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Effects of Financial Incentives and Economic Reforms in Agriculture on Income and Gender Inequality in Iran

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ABSTRACT

Agriculture, as one of the most important economic sectors in Iran, plays a key role in ensuring food security, employment, and economic development. Despite the high importance of this sector, Iran's agricultural structure faces widespread inequalities in various dimensions, including income inequality among farmers, regional inequality among provinces, and gender inequality in access to resources and opportunities. These inequalities have emerged due to multiple factors, such as differences in the distribution of natural resources, climatic diversity, unequal access to technology, institutional weaknesses, and inadequate support policies. The present study is applied in terms of purpose and descriptive–analytical in nature, and it falls within the category of ex post facto research covering the period from 1986 to 2023. This study examines the effects of financial incentives and economic reforms in agriculture on income and gender inequality in Iran. Using a Smooth Transition Regression (STR) model in which the transition variable is the price of agricultural products, the nonlinear relationship between financial incentives and economic reforms in agriculture and income and gender inequality in Iran is modeled in the presence of threshold effects of agricultural product prices. The estimation results of the nonlinear component of the income inequality model (regime two) indicate that the variables of credit facilities granted to the agricultural sector, development expenditures in agriculture, agricultural product prices, labor force, gross domestic product per capita, real exchange rate, and education level have a negative effect on income inequality in Iran and, based on the calculated probabilities for these variables, all of which are less than 0.05, they exert a statistically significant effect on income inequality at the 5% error level. In the second model, where the response variable is gender inequality, the estimation results of the nonlinear component of the model (regime two) indicate a positive relationship between the unemployment rate and inflation rate with gender inequality. In addition, the variable of financial incentives in the agricultural sector has a negative and statistically significant effect on gender inequality at the 95% confidence level.

Keywords: Financial incentives; economic reforms in agriculture; income inequality; gender inequality; agricultural product prices

Introduction

Agriculture remains one of the most structurally significant sectors in national economies, particularly in developing and transition countries where it plays a pivotal role in employment creation, food security, rural livelihoods, and poverty reduction. Beyond its direct contribution to gross domestic product, the agricultural sector constitutes a primary mechanism through which income distribution patterns are shaped, especially in rural societies characterized by limited industrial diversification and high dependency on land-based production systems. Over the

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past two decades, the nexus between agricultural development, institutional reform, and income inequality has attracted growing scholarly attention, as evidence increasingly demonstrates that structural transformations in agriculture generate profound redistributive consequences. These dynamics are especially pronounced in contexts where land ownership regimes, production technologies, labor allocation, and policy incentives interact in complex and nonlinear ways (1-3).

One of the central channels through which agriculture influences income inequality is land governance. Patterns of land ownership, land redistribution, tenure security, and land market regulations critically determine who benefits from agricultural growth and who remains marginalized. Recent international research has shown that poorly designed land policies can exacerbate inequality, while well-structured land reforms can significantly reduce income disparities by enhancing access to productive assets among disadvantaged groups (4-6). Land redistribution initiatives, particularly when integrated with supportive agricultural policies, can create inclusive growth trajectories by expanding smallholder participation in markets and increasing their capacity to accumulate income and assets (7-9).

At the household level, the structure of agricultural production further conditions inequality outcomes. Empirical studies consistently indicate that diversification into higher value subsectors, such as horticulture and livestock, contributes to narrowing rural income gaps by generating more stable and higher returns for small and medium-scale farmers (10-12). Conversely, reliance on low-productivity staple crops under weak institutional frameworks often reinforces income polarization and deepens regional disparities (13-15). These findings highlight the importance of agricultural structural change not merely as a growth strategy, but as a distributional policy instrument.

In recent years, governments have increasingly turned toward financial incentives and economic reforms as policy tools to stimulate agricultural modernization. Such interventions include subsidized credit, public investment in agricultural infrastructure, price stabilization mechanisms, land consolidation programs, and reforms aimed at enhancing property rights and market efficiency. While these measures are generally designed to promote productivity and competitiveness, their distributional consequences remain highly contested. On the one hand, financial incentives can empower smallholders by relaxing credit constraints and enabling investment in improved technologies (16, 17). On the other hand, if captured disproportionately by large landholders and agribusiness elites, such policies may intensify income inequality and marginalize vulnerable farming populations (6, 18).

