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Economic Benefits of the Sugar Industry Zoning Policy of Pakistan

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Abstract

Zoning policy was best implemented, and it provided credit and input subsidies to farmers to increase seed variety, efficient use of chemical fertilizer, install tube wells, adoption of modern technology, and improve road infrastructure. The objective of this paper is to examine the benefits of zoning policy for the sugar industry. The paper uses data from 1951 to 2019 and has broken down the time series for Zoning and De-zoning Policy. The study uses Auto Regressive Distribution Lag Model (ARDL) cointegration and Error-Correction Model (ECM) model and Granger Causality Wald Test. Results found that Auto Regressive Distribution Lag Model (ARDL) bound test and Error-Correction model have established long-term cointegration association among fertilizer growth, irrigation land growth, transport growth, labor growth, technological growth, maximum temperature, mean temperature, minimum temperature, and rainfall and sugarcane yield. Results also found bi-directional causality the above variables within zoning policy and these results prove that zoning policy was better implemented, and farmers were supported by subsidized seed-fertilizer-water package, adopted labor-intensive technology and better-mechanized farming to increase irrigated land productivity. Climate change impact was also present and changing temperature and rainfall had a direct impact on sugarcane yield. Hence, the government should revive the zoning policy and reduce the role of middlemen, improve roads to reduce transportation costs, and improve the price mechanism of the sugar industry.

Introduction

The sugar industry is Pakistan's second largest industry after textiles, and the country ranks fifth in sugarcane production of the world, with 88.65 tonnes produced in the year 2021. Brazil is one of the world’s leading sugarcane producer, with the production of 715.65 tonnes, followed by India, and China, with 405.40 tonnes and 214.52 tonnes, respectively. Pakistan's sugarcane yield is 70.34 tonnes per hectare, which is lower than the global sugarcane yield of 71.55 tonnes per hectare (FAO, 2021) . The reason for declining sugarcane yield is sugar mills pay sugarcane prices lower than the minimum support price. In addition, delays in crushing season, waiting of growers in a long queue to purchase sugarcane, and delaying payments are other reasons to reduce sugarcane production. Landlords also play a significant role in price manipulation by gaining access to government institutes on behalf of producers and sugar mills (Khushk et al., 2011).

The zoning policy was introduced in the early 1960s and each firm was assigned a zone or territory to purchase sugarcane at a certain proportion of cane demand. The government and sugar mills also offered credit support to sugarcane growers to improve the quality of sugarcane varieties, fertilizer, irrigation (canal and tube wells), electricity, diesel, drilling services, free pump sets, and pesticides (Khushk, 2010; Pirzada et al., 2022; Qureshi & Afghan, 2005)

The government also fixed the minimum support price of sugarcane on the other hand they also tried to restrict middlemen to enter the sugarcane markets. Therefore, these kinds of policies help for increasing the irrigation area from 10 to 19 million hectares between 1960 and 2005. The installation of tube wells also increased from 10000 to 0.8 million from 1960 to 2006(Zhang et al., 2021). The technological change was also quite impressive in the 1960s and 1970s and as a result, sugarcane yield showed quite good performance in these decades (see Figure 1). The production capacity of sugar also increased along with the high d prices of sugar in the domestic market, sanctioning, and credit policies coupled with protection provided to domestic sugar production by import substitution policy till the 1980s. In 1981, the government offered a quality premium to increase sucrose content and if the sugarcane sucrose rate exceeded 8.3 percent in Khyber Pakhtunkhwa (KP), 8.5 percent in the Punjab, and 8.7 percent in the Sindh, growers received Rs. 0.14 per maund (equivalent to 37.35 kg) per each 0.1 percent from exceeded amount. The Sindh province profited from this program since it surpassed the state's authorized sucrose recovery rate. This policy supported the agriculture sector and agriculture growth was surpassed by 5 percent and it declined income distribution and poverty (Aslam, 2016; Lodhi et al., 1988; Qureshi & Afghan, 2005). During this regime, the application of fertilizer had a positive impact on sugarcane output with the support of irrigation land, transportation, labor growth, tube well, and technology. Road infrastructure also reduced transportation costs to reach sugar mills and markets from farm gates. In addition to it, temperature and rainfall also positively affected sugarcane yield, fertilizer, and irrigation growth (see Figure 1).

