows for the control of endogeneity by incorporating instrumental variables (MOTIV) to disentangle the true causal effects of FPO membership on price and poverty alleviation from confounding factors, resulting in more reliable and robust estimates.

Treatment Effects: The ESRMs results on the expected outcomes under actual and counter factual conditions for treated and untreated are shown in Table 8. A simple comparison of observed outcomes of treated and untreated alone can be misleading [16], as it suggests that on average the treated (a) farmer's price and income are 2.28 and 5.79 percent respectively higher than the untreated (b). However, the correct comparison is between the observed outcomes for treated (a) and the counter factual case (c), which shows that by having membership in FPO, the treated are earning on average 2.11 percent higher price than if they had become untreated. Similarly, comparing the expected price in the counter factual case (d) and observed outcome (b), by not having membership in FPO, untreated are forgoing 1.25 percent of the price. That is, the untreated would have received a higher price by 1.25 percent if they had become treated. These results indicate that FPO membership has a significant positive impact on the prices realized by the treated farmers compared to the untreated farmers. This is further supported by the TH effect, which is positive for prices, indicating that the effect of FPO membership is even greater for the treated farmers compared to the untreated farmers [40,41].

Table 8. Treatment and heterogeneity effects.

	Treated	**Untreated**	**Treatment effects**
Price			
Treated	(a) 3.2934	(c) 3.2253	TT = 0.0681**
Untreated	(d) 3.2601	(b) 3.2199	TU = 0.0402**
Heterogeneity effects	BH_1 = 0.0333	BH_2 = 0.0054	**TH = 0.0279****
Poverty			
Treated	(a) 16.0723	(c) 11.5511	TT = 4.5212**
Untreated	(d) 13.8569	(b) 11.4114	TU = 2.4455**
Heterogeneity effects	BH_1 = 2.2154	BH_2 = 0.1397	**TH = 2.0757****

Raw data source: Field survey, 2022-2023.

Furthermore, in terms of income, the comparison between the observed outcomes for the treated farmers (a) and the counter factual case (c) shows that by being a member of an FPO, the treated farmers earn, on average, 39.14 percent higher annual income compared to what they would have earned if they were untreated. Similarly, comparing the expected income in the counter factual case (d) and the observed outcome (b) for the untreated farmers, it is found that the untreated farmers are forgoing 21.43 percent of annual income by not being members of an FPO. In other words, the untreated farmers would have received a 21.43 percent higher income if they had chosen to become treated. These results indicate that FPO membership significantly increases the income realized by the treated farmers compared to the untreated farmers. The TH effect is also positive for income, indicating that the effect is even greater for the treated farmers compared to the untreated farmers [39].

Overall, the results from both the price and poverty models, as indicated by the TH effects, demonstrate that farmers who enjoy membership in an FPO have realized higher prices and incomes at a significant level compared to untreated farmers at both decision stages. Therefore, the sources of heterogeneity suggest that treated farmers obtain higher prices and incomes than untreated farmers regardless of their participation status. In other words, farmers who have FPO membership are still better off than those who are non-members.

5. Conclusions and Policy Implications

The agriculture sector plays a significant role in the Indian economy, contributing approximately 13.39 percent to the GDP and employing 55 percent of the total workforce. However, small and marginal farmers, who constitute a majority of the farming population, face various challenges such as low output, limited marketable surplus, inadequate market access, and lack of access to credit and training. These challenges contribute to poverty and hinder the development of the agricultural sector. To address these issues, the Government of India has promoted the formation of FPOs as a means to alleviate poverty among farmers. In the case of dry chilli production in Guntur, Andhra Pradesh, smallholder farmers face challenges in both production and marketing. To support these farmers, the government has facilitated the establishment of six FPOs specifically focused on dry chillies in Guntur district. The participation of smallholder farmers in these FPOs has provided them with numerous benefits, including economies of scale, strengthened market linkages, access to quality inputs and extension services, reduced transaction costs, enhanced bargaining power, and access to remunerative prices for their produce. However, previous studies on FPOs have primarily focused on growth, linkages, transaction volumes, and prices, without providing a comprehensive assessment of the overall impact of FPOs. Therefore, this study aims to fill that gap by examining the factors driving smallholder dry chilli farmers' decision to engage with FPOs. Moreover, this study assesses the impact of FPOs on the attainment of remunerative prices and poverty alleviation among smallholder farmers. The analysis focuses on the state of Andhra Pradesh and Guntur district, considering their potential for dry chillies production and the presence of functioning FPOs in the region. Two specific FPOs, Red Chilli Farmer Producer Organisation and Spoorthi Chilli Producers Company Ltd, were selected for an in-depth study. The study utilized cross-sectional data consisting of 161 treated farmers (FPO members) and 315 untreated farmers (non-members) randomly selected. To address potential endogeneity issues, the study utilizes the Endogenous Switching Regression model, which incorporates a selection equation with a relevant instrumental variable. This approach helps account for self-selection bias in the decision to join FPOs and provides a robust analysis of the impact of FPO membership on poverty alleviation among smallholder chilli farmers. The empirical results of the ESRM analysis revealed a positive and significant association between FPO membership and both price realization and poverty alleviation. Specifically, FPO membership was found to increase prices by 2.11 percent and annual agricultural income by 39.14 percent. Several factors were identified as major drivers of farmers' participation in FPO membership, including EDU, GAP, FE, AII, ATIC, LHS, DTF, AMI, ATE and ATIV. These factors influenced both the price and poverty models. The negative signs of the parameter (ρ_j) for the treated group in both the price and poverty models indicate a positive bias, suggesting that farmers with above-average prices and income are more likely to join FPOs. Furthermore, the comparison of parameters ($\rho_1 < \rho_2$) indicates that farmers with FPO membership achieved higher prices and annual income compared to those who remained untreated. Based on the findings, the study concludes that FPO membership contributes to an improved standard of living for smallholder dry chilli farmers by increasing prices and income compared to non-members. The positive impact of FPO membership on prices and income can have long-term beneficial effects and potentially extend to other aspects of farmers' lives. Therefore, it is recommended that the Government promote the popularity of FPOs among farm-

ers. Initiatives such as the Agriculture Infrastructure Fund (AIF) Scheme and linking FPOs to the electronic National Agriculture Market (e-NAM) portal provide ample opportunities to promote and support FPOs. By creating awareness, providing financial support, and facilitating market access, policy-makers can encourage more farmers to join FPOs and reap the benefits of collective action and market integration.

Author Contributions

K. Nirmal Ravi Kumar: conceptualization, review, methodology, data collection, data curation, data analysis, writing initial draft; M. Jagan Mohan Reddy: expert comments and suggestions; Adinan Bahahudeen Shafiwu: expert comments and suggestions; A. Amaraendar Reddy: expert comments and suggestions. All the authors have read and agreed to the published version of the manuscript.

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Data Availability

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest

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Appendices

Appendix 1. VIF among selected independent variables.

Variables	VIF	1/VIF
FPO membership	1.39	0.7190
AMI	2.33	0.4293
GND	2.19	0.4561
ATE	1.41	0.7113
ATIV	1.4	0.7133
LO	1.36	0.7337
ATIC	1.3	0.7663
EDU	1.23	0.8155
MOTIV	1.12	0.8909
LHS	1.08	0.9223
GAP	1.07	0.9305
DTM	1.04	0.9632
FE	1.02	0.9824

Appendix 2. Breusch-Pagan/Cook-Weisberg test for heteroskedasticity.

	Price	Income (Poverty)
χ^2 (1)	0.09	0.13
Prob (χ^2)	0.7625	0.7178