

# ASSESSING THE IMPACT OF ECONOMIC CHANGES ON WHEAT PRODUCTION IN SAUDI ARABIA: AN APPLICATION OF THE INTERRUPTED TIME SERIES MODEL

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## ABSTRACT

This research examines how Policy 335, which reduced governmental subsidies for wheat cultivation, affected wheat production patterns in Saudi Arabia. The Interrupted Time Series (ITS) methodology was used to assess both the immediate and long-term effects of this policy from 1990 to 2023. The analysis shows an instant reduction in wheat output following policy enactment, although this effect was not statistically significant at the 5 % threshold. In subsequent years, a substantial long-term production decline was documented, with the reduction in governmental assistance identified as the principal driver of this downward trend. Additional economic variables, including producer pricing and pesticide expenditures, showed no meaningful impact on wheat output. In contrast, increased fertilizer utilization helped offset the policy's adverse effects, emphasizing the importance of resource optimization. The outcomes indicate that governmental assistance plays a vital role in maintaining stability in agricultural production. The evidence highlights the necessity for effective resource management and environmentally sustainable farming approaches, especially in resource-limited settings such as Saudi Arabia, to reduce dependence on wheat imports. Continuous assessment and flexible policy adjustments are essential for ensuring long-term viability and food security amid evolving economic and environmental conditions.

**Keywords:** Policy 335, fertilizer consumption, government support.

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## INTRODUCTION

Wheat (*Triticum aestivum* L.) has historically served as a fundamental component of Saudi Arabia's food security framework, with grain output totaling 1.75 million Mg in 2023, of which wheat constitutes a substantial share. Nevertheless, the nation faces difficulties in sustaining long-term wheat production independence due to the area's dry climate conditions, scarce water availability, and depletion of finite groundwater reserves. These obstacles, together with ongoing economic and environmental transformations, have progressively increased the country's dependence on wheat imports.

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By 2023, wheat imports represented 69 % of total agricultural imports, indicating a transition from a self-reliant producer to one of the globe's leading wheat-importing nations. This transformation mainly results from reduced governmental assistance for wheat cultivation, particularly emphasized by Policy No. 335, implemented in 2008, which gradually phased out domestic wheat farming. This policy, together with groundwater resource depletion, has fundamentally reshaped Saudi Arabia's wheat production environment.

The Interrupted Time Series (ITS) model has been widely used to assess the impact of policy changes and external shocks on agricultural production. Cariappa *et al.* (2022) highlighted the role of government interventions in mitigating the disruptions caused by external shocks such as the COVID-19 pandemic in India. While market disruptions were temporary, state interventions provided resilience. Similarly, Praveen *et al.* (2020) demonstrated the long-term effects of fertilizer policies in India, which mirrors the role of fertilizers in mitigating the impacts of Policy 335 in Saudi Arabia. These studies, together with Hyndman and Rostami-Tabar (2025), who addressed forecasting challenges during disruptions, provide a solid methodological foundation for examining the impact of Policy 335.

Alamri and Tyler (2018) determined that governmental policies directly affected Saudi Arabia's wheat supply and demand dynamics, with Resolution 335 notably decreasing production levels. Ghanem *et al.* (2018) examined the economic drawbacks of using desalinated water for agricultural irrigation, reinforcing the justification for reducing wheat cultivation to preserve water resources. Likewise, Alrwis *et al.* (2016) highlighted the extended consequences of diminished wheat production on food security, representing a vital issue for Saudi Arabia. Alamri and Al-Duwais (2019) projected that policies such as Resolution 335 heightened the nation's dependence on wheat imports, remarking on the necessity to reassess these policies for enhanced food security outcomes.

This study evaluates the impact of Policy 335 on Saudi wheat production dynamics by employing the ITS model to examine both immediate and long-term effects. The model allows for a comparison of pre- and post-policy periods, shedding light on the influence of reduced government support on wheat production trends. Additionally, the study considers regional production variations, sustainability challenges due to water scarcity, and the potential for policy adjustments in improving resource efficiency, particularly in sustainable agricultural practices.

Considering the escalating dependence on imports and mounting challenges from climate change and water scarcity, this study's findings are essential for Saudi Arabia's food security planning. The research evaluates the impact of Policy 335 on wheat production dynamics from 1990 to 2023, with the objective of assessing both immediate and long-term effects using the ITS model, analyzing the influence of economic and environmental variables such as fertilizer consumption, rainfall, and temperature, and providing policy implications to support sustainable wheat production, improve resource efficiency, and reduce reliance on imports. Additionally, the study contributes

to broader discussions on agricultural policy effectiveness in arid regions and offers guidance for strengthening food security in countries facing similar constraints.