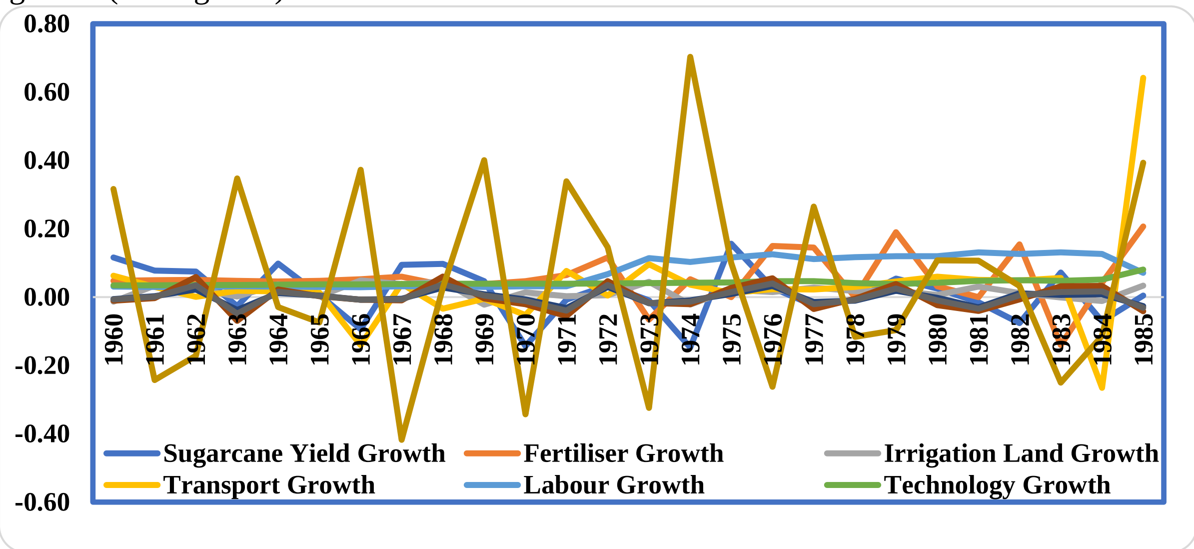

Figure 1: Growth Rates during Zoning Policy

Note: Adapted from "50 Years of Pakistan," and "Labour Force Survey of Pakistan," (https://www.pbs.gov.pk/), (https://www.pbs.gov.pk/labour-force-publications).

Following de-zoning in 1986, sugar mills purchase sugarcane by accessing other sugar-mill regions. Farmers also are compelled to sell sugarcane at lower prices than the minimum support price, partly because of high transportation costs and partly because of supply-side pressure during the bumper crop. In addition, the quality premium does not improve sugarcane quality and the government do not also provide subsidy and a variety of sugarcane to small growers, hence, growers bear increasing high input cost (Khushk, 2010; Lodhi et al., 1988). The fertilizer growth and irrigation had a positive impact on sugarcane yield during these periods and technology also had a positive impact on sugarcane yield (see Figure 2).

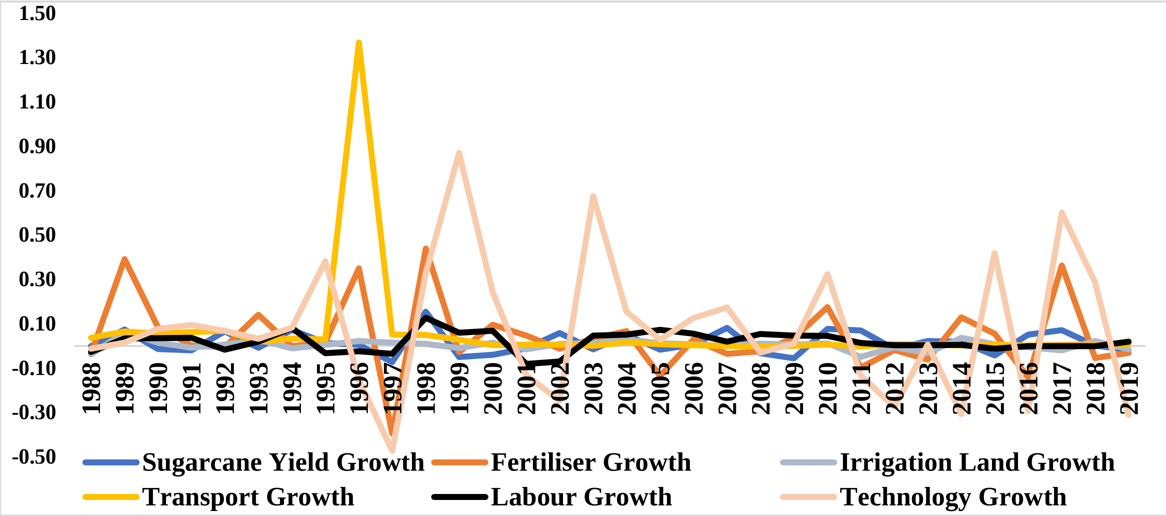

Figure 2: Growth Rates during Zoning Policy

Note: Adapted from "50 Years of Pakistan," Pakistan Statistical Yearbook, and "Labour Force Survey of Pakistan,"(https://www.pbs.gov.pk), (https://www.pbs.gov.pk/labour-force-publications).

Climate has also affected sugarcane production and irregular rainfall and rising temperature, over the last 20 years, have shrunk the sugar industry season from 6 months to 3-4 months (Hussain et. al., 2006)

The current article explores the benefits of zoning policy for sugarcane producers and sugar mills. It examines the characteristics of variables that have the greatest impact on sugarcane output and compares them to de-zoning policies. As per the authors' best knowledge, there are few studies have attempted to analyze the benefits of zoning policy for sugarcane production. Therefore, the authors tried to incorporate both zoning and de-zoning elements in this study to contribute to the literature. The remainder of this paper is organized as follows: The review of the literature is presented in section 2. section 3 introduces methodology, section 4 describes the findings, and section 5 and 6 explain the discussion and conclude results.

Research Questions

The research questions of the study are:

- Does the zoning policy benefit both sugarcane growers and sugar mills and overcome the crises of the sugar industry as compared to the dezoning policy?
- What economic and environmental factors have the short-run and the long-run impact on better sugarcane yield in both policies?