Land system reforms constitute another crucial dimension of this policy landscape. Evidence from diverse institutional settings indicates that strengthening land property rights stimulates investment in movable and immovable farm assets, enhances production efficiency, and alters income distribution patterns across rural societies (5, 16, 19). However, the distributive effects of these reforms are far from uniform. In contexts characterized by historical land concentration and weak regulatory capacity, land reforms may initially widen inequality before generating inclusive growth benefits over the long term (4, 8).

Parallel to land governance, the transformation of agricultural labor markets plays a decisive role in shaping income and gender inequality. The reallocation of labor from agriculture to non-agricultural sectors, often facilitated by technological progress and urbanization, has been shown to influence both productivity and income distribution (20, 21). While labor mobility can reduce rural poverty by increasing household earnings through diversification, it may simultaneously exacerbate gender inequality when women remain concentrated in low-paying informal agricultural employment (19, 22). Consequently, agricultural reforms that fail to integrate gender-sensitive labor policies risk reproducing structural inequalities despite overall economic growth.

The interrelationship between agricultural modernization and gender inequality has emerged as a critical research frontier. Numerous studies emphasize that women's access to land, credit, extension services, and markets remains significantly constrained by institutional, cultural, and legal barriers. These constraints systematically limit women's productive potential and income-generating capacity, thereby reinforcing gendered income disparities within rural households and communities (6, 18, 22). Evidence from land reform programs demonstrates that unless gender equity is explicitly embedded within reform design, redistribution and productivity gains may disproportionately benefit men, leaving women's economic position largely unchanged (7, 9).

In addition, the growing digitalization of agricultural systems is reshaping income distribution in both promising and problematic ways. Digital technologies enhance production efficiency, facilitate market access, and optimize resource allocation. Yet the unequal diffusion of these technologies risks creating new forms of digital inequality, particularly for small-scale farmers and women who often lack access to capital, training, and infrastructure (20, 21). The digital divide thus emerges as a new structural determinant of agricultural income inequality in the contemporary rural economy.

Environmental and ecological dimensions further complicate the inequality landscape. Sustainable land management, biodiversity conservation, and climate resilience policies increasingly intersect with agricultural reform agendas. While these initiatives are essential for long-term productivity, their short-term costs may fall disproportionately on poorer farmers who lack adaptive capacity (23, 24). Without compensatory financial mechanisms, sustainability-oriented reforms may inadvertently intensify income inequality despite generating aggregate welfare benefits.

Within the Iranian context, these global dynamics acquire particular significance. Iran's agricultural sector exhibits pronounced regional, income, and gender inequalities shaped by climatic heterogeneity, historical land distribution patterns, policy distortions, and uneven access to financial resources. Empirical studies conducted across Iranian provinces consistently document the crucial role of agricultural subsector development, value-added expansion, and productivity growth in reducing rural income disparities (2, 13, 25). However, these benefits remain spatially uneven, with marginalized regions experiencing limited gains from national agricultural modernization programs (11, 26).

Moreover, Iran's financial support mechanisms for agriculture—encompassing subsidized credit, development expenditures, and price interventions—have produced mixed distributive outcomes. While supportive policies have improved income conditions for segments of the rural population, concerns persist regarding their unequal allocation and effectiveness in reaching smallholders and women farmers (3, 14). At the same time, ongoing economic reforms, currency fluctuations, and macroeconomic instability have intensified vulnerability among low-income rural households, amplifying both income and gender inequalities.

Despite the growing body of international and domestic literature, critical gaps remain. Most existing studies examine either income inequality or agricultural development in isolation, with limited attention to their nonlinear interactions under changing policy regimes. Moreover, few investigations simultaneously analyze income and gender inequality within a unified empirical framework that accounts for threshold effects and regime shifts induced by agricultural price dynamics and policy interventions. This omission is particularly consequential given mounting evidence that agricultural reforms do not exert uniform effects across different economic conditions, but rather generate regime-dependent outcomes that require nonlinear modeling approaches (17, 19, 20).

Therefore, a comprehensive examination of how financial incentives and economic reforms in agriculture shape both income and gender inequality in Iran—while accounting for nonlinearities and threshold effects—constitutes an essential contribution to the literature. Such an approach not only advances theoretical understanding of agricultural development and inequality dynamics but also offers concrete policy insights for designing inclusive and gender-responsive agricultural strategies in emerging economies.

Accordingly, the aim of this study is to investigate the nonlinear effects of financial incentives and economic reforms in the agricultural sector on income and gender inequality in Iran under agricultural price threshold conditions.