## MATERIALS AND METHODS

This study employs a quantitative time-series design covering the period 1990–2023, utilizing secondary data collected from the General Authority for Statistics (GASTAT, 2025) of Saudi Arabia, the Food and Agriculture Organization of the United Nations (FAO, 2025), and the World Development Indicators (WDI) (World Bank, 2025). The dataset includes key annual variables relevant to wheat production, such as area harvested, total production, yield ( $\text{Mg ha}^{-1}$ ), producer prices, import prices, fertilizer consumption, pesticide use, average temperature, and total annual rainfall.

The main intervention variable is “Policy 335,” representing the government’s decision to phase out wheat production support starting in 2008. To capture the effect of this policy intervention, the data are structured into two distinct periods: the pre-policy phase (1990–2008) and the post-policy phase (2009–2023). This temporal segmentation allows the econometric model to isolate and measure both the immediate and sustained effects of the policy on wheat production dynamics in Saudi Arabia.

### Experimental design

The study utilizes an Interrupted Time Series (ITS) design to analyze the impact of Policy 335 on wheat production. The ITS model is well-suited for national-level data, particularly when regional control groups are unavailable, as it compares production trends before and after the policy intervention while controlling for covariates. The model incorporates three components: the baseline trend, which reflects the pre-policy trajectory of wheat production and represents the counterfactual scenario without policy change; the immediate effect, which denotes a discrete shift in production levels following the introduction of Policy 335; and the post-policy trend, which captures long-term changes in production patterns after the policy.

The ITS model is expressed as:

$$Y_{it} = \alpha + \beta_1 \text{Time}_t + \beta_2 \text{Post}_t + \beta_3 (\text{Time}_t \times \text{Post}_t) + \gamma X_t + \epsilon_{it}$$

where  $Y_{it}$  represents wheat production at time  $t$ ,  $\text{Time}_t$  is the continuous variable representing the year,  $\text{Post}_t$  is the binary indicator for the post-policy period (1 if  $t \geq 2009$ , 0 otherwise),  $\text{Time}_t \times \text{Post}_t$  is the interaction term capturing changes in the production trend post-policy,  $X_t$  is control variables (e.g., producer prices, rainfall, temperature), and  $\epsilon$  is the error term. The econometric model incorporates covariates such as producer prices, import prices, pesticide use, and climatic variables to account for potential confounding factors.

Conceptually, the ITS framework used in this study is equivalent to a piecewise linear regression model, where the year 2008 serves as a structural break or “knot.” This

specification allows separate estimation of pre- and post-policy slopes and intercepts, thereby capturing both the immediate level shift and the long-term trend change associated with the policy intervention.

### Advanced analyses

In addition to the baseline analysis, several advanced analyses were conducted to improve the robustness and depth of the findings:

**Interaction examination.** Potential relationships among critical variables, including producer pricing, pesticide application, and climate conditions (such as precipitation and temperature), were investigated to determine whether policy effects on wheat production differ based on these elements.

**Temporal period assessment.** The data were segmented into shorter timeframes (such as five-year intervals), both preceding and following policy implementation. This methodology enables the detection of delayed policy consequences on wheat production and helps determine whether the policy's influence changes over time.

**Price impact evaluation.** The research additionally examines whether wheat price variations, especially following policy intervention, correlate with production level changes, thereby assessing the wider economic environment and its influence on wheat production patterns.

**Validation and sensitivity testing.** To guarantee result reliability and accuracy, validation procedures were conducted, including assessments for autocorrelation, heteroscedasticity, and model design. Sensitivity evaluations examined delayed policy effects and the influence of exceptional years, such as determining whether severe weather conditions or market irregularities (like global price spikes) affected production trends and policy consequences.

**Agricultural sustainability assessment.** The study extends its examination to encompass a long-term sustainability evaluation of wheat cultivation in Saudi Arabia, accounting for environmental modifications (including decreased precipitation and rising temperatures) and analyzing whether policy modifications can address these challenges.

### Statistical procedures

The study employs non-parametric statistics where necessary, particularly for robustness checks in the presence of non-normality in the residuals. In addition, to account for autocorrelation and heteroscedasticity, Newey-West standard errors were used to adjust the coefficients and provide more reliable estimates. In cases of temporal dependence, Autoregressive Integrated Moving Average (ARIMA) models were applied to model the time-series data more accurately and address any autocorrelation issues. The software used for data analysis includes R (version 4.0 or

later), with the “auto.arima” function from the forecast package, and the “lmtest” and “sandwich” packages for regression analysis and heteroscedasticity adjustments. All tests were conducted at a significance level of 5 %.