Hypothesis

The main hypothesis of the paper is as under:

H_1: Sugarcane yield has a positive association with economic and environmental variables in the short-run and the long-run under zoning policy in the sugar industry

H_2: There is a causality relationship between economic and environmental variables with the sugarcane yield under zoning policy in the sugar industry

Review of the Literature

Agriculture in Pakistan employs, directly and indirectly, 67% of the rural population and supplies raw materials to enterprises Sugarcane is an important cash crop in Pakistan and it offers employment and revenue to rural inhabitants(Ahmad et al., 2022)

Farmers face significant input costs for sugarcane production and do not get subsidies to overcome this (Qureshi & Afghan, 2005). Thailand has addressed this issue by establishing contract farming systems in which growers receive input subsidies for production services, credit aid, technology, skills, and a guarantee and fixed payment from sugar mills depending on the sucrose rate. Sugarcane output is therefore boosted by 71.8-82 percent with irrigation, effective fertilizer application, and timely transportation of sugarcane from farm gate to sugar mills (Manivong & Bourgois, 2018; Martiniello, 2021; Tukaew et al., 2016). On the other hand, sugarcane yield fluctuates in countries that do not implement contract farming policies and growers of these countries face high costs of inputs, delaying payment, lack of training facilities to cultivate sugarcane, adoption of the latest technology, and late harvesting. They also deal challenges of bugs, pests, diseases, shortage of clean seeds, and sugar mills' noncooperation (Bee & Rahman, 2020; Dlamini et al., 2010; Vishwakarma et al., 2021; Zulu et al., 2019).

During the zoning policy, the government supported the sugar industry by raising sugarcane prices relative to other crops and local sugar prices relative to imported sugar, and afterward, placed an import regulatory tariff on sugar. As a result, sugarcane output rose by more than 4% every year over the previous 40 years (Lodhi et al., 1988). But sugar mills did not follow fully the government's regularity of zoning policy and these mills get sugarcane at minimum support price in sugarcane zoning area and paid premium price outside the zone(Lodhi et al., 1988; Pirzada et al., 2022) Furthermore, sugar mills provide transport subsidies to growers who bring sugarcane from far away sugar mills, and their sugarcane price is paid more instantly than growers who are nearby these mills' factories. Subsidies were also required for high-quality sugarcane to recover sucrose content and high yield of sugarcane, in order to build a long-term solution for crop availability (Ahmad et al., 2022a; Khushk et al., 2011; Rehman et al., 2015)

After the dezoning policy, the majority of sugar mills have stopped providing subsidies for growers to improve the quality of inputs, and middlemen have now entered to supply credit facilities to growers on high charges (Khushk, 2010) and there is a huge gap between the potential and actual sugarcane production because of the high cost of land preparation, inputs, application of inputs at the wrong time, shortage of water and land usage, and insufficient information about insect pest and weed management, labor, lack of appropriate technology, inappropriate transportation infrastructure. Farmers also face payment delays, illegal deduction of cane weight, and low price of the product than the cost of production per maund, low sucrose content due to pest attacks, long waits to supply sugarcane, low rainfall, soil erosion, and lack of scientific knowledge (Habib et al., 2014; Nazir et al., 2013). Transportation cost has also increased, and it varied between the range of Rs.250 to Rs.262.5 per tonne during 2007-08. It also maintains sugar mills' monopsony power near the factories (Khushk et al., 2011; Rehman et al., 2015).

Pakistan also faces agronomic, irrigation management, environmental, technical, institutional, and socioeconomic constraints for sugarcane production (Aslam, 2016). Sugarcane growers and agriculture experts, in the Sindh province, also rely on finance to deal with varying temperature, climate change, water shortage, and input costs (Aslam, 2016; Ahmad et al., 2022; Qureshi & Afghan, 2005; Raza et al., 2021). This crop should be based on import substitution to make it competitive in the international market to reduce hurdles to improve the sugar industry (Hussain et al., 2006)

The impact of these policies, in the short run and the long run, can be gauged by the Ordinary Least Square (OLS) method. This technique stated that the dependent and independent variables should be cointegrated on Level or I(0) or the first difference I(1) (Rehman, F. U. et al., 2011; Zulu et al., 2019). But this OLS technique becomes a biased estimator in the presence of autocorrelation, and heteroskedasticity and cannot hold Classical Linear Regression Model (CLRM) assumptions. This OLS method also cannot be applied when dependent and independent variables show mixed cointegration I(0) and I(1) (Granger & Newbold, 1974; Pesaran et al., 2001). Hence, the best model is to employ the Autoregressive Distributed Lag (ARDL) bound test model to estimate the short-run and the long-run relationship between dependent and independent variables, having mixed cointegration I(0) and I(1) (Ali et al., 2021; Nkoro & Uko, 2016; Pesaran et al., 2001; Pesaran & Shin, 1995).

Methodology

The study employs Autoregressive Distributed Lag (ARDL) model to establish the long-run and short-run association between dependent and independent variables because it expects mixed cointegration, I(0) and I(1), among these variables (Cho et al., 2021; Pesaran et al., 2001). ARDL method requires two stages. In the first stage, the F-test will determine the long-run relationship between variables. In the second stage, long-run coefficients will be evaluated, and then the short-run elasticity of the variables to converge toward equilibrium (Asumadu-Sarkodie & Owusu, 2016). The ARDL Error-Correction Model (ECM) is also evaluated to establish the speed of adjustment towards long-run equilibrium (Pesaran et al., 2001).

The ARDL bound test identifies the long-run relationship between variables, but it does not suggest causality direction. Therefore, for this purpose, we use the Granger Causality Wald Test to establish causal associations among variables. The study also tests Augmented Dickey Fuller (ADF) for stationarity, and White heteroscedasticity (ARCH) Lagrange Multiplier (LM) test (F-statistics.), Jarque and Bera test of normality (χ^2), and Breusch-Godfrey Serial Correlation LM test for heteroskedasticity and autocorrelation problem and normality of distribution. It also performs parameters stability test using Cumulative Sum of Squares (Cusum) and Recursive Cumulative Sum of Squares (Brown et al., 1975).