Methods and Materials

The present study is applied in terms of purpose and descriptive–analytical in nature, and it falls within the category of ex post facto research covering the period from 1986 to 2023. Based on the theoretical foundations regarding the effects of financial incentives and economic reforms in agriculture on income and gender inequality in Iran, and following the studies of Tang and Sun (2022) and Mezonaw et al. (2022), this research examines the impact of financial incentives and economic reforms in agriculture on income, regional, and gender inequality in Iran. For this purpose, the Smooth Transition Autoregressive (STAR) and Panel Smooth Transition Autoregressive (PSTAR) models developed by Teräsvirta and Anderson (1992) and further extended by Teräsvirta (1994) are employed. Unlike the Threshold Autoregressive (TAR) models, which use indicator functions to control the regime-switching process, the STAR model applies logistic and exponential functions for this purpose. According to van Dijk and Teräsvirta (2002), these models are particularly appropriate for analyzing asymmetric cycles of variables, and numerous studies have demonstrated that they effectively capture regime-switching mechanisms when examining nonlinear dynamics among variables. In fact, the STAR threshold model continuously models nonlinear relationships among variables using a transition variable and a slope parameter. The Smooth Transition Regression model proposed by Teräsvirta is specified in the following general regression form:

$$y_t = \pi' z_t + \theta' z_t F(s_t, \gamma, c) + u_t \quad (1)$$

where $z_t$is a vector of exogenous variables of the model; πrepresents the vector of linear parameters; θdenotes the vector of nonlinear parameters; and $u_t$is the error term, which is assumed to be independently and identically distributed with zero mean and constant variance, i.e., $u_t \sim iid(0, \sigma^2)$. The transition function $F(s_t, \gamma, c)$can be specified in either logistic or exponential form as follows:

$$F(s_t, \gamma, c) = \frac{1}{1+\exp\left[-\gamma(s_t - c)\right]} - \frac{1}{2} \quad (2)$$

$$F(s_t, \gamma, c) = 1 - \exp\left[-\gamma(s_t - c)^2\right] \quad (3)$$

where Equation (2) represents the logistic transition function and Equation (3) represents the exponential transition function. In these functions, $s_t$denotes the transition variable, γrepresents the slope parameter, and $c$indicates the threshold value or the regime-switching location. If the slope parameter γ, which represents the speed of transition from one regime to another, approaches infinity, the STAR model converges to a TAR model. In this case, if the transition variable exceeds the threshold value $(s_t > c)$, the transition function equals one $(F = 1)$; conversely, if $(s_t < c)$, the transition function equals zero $(F = 0)$. If the slope parameter approaches zero, the STAR model reduces to a linear model.

Final Model Specifications:

(4) **Income Inequality Model**

$$INQ_t = \alpha_0 + \beta_1 FAC_t + \beta_2 INV_t + \beta_3 AGRprice_t + \beta_4 L_t + \beta_5 POP_t + \beta_6 GDPper_t + \beta_7 EX_t + \beta_8 UNE_t + \beta_9 EDU_t + \beta_{10} INF_t + (\theta_1 FAC_t + \theta_2 INV_t + \theta_3 AGRprice_t + \theta_4 POP_t + \theta_5 L_t + \theta_6 GDPper_t + \theta_7 EX_t + \theta_8 UNE_t + \theta_9 EDU_t + \theta_{10} INF_t) F(S_t, \gamma, c) + u_t$$

(5) **Gender Inequality Model**

$$GII_t = \alpha_0 + \beta_1 FAC_t + \beta_2 INV_t + \beta_3 AGRprice_t + \beta_4 L_t + \beta_5 POP_t + \beta_6 GDPper_t + \beta_7 EX_t + \beta_8 UNE_t + \beta_9 EDU_t + \beta_{10} INF_t + (\theta_1 FAC_t + \theta_2 INV_t + \theta_3 AGRprice_t + \theta_4 POP_t + \theta_5 L_t + \theta_6 GDPper_t + \theta_7 EX_t + \theta_8 UNE_t + \theta_9 EDU_t + \theta_{10} INF_t) F(S_t, \gamma, c) + u_t$$

Study Variables:

INQ: Gini coefficient index; a measure of statistical dispersion intended to represent income inequality or wealth inequality within a country or any other population group. A Gini coefficient of zero indicates perfect equality, where all values are identical. A Gini coefficient of one represents maximum inequality. A high Gini coefficient in a country is generally considered an indicator of substantial income disparity and class inequality.