## RESULTS AND DISCUSSION

The findings from this research offer significant perspectives on Saudi Arabia’s wheat production across both immediate and extended timeframes, explaining how Policy 335 resulted in a considerable reduction in wheat output. This outcome aligns with earlier studies, which emphasized how external disruptions generated disturbances in agricultural production (Cariappa *et al.*, 2022). Likewise, policy-driven interruptions can produce enduring effects, with the decrease in production persisting over an extended period and reflecting a fundamental transformation in the nation’s wheat production framework.

The post-policy impact variable in the ITS model indicated an immediate reduction in production following the policy change, with a coefficient of -531 283 (Table 1).

**Table 1.** Estimates and significance of key variables assessing wheat production analysis in Saudi Arabia using Interrupted Time Series (ITS), Autoregressive Integrated Moving Average (ARIMA), and Newey-West adjusted models.

Variable	ITS model estimate (in thousands)	ITS model standard error (in thousands)	ARIMA model estimate (in thousands)	ARIMA model standard error (in thousands)	Newey-West model estimate (in thousand)	Newey-West model standard error (in thousands)	p-value (Newey-West)
Intercept	-29.61	49.63	3.01	0.60	-20.53	41.74	0.63
Time (years)	-	-	-	-	9.68	20.69	0.64
Post-policy impact	-531.28	358.05	-	-	-536.53	324.47	0.11
Post-policy trend	-211.66	63.24	-	-	-202.60	73.96	<0.01 *
Producer price (USD Mg <sup>-1</sup> )	1.60	1.23	-1.04	0.82	1.53	1.95	0.44
Pesticide import price (USD Mg <sup>-1</sup> )	60.73	127.82	-162.56	66.21	65.05	76.72	0.40
Fertilizer consumption (kg ha <sup>-1</sup> )	28.31	5.32	-	-	27.99	5.91	<0.01 *
R-squared	-	-	-	-	0.90	-	-
Adjusted R-squared	-	-	-	-	0.88	-	-
Akaike information criterion (AIC)	-	-	968.96	-	937.8	-	-
Bayesian information criterion (BIC)	-	-	978.12	-	968.96	-	-
Log-likelihood	-478.48	-	-	-	-	-	-

\*Significant variables ( $p < 0.05$ ).

Although this decline was not statistically significant at the 5 % level ( $p = 0.11$ ), it remains noteworthy and aligns with Mulwa *et al.* (2025), who observed that agricultural policy shifts often lead to immediate production drops. Despite the lack of statistical significance, the reduction in wheat output immediately after the policy is consistent with literature showing that abrupt policy changes tend to disrupt agricultural sectors, particularly wheat production, which is highly sensitive to such interventions. Overall, the results indicate that the policy triggered an immediate downturn in wheat production.

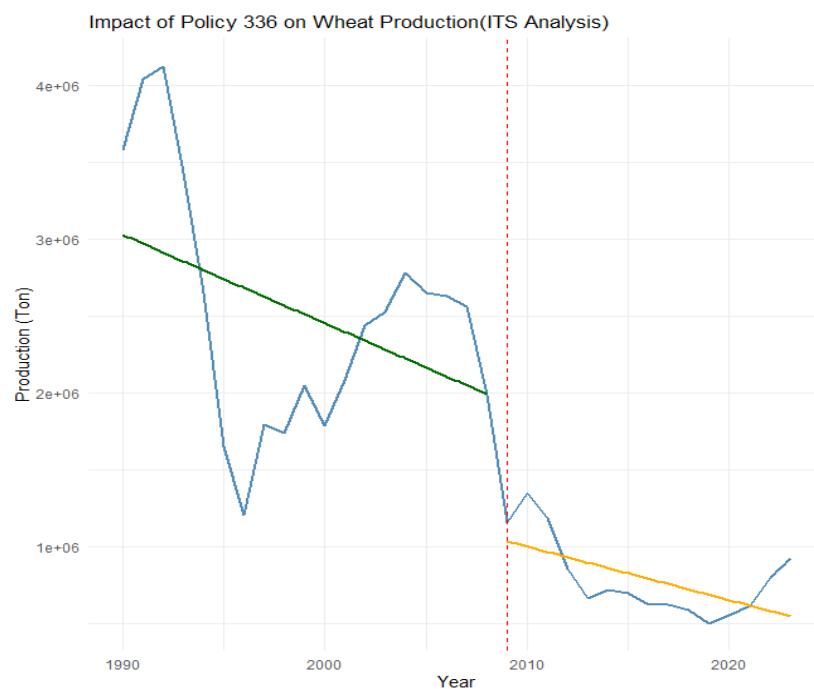
After the initial decline, the post-policy trend revealed a significant and sustained long-term reduction in wheat production, with a coefficient of -211 664 ( $p = <0.01$ ), confirming that the policy's effects persisted over time. This pattern aligns with Plewis (2019), who found that agricultural policy changes frequently lead to long-lasting structural shifts after early disruptions. In Saudi Arabia's case, the continued decrease in production following Policy 335 demonstrates the enduring consequences of reduced governmental support, reinforcing the findings of Chitikela *et al.* (2025), who showed that policy interventions commonly reshape agricultural output trajectories. These results highlight that, although the immediate impact was not statistically significant, the long-term effects were substantial and indicative of a structural shift in wheat production trends.