Data

The research collects and uses the annual secondary source of data from 1951 to 2019 (see Table 1). The time series has broken into two policies or data sets 1) the Zoning Policy, which started in the Ayub Khan era from 1960-1986[1], and 2) the de-zoning Policy or Post-Zoning Policy, 1987-2019. Data is z analyzed using Stata.

[1] The Zoning Policy starting after Ex-President the Ayub Khan took government. He initiated the Second Five-Year Plan during 1960-1965. The Sugarcane Research Development Board (SRDB), Punjab Province, suggested that the Zoning Policy was started before the year of 1960 but for simplicity and to maintain time-series problems, the study is taking 1960 year as start of the Zoning Policy.

Table 1: Data Description of Dependent and Independent Variables

Variables	Unit	Symbol	Definition/ Construction	Source of Data
Sugarcane Yield	Tonnes/Acre	SY	Sugarcane production is divided by the Area of the Sugarcane	50 years of Pakistan, Pakistan Statistical yearbook
Fertilizer	000 nutrient tonnes	FERT	A chemical or natural substance added to soil or land to increase its fertility	50 years of Pakistan, Pakistan Statistical yearbook, Pakistan Statistical yearbook
Irrigation Land	Million Acres	IRLA	To irrigate land means to supply it with water in order to help crops grow	50 years of Pakistan, Pakistan Statistical yearbook,
Transport	000 Kilometers	TRANS	The road has been taken as a proxy of transport and as a means of government intervention for the Zoning Policy	50 years of Pakistan, Pakistan Statistical yearbook
Labor	Million	LAB	Manpower to produce the crop	Labor Force Survey of Pakistan
Technology	000 tractors	TECH	Technology is the application of scientific knowledge for practical purposes, especially in industry. Tractor has taken as a proxy for technology	50 years of Pakistan, Pakistan Statistical yearbook
Temperature	Max Degree Centigrade	MAX	The maximum temperature is the highest temperature at a place in each time period.	50 years of Pakistan, Pakistan Statistical yearbook
	Min Degree Centigrade	MIN	The minimum temperature is the highest temperature at a place in each time period.	50 years of Pakistan, Pakistan Statistical yearbook
	Mean Degree Centigrade	MEAN	The mean temperature is the Average temperature at a place in each time period.	50 years of Pakistan, Pakistan Statistical yearbook
Rainfall(mm)	Millimeter	RAIN	Rainfall is falling within a given area in each time.	50 years of Pakistan, Pakistan Statistical yearbook

Results

For Zoning Policy

The ADF test shows that variables have mixed cointegration and are stationary at I(0) and I(1) levels (see Table 2). Hence, the study estimates the ARDL model and its equation is as under:

$$\Delta SY_t = \propto_0 + \delta_1 SY_{t-i} + \delta_2 \mathrm{Ln}(\mathrm{FERT})_{t-1} + \delta_3 \mathrm{Ln}(\mathrm{IRLA})_{t-1} + \delta_4 \mathrm{Ln}(\mathrm{TRANS})_{t-1} + \delta_5 \mathrm{Ln}(\mathrm{LAB})_{t-1} + \delta_6 \mathrm{Ln}(TECH)_{t-1} + \delta_7 \mathrm{MAX}_{t-1} + \delta_8 MIN_{t-1} + \delta_9 MEAN_{t-1} + \delta_{10} RAIN_{t-1} + \sum_{i=1}^{n} \beta_{1i} \Delta SY_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta \mathrm{Ln}(\mathrm{FERT})_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta Ln(\mathrm{IRLA})_{t-i} +$$

$\sum_{i=0}^{n} \beta_{4i}\, \Delta Ln(\text{TRANS})_{t-i} + \sum_{i=0}^{n} \beta_{5i}\, \Delta Ln(\text{LAB})_{t-i} + \sum_{i=0}^{n} \beta_{6i}\, \Delta Ln(\text{TECH})_{t-i} +$
$\sum_{i=0}^{n} \beta_{7i}\, \Delta MAX_{t-i} + \sum_{i=0}^{n} \beta_{8i}\, \Delta MIN_{t-i} + \sum_{i=0}^{n} \beta_{9i}\, \Delta MEAN_{t-i} + \sum_{i=0}^{n} \beta_{10i}\, \Delta RAIN_{t-i} + \varepsilon_{1t} \ldots (1)$

Table 2: Unit Root Test – Augmented Dickey Fuller Test with Intercept

Variable	T-statistic	1% Critical Value	5% Critical Value	10% Critical Value	Probability
SY	-3. 843	-3.743	-2.997	-2.629	0.0025**
Ln(FERT)	-3.374	-4.371	-3.596	-3.238	0.0549*
Ln(IRLA)	-6.567	-3.750	-3.000	-2.630	0.0000*
Ln(TRANS)	-8.511	-3.750	-3.000	-2.630	0.0000***
Ln(LAB)	-2.813	-3.750	-3.000	2.630	0.0564*
Ln(TECH)	-2.950	-3.750	-3.000	-2.630	0.0399**
MAX	-4.853	-3.743	-2.997	-2.629	0.0000***
MIN	-4.644	-3.743	-2.997	-2.629	0.0001***
MEAN	-4.815	-3.743	-2.997	-2.629	0.0001***
RAIN	-4.783	-3.743	-2.997	-2.629	0.0001***

Note. *p<0.1. **p<0.05. ***p<0.01.