Gender Development Index (GDI):

The significance of the gender gap is such that international institutions adjust countries' rankings based on human development indices by gender. While the Human Development Index (HDI) reflects average access, the GDI adjusts average access based on gender inequality across three dimensions: life expectancy, income, and education. The Gender Development Index is calculated using the same variables as the HDI, with the distinction that it reflects disparities between women and men in average access to life expectancy, education, and income.

Gender Inequality Index (GII):

Since the HDI reflects overall national achievement in human development and the GDI evaluates the weighted average achievements of women and men, a meaningful comparison can be made between countries' HDI and GDI values. This comparison indicates the degree of fairness in the distribution of basic capabilities between women and men within a society and is expressed through the Gender Inequality Index (GI), which ranges between zero and one.

$GI = 0$indicates that women have achieved equal access to education, income, and life expectancy compared to men.

$$GI = (HDI - GDI)/HDI$$

Indicators of Financial Incentives and Economic Reforms in Agriculture:

FAC: Government credit facilities granted to the agricultural sector.

INV: Development budget allocated to the agricultural sector.

AGRprice: Price of agricultural products.

L: Labor force employed in the agricultural sector.

POP: Total population.

GDPper: Gross domestic product growth.

EX: Real exchange rate.

UNE: Unemployment rate.

EDU: Education level.

INF: Inflation rate.

Findings and Results

Initially, to ensure the absence of spurious regression, unit root and cointegration tests were applied. In this study, the conventional Phillips–Perron unit root test was employed. Based on the theoretical foundations of stationarity testing, the null hypothesis H_0in these tests assumes non-stationarity of the variables. Considering the test results, it can be concluded that all variables in the model are stationary at the first difference, i.e., integrated of order one $I(1)$.

Since the variables in the model are integrated of the same order $I(1)$, the Johansen–Juselius cointegration approach was applied to detect the existence of a long-run equilibrium relationship among the variables. Implementing this test requires determining the number of cointegrating vectors. For interpreting the cointegration test results, the appropriate specification regarding the inclusion of intercepts and time trends in the cointegrating equation must be selected. Five alternative models are considered: (1) no intercept and no trend; (2) restricted intercept and no trend; (3) unrestricted intercept and no trend; (4) unrestricted intercept and restricted trend; and (5) unrestricted intercept and unrestricted trend. These five specifications range from the most restricted (Model 1) to the least restricted (Model 5). Subsequently, the null hypothesis of no cointegrating vector is tested against the alternative of at least one cointegrating vector, followed by testing the null of at most one cointegrating vector against two, and so forth, up to $n-1$cointegrating vectors (where $n$denotes the number of variables). The summary of the trace statistic (λ_{Trace}) and the maximum eigenvalue statistic (λ_{Max}) for the number of cointegrating vectors under the five model specifications is reported in the following. As shown, the null hypothesis of no cointegration is rejected in favor of the existence of at least one cointegrating vector among the variables. According to the trace test, the existence of six cointegrating vectors is confirmed, and the maximum eigenvalue test also supports the presence of six cointegrating vectors at the 5% significance level.

Given the limitations of linear models, numerous studies have recommended the application of various nonlinear models to adequately specify nonlinear behavior in time series data. Accordingly, this study employs the Smooth Transition Regression (STAR) model, developed by Teräsvirta and Anderson (1992) and further extended by Teräsvirta (1994), to model the threshold effects of financial incentives and economic reforms in agriculture on income and gender inequality in Iran. Unlike Threshold Autoregressive (TAR) models, which rely on indicator functions to control regime switching, the STAR model uses logistic and exponential functions for this purpose. As noted by van Dijk and Teräsvirta (2002), these models are particularly suitable for analyzing asymmetric cycles in variables, and extensive empirical evidence shows that they effectively capture nonlinear dynamics and regime-switching mechanisms. The STAR model continuously specifies nonlinear relationships among variables through a transition variable and a slope parameter. The general STAR regression model is expressed as:

$$y_t = \pi' z_t + \theta' z_t F(s_t, \gamma, c) + u_t \quad (1)$$

where $z_t$is a vector of exogenous variables; $\pi$is the vector of linear parameters; $\theta$is the vector of nonlinear parameters; and $u_t$is the error term assumed to be independently and identically distributed with zero mean and constant variance. The transition function $F(s_t, \gamma, c)$may take either the logistic or exponential form:

$$F(s_t, \gamma, c) = \frac{1}{1+\exp\left[-\gamma(s_t - c)\right]} - \frac{1}{2} \quad (2)$$

$$F(s_t, \gamma, c) = 1 - \exp\left[-\gamma(s_t - c)^2\right] \quad (3)$$

In these expressions, $s_t$denotes the transition variable, γrepresents the slope parameter, and $c$is the threshold value determining the location of regime switching. As $\gamma \to \infty$, the STAR model converges to a TAR model such

that if $s_t > c$, then $F = 1$, and if $s_t < c$, then $F = 0$. Conversely, as $\gamma \to 0$, the STAR model collapses into a linear specification.