In contrast, the fertilizer consumption variable showed a statistically significant positive effect on wheat production (coefficient = 28 308,  $p = <0.01$ ), indicating that increased fertilizer use played a critical role in mitigating the negative impacts of the policy shift. This significant positive relationship confirms the importance of fertilizers in sustaining agricultural productivity even when government support is reduced. The finding aligns with Praveen *et al.* (2020), who reported that greater fertilizer use in India helped offset the adverse effects of declining subsidies and enhanced overall productivity. Similarly, in Saudi Arabia, the expanded reliance on fertilizers appears to have supported wheat production despite diminished governmental assistance, underscoring the relevance of resource inputs during periods of policy transition.

External factors such as producer price, pesticide import price, and annual mean precipitation did not show significant effects on wheat production, indicating that these variables did not meaningfully influence output during the study period. This finding aligns with Kumar *et al.* (2024), who noted that when major policy changes occur, their influence on agricultural production can outweigh the effects of other economic variables. In this case, the policy shift had a more pronounced impact on wheat production, a conclusion supported by the model's strong performance, with an R-squared of 0.9 and an adjusted R-squared of 0.88. The complete model demonstrates robust explanatory power, accounting for a substantial proportion of the variation in wheat production, and the F-statistic of 35.14 and a  $p$ -value of  $1.108 \times 10^{-11}$  confirm its overall statistical significance.

The visual representation of the results, which shows a clear shift in the production trend before and after the policy change, provides additional support for the conclusions

derived from the statistical analysis (Figure 1). The marked change in the production slope in 2009 remarks that Policy 335 produced both an immediate and sustained impact on wheat production in Saudi Arabia. This graphical depiction, contrasting pre- and post-policy trends, strengthens the hypothesis that policy adjustments can generate significant changes in agricultural production, aligning with the findings reported by Praveen *et al.* (2020) and Chitikela *et al.* (2025) on the long-term effects of policies.



**Figure 1.** Shift in wheat production following Policy 335 in Saudi Arabia (Interrupted Time Series analysis).

In summary, the findings confirm that the reduction of governmental support for wheat cultivation under Policy 335 had immediate and sustained negative effects on wheat production. This aligns with Mulwa *et al.* (2025) and Cariappa *et al.* (2022), who found that major policy shifts can destabilize agricultural systems. This shows the importance of maintaining governmental support to ensure long-term stability and productivity in the sector. Furthermore, the beneficial impact of fertilizers in offsetting the policy transition's negative consequences emphasizes the significance of optimizing resource utilization and implementing environmentally sustainable farming methods.

These results carry substantial policy ramifications for Saudi Arabia, where constraints such as water scarcity and climate change increasingly threaten wheat production.

Improving resource efficiency, particularly through optimized fertilizer use, and adopting sustainable agricultural practices could help reduce dependence on wheat imports. This study contributes to the broader discussion on agricultural policy in resource-limited contexts by offering insights for policymakers seeking to strengthen food security and mitigate the long-term effects of policy shifts on production. Future research should examine regional variability and climate-related pressures to develop a more comprehensive understanding of the enduring impacts of policy changes on wheat cultivation.

### CONCLUSIONS

This study found that Policy 335 had a significant impact on wheat production in Saudi Arabia, resulting in both immediate and long-term declines due to reduced government support. Increased fertilizer consumption helped to mitigate some of these negative effects, highlighting its critical role in maintaining productivity during policy transitions. Variables such as producer prices, pesticide costs, and annual mean precipitation had no significant influence, indicating that the policy shift was the primary cause of changes in wheat output.

Overall, the findings emphasize the importance of government support in stabilizing agricultural systems, particularly in resource-constrained settings like Saudi Arabia. Because long-term effects of policy changes tend to outweigh short-term disruptions, targeted assistance for strategic crops, efficient fertilizer use, and adaptive strategies addressing water scarcity and climate stress are recommended. These measures are vital for strengthening food security and improving the resilience of the country's agricultural sector.

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