Descriptive Statistics indicates that the average Sugarcane Yield, during this policy, was 14.58 tonnes per acre and fertilizer grew by 407 percent while irrigation land and transportation improved by 2 percent and 3 percent, respectively. Labor and technology growth improved by 0.2 percent. The average maximum temperature should be between 19.71 degree centigrade to 27.99 percent degree centigrade. Similarly, rainfall was between 200.29 to 389.10 millimeters (see Table 3).

Table 3: Descriptive Statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
SY	14.58	1.29	10.88	17.21
Ln(FERT)	4.07	0.42	3.43	4.79
Ln(IRLA)	0.02	0.02	-0.02	0.05
Ln(TRANS)	0.03	0.12	-0.31	0.49
Ln(LAB)	0.002	0.02	-0.06	0.04
Ln(TECH)	0.002	0.01	-0.01	0.03
MAX	27.33	0.37	26.8	27.99
MIN	13.24	0.34	12.66	13.82
MEAN	20.26	0.34	19.71	20.88
RAINFALL	293.50	55.04	200.29	389.10

Diagnostic Test

The study performs diagnostic tests to determine heteroskedastic, Autocorrelation, and normality in the model. The White Heteroscedasticity LM test shows there is no heteroskedastic problem (χ^2 = 25.00, p-value = 0.4058), and the Breusch-Godfrey LM test shows no serial correlation problem in the model (χ^2 = 8.529, p-value = 0.203), at 5% level of significance, the Jarque-Bera normality test suggests variables are normally distributed (χ^2 = 1.188, p-value = 0.552).

ARDL Model

ARDL model (2 0 0 1 0 0 0) lags are selected based on Akaike Information Criteria (AIC). Results show that at 10% level of significance, the F-test value is 2.68 with a probability value of 0.0612. Hence there is cointegration between dependent and independent variables by rejecting the null hypothesis of no cointegration (see Table 4).

Table 4: ARDL Cointegration Test

Variable	Coefficient	Std. Error	t-statistic	Prob.
SY(-1)	0.17	0.19	0.87	0.41
SY(-2)	0.17	0.18	0.95	0.36
Ln(FERT)	-2.05	4.06	-0.51	0.62
Ln(FERT)(-1)	5.69	3.33	1.71	0.12
Ln(FERT)(-2)	-3.42	5.15	-0.66	0.52
Ln(IRLA)	-5.01	13.63	-0.37	0.72
Ln(TRANS)	-0.06	2.90	-0.02	0.98
Ln(TRANS)(-1)	-5.66	3.76	-1.51	0.16
Ln(LAB)	14.78	11.89	1.24	0.24
Ln(TECH)	-4.38	44.55	-0.10	0.92
MAX	78.88	29.82	2.64	0.03**
MIN	78.62	29.09	2.70	0.02**
MEAN	-156.44	59.15	-2.64	0.03**
RAIN	-0.0001	0.004	-0.03	0.98
RAIN(-1)	-0.001	0.004	-0.28	0.79
C	-14.79	32.24	-0.46	0.66
Adjusted R^2	**Root MSE**	**F-Statistic**		**Prob(F-statistic)**
0.4949	0.6852	2.68		0.0612

Note. **p<0.05.

The short-run and the long-run association between dependent and independent variables are estimated by performing the bound test and the ECM model. At 1% level of significance, the F-statistic estimated value is 4.209 which is above than upper critical value I(1) 3.97 (see Table 5). Hence, we accept there is a long-run relationship between variables by rejecting the null hypothesis. Now, we calculate ECM as shown in equation (2):

$$\Delta SY_t = \beta_0 + \sum_{i=1}^{n}\beta_{1i}\Delta SY_{t-i} + \sum_{i=0}^{n}\beta_{2i}\Delta \mathrm{Ln}(FERT)_{t-i} + \sum_{i=0}^{n}\beta_{3i}\Delta \mathrm{Ln}\ (\mathrm{IRLA})_{t-i} + \sum_{i=0}^{n}\beta_{4i}\Delta\ \mathrm{Ln}\ (TRANS)_{t-i} + \sum_{i=0}^{n}\beta_{5i}\Delta\ \mathrm{Ln}(LAB)_{t-i} + \sum_{i=0}^{n}\beta_{6i}\Delta Ln(\ TECH)_{t-i} + \sum_{i=0}^{n}\beta_{7i}\Delta\ MAX_{t-i} + \sum_{i=0}^{n}\beta_{8i}\Delta MIN_{t-i} + \sum_{i=0}^{n}\beta_{9i}\Delta\ MEAN_{t-i} + \sum_{i=0}^{n}\beta_{10i}\Delta\ RAIN_{t-i} + \lambda ECT_{t-i} + \varepsilon_{1t} \ \ldots.. (2)$$

Table 5: ARDL Bound Test Results

Test Statistic	Value	K
F-statistic	4.209	9
	Critical Values	
Significance level	**Lower Bound value**	**Upper Bound value**
10%	1.88	2.99
5%	2.14	3.30
2.5%	2.37	3.60
1%	2.65	3.97

The ECM model explains maximum, mean, and minimum temperature has a long-run relationship with sugarcane yield. Maximum temperature and minimum temperature should be maintained between 12.66^{0}C and 27.99^{0}C and below this temperature, sugarcane yield started to decline in the long run. The Error-Correction Model (ECM) indicates the pace of convergence or correction in the long run. The coefficient ΔSY(-1) shows EC term and it indicates that if any shock arises in the short-run, it adjusts by 83 percent within one year (see Table 6).