The estimation of the STAR model follows a sequential process. First, the optimal lag structure of the dynamic model is selected. Next, the presence of nonlinearity is tested, and based on these results, the appropriate transition variable and number of regime switches are determined. In the second step, the selected STAR model is estimated using the Newton–Raphson algorithm and the Maximum Likelihood method. Finally, a series of diagnostic tests are conducted to ensure the reliability and robustness of the estimated results.

Linearity Test, Selection of Transition Variable, and Model Type:

To examine whether the relationship among the model variables is linear or nonlinear, the null hypothesis assumes linearity, whereas the alternative hypotheses correspond to either a logistic STR model $(m = 1)$or an exponential STR model $(m = 2)$. The diagnostic test results reported in Table 1 indicate that the null hypothesis of linearity is rejected. Therefore, a nonlinear relationship exists between financial incentives and economic reforms in agriculture and income and gender inequality in Iran in the presence of agricultural product price threshold effects, necessitating the use of the STR methodology for parameter estimation.

Table 1. Linearity Test Results for the Income Inequality Model

Test	F Statistic	Significance Level (p-value)
Wald Test	4.369	0.000
Fisher Test	5.985	0.000
LRT Test	5.748	0.000

Table 2. Linearity Test Results for the Gender Inequality Model

Test	F Statistic	Significance Level (p-value)
Wald Test	6.365	0.000
Fisher Test	5.287	0.000
LRT Test	4.298	0.000

As shown by the test results reported in the above tables, the null hypothesis of linearity in the relationships among the variables is rejected; therefore, the possibility of a linear relationship between the variables is ruled out. It should also be noted that the proposed Smooth Transition Regression (STR) model, based on the selected transition variable, is identified as the optimal model for estimation. Accordingly, following González et al. (2005) and Colletaz and Hurlin (2006), the null hypothesis of the existence of an STR model with a single transition function was tested against the alternative hypothesis of an STR model with at least two transition functions. The results, presented in the following tables, indicate that the null hypothesis asserting the sufficiency of a single transition function is not rejected in both the one-threshold and two-threshold cases. Hence, a single transition function is adequate to capture the nonlinear behavior between financial incentives and economic reforms in agriculture and income and gender inequality in Iran, in the presence of agricultural product price threshold effects.

Table 3. Residual Nonlinearity Test (Income Inequality Model)

Threshold Case	Statistic	LR	LMf	LMw
Two thresholds (M = 2)	Value (p-value)	1.297 (0.802)	1.362 (0.751)	1.425 (0.675)
One threshold (M = 1)	Value (p-value)	1.432 (0.654)	1.471 (0.630)	1.352 (0.743)

H_0: r = 1; H_1: r = 2

Table 4. Residual Nonlinearity Test (Gender Inequality Model)

Threshold Case	Statistic	LR	LMf	LMw
Two thresholds (M = 2)	Value (p-value)	1.425 (0.489)	1.239 (0.532)	1.258 (0.521)
One threshold (M = 1)	Value (p-value)	1.236 (0.542)	1.116 (0.612)	1.012 (0.687)

H_0: r = 1; H_1: r = 2

After confirming the existence of nonlinear relationships and the adequacy of a single transition function, the optimal specification between one-threshold and two-threshold transition functions must be selected. Accordingly, STR models corresponding to both cases were estimated, and based on the criteria of Residual Sum of Squares, Schwarz Information Criterion, and Akaike Information Criterion, the STR model with one threshold was identified as the optimal specification. Therefore, a single-transition-function, single-threshold STR model is adopted to investigate the nonlinear behavior among the study variables.

Using the STR model with agricultural product prices as the transition variable, the nonlinear relationship between financial incentives and economic reforms in agriculture and income and gender inequality in Iran is estimated in the presence of agricultural product price threshold effects.