Table 6: ARDL ECM Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LR (Long-Run)				
Ln(FERT)	0.26	0.71	0.37	0.72
Ln(IRLA)	-6.03	16.59269	-0.36	0.724
Ln(TRANS)	-6.89	5.58	-1.24	0.25
Ln(LAB)	17.78	15.02	1.18	0.26
Ln(TECH)	-5.27	53.59	-0.10	0.92
MAX	94.93	36.35	2.61	0.03**
MIN	94.61	36.70	2.58	0.03**
MEAN	-188.26	73.23	-2.57	0.03**
RAIN	-0.001	0.01	-0.24	0.82
C	-14.79	32.24	-0.46	0.66
SY (-1)	-0.83	0.19	-4.27	0.002***
SR(Short-Run)				
Ln(FERT)	-2.27	4.11	-0.55	0.59
Ln(FERT)(-1)	3.42	5.15	0.66	0.52
Ln(TRANS)	5.66	3.76	1.51	0.16
Adjusted R^2		**Root MSE**		
0.6252		0.6852		

Note. *p<0.1, **p<0.05. ***p<0.01.

The Granger the Causality Wald Test results also show that there is unidirectional causality between sugarcane yield and labor growth, sugarcane yield to technology, sugarcane yield, and minimum temperature. Similarly, there is also unidirectional causality runs between transport growth and labor growth.

In addition, there is a bi-directional relationship between sugarcane yield and fertilizer growth; irrigation growth; transport growth; maximum and minimum temperatures; and rainfall each other, There is also a bi-directional relationship between irrigation growth, transport growth, sugarcane yield and labor growth, technology growth, maximum and minimum temperatures and rainfall each other (see Table 7).

Table 7: Granger Causality Test

Hypothesis			Chi-Square Statistic	Probability	Direction
SY	➔	Ln(FERT)	32.02	0.000***	Bi-directional causality between
Ln(FERT)	➔	SY	18.40	0.000***	Sugarcane Yield and Fertilizer Growth
SY	➔	Ln(IRLA)	17.34	0.000**	Bi-directional causality between
Ln(IRLA)	➔	SY	100.12	0.000***	Sugarcane Yield and Irrigation land Growth
SY	➔	Ln(TRANS)	11.87	0.003***	Bi-directional causality between
Ln(TRANS)	➔	SY	456.55	0.000***	Sugarcane Yield and Transportation Growth
SY	➔	Ln(LAB)	62.74	0.000***	Unidirectional causality between
Ln(LAB)	➔	SY	3.43	0.180	Sugarcane Yield and Labor Growth
SY	➔	Ln(TECH)	3.44	0.179	Unidirectional causality between
Ln(TECH)	➔	SY	89.05	0.000***	Sugarcane Yield and Technology Growth
SY	➔	MAX	18.38	0.000***	Bidirectional causality between
MAX	➔	SY	4700.20	0.000***	Sugarcane Yield and Maximum Temperature

SY	➔	MIN	20.80	0.000***	Unidirectional causality between
MIN	➔	SY	2.64	0.267	Sugarcane Yield and Minimum Temperature
SY	➔	MEAN	18.71	0.000***	Bi-directional causality between
MEAN	➔	SY	95.02	0.000***	Sugarcane Yield and Mean Temperature
SY	➔	RAIN	20.14	0.000***	Bi-directional causality between
RAIN	➔	SY	56.78	0.000***	Sugarcane Yield and Rainfall
Ln(FERT)	➔	IRLA	49.82	0.000***	Bi-directional causality between
IRLA	➔	Ln(FERT)	105.10	0.000***	Fertilizer Growth and Irrigation Land Growth
Ln(FERT)	➔	Ln(TRANS)	14.71	0.001***	Bi-directional causality between
Ln(TRANS)	➔	Ln(FERT)	1277.3	0.000***	Fertilizer Growth and Transportation Growth
Ln(FERT)	➔	Ln(TECH)	15.81	0.000***	Bi-directional causality between
Ln(TECH)	➔	Ln(FERT)	31.12	0.000***	Fertilizer Growth and Technology Growth
LnFERT	➔	MAX	42.02	0.000***	Bi-directional causality between
MAX	➔	Ln(FERT)	10802	0.000***	Fertilizer Growth and Maximum Temperature
Ln(FERT)	➔	MIN	45.56	0.000***	Bi-directional causality between
MIN	➔	Ln(FERT)	32.96	0.000***	Fertilizer Growth and Minimum Temperature
Ln(FERT)	➔	MEAN	43.32	0.000***	Bi-directional causality between
MEAN	➔	Ln(FERT)	354.55	0.000***	Fertilizer Growth and Mean Temperature
Ln(FERT)	➔	RAIN	26.18	0.000***	Bi-directional causality between
RAIN	➔	Ln(FERT)	45.098	0.000***	Fertilizer Growth and Rainfall
Ln(IRLA)	➔	Ln(TRANS)	246.69	0.000***	Bi-directional causality between
Ln(TRANS)	➔	Ln(IRLA)	11.571	0.003***	Irrigation Land Growth and Transport Growth
Ln(IRLA)	➔	Ln(LAB)	8.07	0.018**	Bi-directional causality between
Ln(LAB)	➔	Ln(IRLA)	16.58	0.000***	Irrigation Land Growth and Labor Growth
Ln(IRLA)	➔	Ln(TECH)	192.77	0.000***	Bi-directional causality between
Ln(TECH)	➔	Ln(IRLA)	14.03	0.001***	Irrigation Land Growth and Technology Growth
Ln(IRLA)	➔	MAX	84.23	0.000***	Bi-directional causality between
MAX	➔	Ln(IRLA)	36856	0.000***	Irrigation Land Growth and Maximum Temperature
Ln(IRLA)	➔	MIN	65.32	0.000***	Bi-directional causality between
MIN	➔	Ln(IRLA)	318.8	0.000***	Irrigation Land Growth and Minimum Temperature
					Bi-directional causality between
Ln(IRLA)	➔	MEAN	78.56	0.000***	Irrigation Land Growth and Mean
MEAN	➔	Ln(IRLA)	1717.8	0.000***	Temperature
Ln(IRLA)	➔	RAIN	221.27	0.000***	Bi-directional causality between
RAIN	➔	Ln(IRLA)	43.56	0.000***	Irrigation Land Growth and Rainfall
Ln(TRANS)	➔	Ln(LAB)	607.64	0.000***	Unidirectional causality between
Ln(LAB)	➔	Ln(TRANS)	1.6159	0.446	Transport Growth and Labor Growth

Ln(TRANS)	→	LnTECH	158.14	0.000***	Bi-directional causality between
LnTECH	→	Ln(TRANS)	38.68	0.000***	Transport Growth and Technology Growth
Ln(TRANS)	→	MAX	565.81	0.000***	Bi-directional causality between
MAX	→	Ln(TRANS)	22086	0.000***	Transport Growth and Maximum Temperature
Ln(TRANS)	→	MIN	586.84	0.000***	Bi-directional causality between
MIN	→	Ln(TRANS)	225.57	0.000***	Transport Growth and Minimum Temperature
Ln(TRANS)	→	MEAN	574.15	0.000***	Bi-directional causality between
MEAN	→	Ln(TRANS)	1019.4	0.000***	Transport Growth and Mean Temperature
Ln(TRANS)	→	RAIN	765.79	0.000***	Bi-directional causality between
RAIN	→	Ln(TRANS)	99.621	0.000***	Transport Growth and Rainfall
Ln(LAB)	→	LnTECH	31.58	0.000***	Bi-directional causality between
LnTECH	→	Ln(LAB)	31.29	0.000***	Labor Growth and Technology Growth
Ln(LAB)	→	MAX	26.21	0.000***	Bi-directional causality between
MAX	→	Ln(LAB)	8775.30	0.000***	Labor Growth and Maximum Temperature
Ln(LAB)	→	MIN	22.42	0.000***	Bi-directional causality between
MIN	→	Ln(LAB)	154.39	0.000***	Labor Growth and Minimum Temperature
Ln(LAB)	→	MEAN	24.34	0.000***	Bi-directional causality between
MEAN	→	Ln(LAB)	539.22	0.000***	Labor Growth and Mean Temperature
Ln(LAB)	→	RAIN	9.69	0.008***	Bi-directional causality between
RAIN	→	Ln(LAB)	28.41	0.000***	Labor Growth and Rainfall Temperature
Ln(TECH)	→	MAX	34.37	0.000***	Bi-directional causality between
MAX	→	Ln(TECH)	49734	0.000***	Technology Growth and Maximum Temperature
Ln(TECH)	→	MIN	40.33	0.000***	Bi-directional causality between
MIN	→	Ln(TECH)	742.84	0.000***	Technology Growth and Minimum Temperature
Ln(TECH)	→	MEAN	37.053	0.000***	Bi-directional causality between
MEAN	→	Ln(TECH)	2995.4	0.000***	Technology Growth and Mean Temperature
Ln(TECH)	→	RAIN	89.89	0.000***	Bi-directional causality between
RAIN	→	Ln(TECH)	34.317	0.000***	Technology Growth and Rainfall
MAX	→	MIN	14319	0.000***	Bi-directional causality between
MIN	→	MAX	165.51	0.000***	Maximum Temperature and Minimum Temperature
					Bi-directional causality between
MAX	→	MEAN	9764.2	0.000***	Maximum Temperature and Mean
MEAN	→	MAX	534.56	0.000***	Temperature
MAX	→	RAIN	9733.5	0.000***	Bi-directional causality between
RAIN	→	MAX	57.27	0.000***	Maximum Temperature and Rainfall
MIN	→	MEAN	193.64	0.000***	Bi-directional causality between
MEAN	→	MIN	916.47	0.000***	Minimum Temperature and Mean Temperature

MIN	➔	RAIN	113.82	0.000***	Bi-directional causality between
RAIN	➔	MIN	57.66	0.000***	Minimum Temperature and Rainfall
MEAN	➔	RAIN	488.16	0.000***	Bi-directional causality between Mean
RAIN	➔	MEAN	57.78	0.000***	Temperature and Rainfall

Note. **p<0.05, ***p<0.01.

Stability Test

The plot of the Recursive Cumulative Sum of recursive residuals lies inside the critical bounds at 5% level of significance, so we do not reject the null hypothesis and it establishes that the ARDL model was established over the period of time.