Table 5. Estimation Results of the STR Model

Panel A. Linear Component

Variable	Income Inequality Model: Coefficient	p-value	Gender Inequality Model: Coefficient	p-value
Constant	0.422933	0.0160	0.079188	0.0180
FAC	−0.317067	0.2031	−0.016711	0.0036
INV	−0.107792	0.0021	−0.263566	0.0518
AGRPRICE	−0.843308	0.0548	−0.445233	0.2208
L	−0.052690	0.0497	−0.091398	0.0050
POP	0.018904	0.2297	0.007003	0.0304
GDPper	−0.201989	0.0373	−0.010069	0.1505
EX	−0.225487	0.0206	−0.015605	0.0178
UNE	0.348929	0.4019	0.326509	0.0030
EDU	−0.598741	0.0022	−0.267740	0.2158
INF	0.657198	0.0449	0.421277	0.0230

Panel B. Nonlinear Component

Variable	Income Inequality Model: Coefficient	p-value	Gender Inequality Model: Coefficient	p-value
Constant	0.497126	0.0184	0.070218	0.0023
FAC	−0.336659	0.0135	−0.032497	0.0205
INV	−0.239137	0.0010	−0.259333	0.0082
AGRPRICE	−0.998008	0.0164	−0.463260	0.0216
L	−0.063792	0.0002	−0.134958	0.0137
POP	0.052776	0.3115	0.021669	0.2060
GDPper	−0.215493	0.0186	0.026130	0.0163
EX	−0.349741	0.0080	−0.061081	0.0027
UNE	0.340550	0.0107	0.224187	0.0011
EDU	−0.659187	0.0124	−0.459343	0.0182
INF	0.798428	0.0401	3.898570	0.0015
Threshold (c)	0.964102	0.0102	0.217254	0.0013
Slope Parameter (γ)	0.995632	0.0284	0.618469	0.0008

The estimation results of the nonlinear component of the income inequality model (Regime 1) indicate that the variables of government credit facilities to the agricultural sector, development expenditures in agriculture, agricultural product prices, labor force, GDP per capita, real exchange rate, and education level exert a negative effect on income inequality in Iran. Moreover, given that the computed p-values for all these variables are less than 0.05, their effects are statistically significant at the 5% significance level.

In the second model, where the response variable is gender inequality, the estimation results of the nonlinear component (Regime 2) reveal a positive relationship between unemployment rate and inflation rate with gender

inequality. In addition, financial incentives in the agricultural sector exhibit a negative and statistically significant effect on gender inequality at the 95% confidence level.

The comparison of coefficients across the two regimes is conducted based on the transition variable and its values, where the value of the transition variable determines the transition function and, consequently, the prevailing regime. In the above estimations, the transition variable is agricultural product prices, and the estimated threshold value for this variable equals 0.96 in the first model and 0.21 in the second model. Depending on the distance of agricultural product prices from these threshold values, the model follows two distinct extreme regimes. Comparing the model coefficients across the two regimes shows that when agricultural product prices cross the threshold values (0.96 and 0.21, respectively), representing a transition from the linear to the nonlinear regime, the responsiveness of income inequality and gender inequality to changes in these variables increases substantially. Accordingly, as financial incentives and economic reforms in the agricultural sector increase, their stronger reaction leads to a greater improvement in both income and gender inequality.

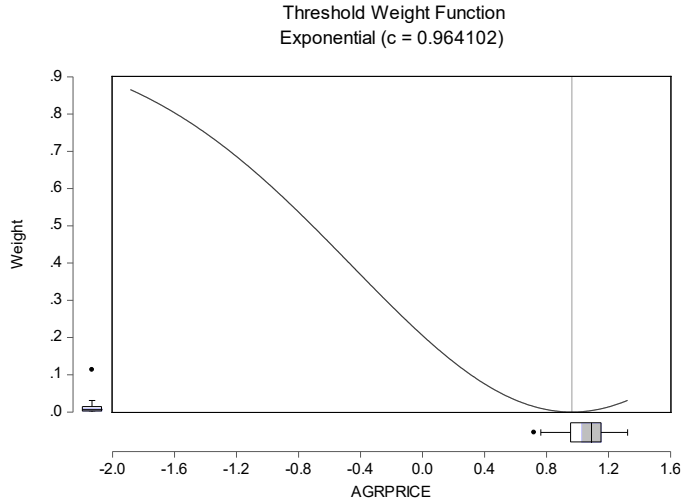

Figure 1. Relationship between the transition function and the agricultural product price transition variable in the income inequality model

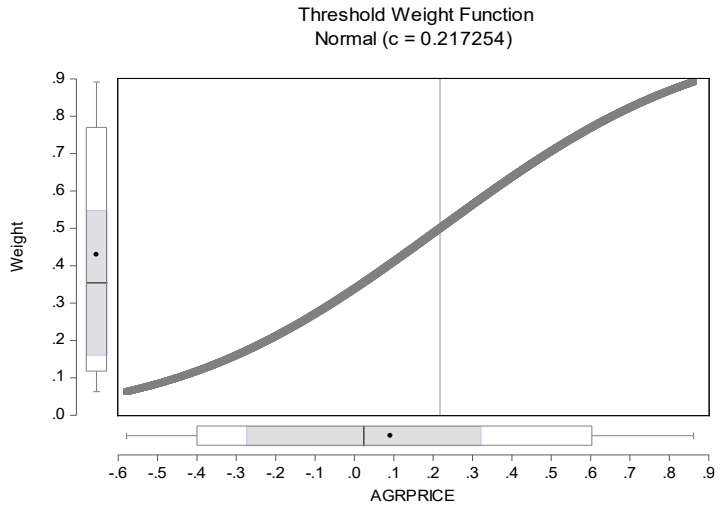

Figure 2. Relationship between the transition function and the agricultural product price transition variable in the gender inequality model.

In the present study, the Durbin–Watson test is employed to examine serial correlation. The results indicate the absence of autocorrelation among the error terms; therefore, the third classical assumption of no serial correlation is not violated. Consequently, the estimators possess the desired properties of minimum variance and efficiency.

Another classical assumption is homoscedasticity. In this study, the Breusch–Pagan–Godfrey test is used for this purpose.

Table 6. Heteroscedasticity Test Results for the Income Inequality Model

Test	F Statistic	p-value
Breusch–Pagan–Godfrey	1.568	0.526

Table 7. Heteroscedasticity Test Results for the Gender Inequality Model

Test	F Statistic	p-value
Breusch–Pagan–Godfrey	1.486	0.598

As shown in the tables, the test results confirm the absence of heteroscedasticity.

Another important criterion for evaluating the quality of the estimated model is the examination of coefficient stability across the two regimes. If the model is properly specified, the coefficients are expected to remain stable and unchanged when regimes shift.

Table 8. Smooth Transition Parameter Stability Test: Income Inequality Model

Null Hypothesis	F Statistic	p-value
$b_1 = b_2 = b_3 = b_4 = 0$	0.745	0.754
$b_1 = b_2 = b_3 = 0$	0.798	0.712
$b_1 = b_2 = 0$	0.821	0.695
$b_1 = 0$	0.836	0.674

Table 9. Smooth Transition Parameter Stability Test: Gender Inequality Model

Null Hypothesis	F Statistic	p-value
$b_1 = b_2 = b_3 = b_4 = 0$	1.236	0.653
$b_1 = b_2 = b_3 = 0$	1.326	0.574
$b_1 = b_2 = 0$	1.348	0.512
$b_1 = 0$	1.487	0.456

As evidenced in the tables, the coefficient stability tests indicate that the estimated coefficients do not change significantly across regimes, confirming the robustness of the model specification.

Discussion and Conclusion

The present study examined the nonlinear effects of financial incentives and economic reforms in the agricultural sector on income inequality and gender inequality in Iran under agricultural price threshold conditions. The results provide strong empirical evidence that agricultural policies and structural reforms do not exert uniform effects on inequality, but rather operate through regime-dependent mechanisms shaped by price dynamics and institutional conditions. These findings significantly enrich existing scholarship on agricultural development and inequality by demonstrating that policy effectiveness is conditional on economic regimes, reinforcing the necessity of nonlinear analytical frameworks in agricultural economics research.

The nonlinear estimation results reveal that in the income inequality model, government credit facilities, development expenditures in agriculture, agricultural product prices, labor force participation, GDP per capita, real

exchange rate, and education levels exert significant negative effects on income inequality. This indicates that well-designed financial incentives and structural reforms in agriculture can substantially reduce income disparities when implemented within appropriate economic regimes. These findings are consistent with evidence from Iran and comparable contexts demonstrating that agricultural subsector development and value-added expansion reduce rural income gaps by raising productivity and stabilizing farm incomes (2, 11, 12, 25). Moreover, the strong role of education and labor in reducing income inequality underscores the importance of human capital accumulation as a complement to agricultural reform, reinforcing prior conclusions that productivity growth alone is insufficient without parallel investments in human resources (13, 14).

The significant negative effect of agricultural product prices on income inequality within the nonlinear regime is particularly noteworthy. Rising agricultural prices, when coupled with adequate institutional support and financial access, enhance farm profitability and strengthen income distribution among rural households. This aligns with findings that price incentives, when transmitted effectively to producers, improve income equality by strengthening smallholder earnings (1, 3). However, this effect is conditional: the threshold behavior observed in the model indicates that only beyond specific price levels do these equalizing effects fully materialize. This reinforces global evidence that agricultural reforms generate inclusive growth only when structural bottlenecks are overcome and market participation becomes sufficiently broad (4, 5, 8).

The gender inequality model further illuminates the differentiated impacts of agricultural reforms. The positive association between unemployment and inflation with gender inequality indicates that macroeconomic instability disproportionately burdens women, particularly in rural labor markets where employment opportunities are more fragile and gender segmentation is pronounced. These findings resonate with cross-country evidence showing that economic shocks and labor market volatility tend to widen gender disparities unless targeted social protection mechanisms are in place (6, 9, 22). Conversely, financial incentives in agriculture demonstrate a significant negative effect on gender inequality, confirming that improved access to credit, infrastructure, and production resources enhances women's economic participation and income security. Similar outcomes have been documented in studies of land reform and agricultural investment programs, where gender-responsive financial policies substantially improve women's bargaining power and economic inclusion (5, 7, 18).

The observed threshold effects constitute one of the study's most important contributions. The transition variable—agricultural product prices—determines regime shifts that amplify the responsiveness of income and gender inequality to policy changes. Once prices exceed the estimated thresholds, the impact of financial incentives and reforms on inequality intensifies significantly. This implies that agricultural policy effectiveness is highly sensitive to market conditions and that reforms may appear ineffective or even regressive when implemented under unfavorable price regimes. These results provide empirical validation for theoretical arguments that agricultural transformation follows nonlinear development trajectories and that policy outcomes depend critically on economic context (17, 19, 20).

From a structural perspective, the study's findings confirm that agricultural reforms generate the strongest redistributive benefits when land governance, financial access, labor mobility, and market incentives operate in a coordinated manner. Land ownership security and land system reforms enhance investment incentives and productivity, thereby reinforcing income equalization when combined with financial support mechanisms (4, 8, 16). Furthermore, rural financial development and land management coordination strengthen the long-term sustainability of these outcomes by stabilizing income streams and reducing vulnerability to external shocks (23, 24).

The Iranian context provides a compelling illustration of these dynamics. Regional disparities in climate, infrastructure, and institutional quality have long constrained equitable agricultural development. The present results indicate that financial incentives and reforms can overcome these structural limitations, but only when macroeconomic stability and favorable price regimes are maintained. This finding is highly consistent with provincial-level studies demonstrating that agricultural value-added expansion and subsector diversification significantly reduce income inequality across Iranian regions (11, 15, 26). At the same time, persistent gender disparities highlight the necessity of explicitly integrating gender equity objectives into agricultural reform strategies, as gender-neutral policies alone are insufficient to dismantle deeply rooted structural inequalities (6, 18, 22).

Overall, the study's findings advance a more nuanced understanding of how agricultural policy operates as a distributive instrument. Rather than exerting linear and uniform effects, financial incentives and economic reforms interact with market conditions, institutional frameworks, and social structures in complex, nonlinear ways. Recognizing and accounting for these regime-dependent dynamics is therefore essential for designing effective and equitable agricultural development policies in Iran and comparable developing economies.

This study is subject to several limitations. First, the analysis relies on aggregate national-level data, which may conceal important regional and local variations in agricultural development and inequality dynamics. Second, the study does not explicitly model informal institutional factors such as social norms, land tenure practices, and cultural constraints that strongly influence gender inequality. Third, potential endogeneity between agricultural reforms and inequality outcomes may not be fully eliminated despite the nonlinear modeling framework.

Future studies should extend the analysis to provincial and household-level data in order to capture spatial heterogeneity and microeconomic mechanisms more precisely. Longitudinal case studies could provide deeper insights into the causal pathways linking agricultural reforms to inequality outcomes. In addition, future research should integrate environmental sustainability and climate resilience variables into nonlinear models to assess their joint effects on income and gender inequality.

Policy makers should design agricultural reforms with explicit attention to economic regimes and price conditions, ensuring that financial incentives are timed and targeted to maximize their distributive impact. Special emphasis should be placed on gender-responsive credit programs, education, and labor market integration. Strengthening rural institutions, stabilizing macroeconomic conditions, and improving access to markets will be essential for sustaining the inequality-reducing effects of agricultural development strategies.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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