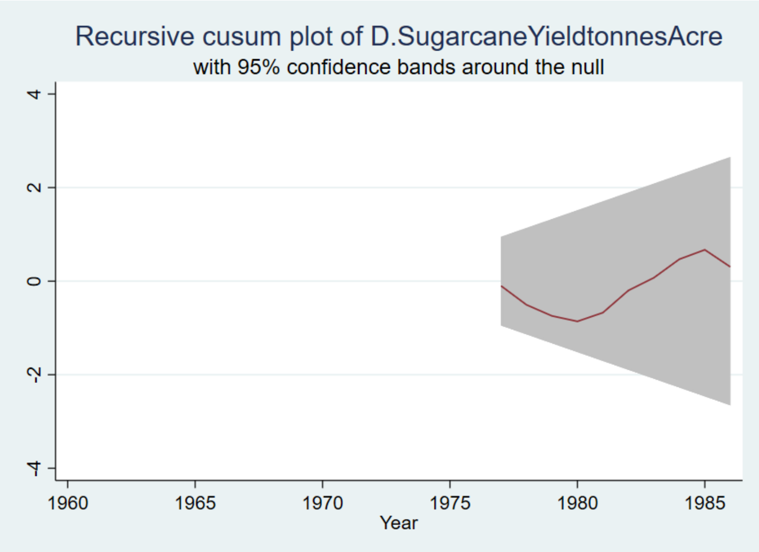

Figure 3: ***Recursive Cusum Plot performed in Stata***

<u>For De-zoning Policy</u>

ADF test results reveal there is mixed cointegration among variables at I(0) and I(1) levels (See table 8). Hence, based on ADF results, the ARDL model is adopted to establish the short-run and the long-run relationship between variables:

Table 8: Unit Root Test – ADF Test with Intercept

Variable	T-statistic	1% Critical Value	5% Critical Value	10% Critical Value	Probability
Ln(SY)	-3. 843	-3.743	-2.997	-2.629	0.0025**
Ln(FERT)	-5.874	-3.750	-3.000	-2.630	0.0000***
IRLAGR	-6.621	-3.750	-3.000	-2.630	0.0000***
LN(TRANS)	-9.652	-3.750	-3.000	-2.630	0.0000***
LABGR	-2.813	-3.750	-3.000	-2.630	0.0564*
LN(TECH)	-2.950	-3.750	-3.000	-2.630	0.0399**
MAX	-4.853	-3.743	-2.997	-2.629	0.0000***
MIN	-4.644	-3.743	-2.997	-2.629	0.0001***
MEAN	-4.815	-3.743	-2.997	-2.629	0.0001***
RAIN	-4.783	-3.743	-2.997	-2.629	0.0001***

Note. *p<0.1, **p<0.05. ***p<0.01.

$$\Delta \mathrm{Ln}(SY)_t = \beta_0 + \delta_1 \mathrm{Ln}(SY)_{t-i} + \delta_2 \mathrm{Ln}(\mathrm{FERT})_{t-1} + \delta_3 Ln(\mathrm{IRLA})_{t-1} + \delta_4 \mathrm{Ln}(\mathrm{TRANS})_{t-1} + \delta_5 Ln(\mathrm{LAB})_{t-1} + \delta_6 Ln(TECH)_{t-1} + \delta_8 MIN_{t-1} + \sum_{i=1}^{n} \beta_{1i} \Delta SY_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta \mathrm{Ln}(\mathrm{FERT})_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta Ln(\mathrm{IRLA})_{t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta \mathrm{Ln}(\mathrm{TRANS})_{t-i} + \sum_{i=0}^{n} \beta_{5i} \Delta \mathrm{Ln}(\mathrm{LAB})_{t-i} + \sum_{i=0}^{n} \beta_{6i} \Delta \mathrm{Ln}(\mathrm{TECH})_{t-i} + \sum_{i=0}^{n} \beta_{8i} \Delta MIN_{t-i} + \varepsilon_{1t} \quad \ldots\ldots \quad (3)$$

The descriptive statistics shows average sugarcane yield growth, during the de-zoning policy, was 2 percent and fertilizer growth was 4.3 percent. The average irrigation land grew by 0.4 percent and transport grew by 6 percent. Labor and technology grew by 2 percent and 8 percent, respectively (See Table 9).

Table 9: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Ln(SY)	0.02	0.05	-0.07	0.15
Ln(FERT)	0.043	0.17	-0.39	0.44
Ln(IRLA)	0.004	0.02	-0.05	0.06
Ln(TRANS)	0.06	0.24	-0.003	1.37
Ln(LAB)	0.02	0.04	-0.08	0.13
Ln(TECH)	0.08	0.30	-0.47	0.87

Diagnostic Test

The study also performs diagnostic tests to determine heteroskedastic, autocorrelation, and normality in the model. The White Heteroscedasticity LM Test shows there is no heteroskedastic problem (χ^2 = 30.00, p-value = 0.4140), Breusch-Godfrey LM Test shows no serial correlation problem in the model (χ^2 = 7.021, p-value = 0.3189), at 5% level of significance. The Jarque-Bera normality test suggests variables are normally distributed (χ^2 = 1.35, p-value = 0.5091).

ARDL Model

The ARDL Model (2 0 0 1 0 0 0) is selected based on Akaike Information Criteria (AIC). The results show that at 5% level of significance, the F-test value is 2.85 with a probability value of 0.0251. Hence, we establish that there is cointegration between dependent and independent variables by rejecting the null hypothesis of no cointegration (see Table 10).

Table 10: Autoregressive Distribution Lag Cointegration Test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Ln(SY) (-1)	-0.408	0.179	-2.28	0.037**
Ln(SY) (-2)	-0.539	0.176	-3.06	0.008***
Ln(FERT) (-1)	-0.066	0.071	-0.94	0.363
Ln(IRLA)	-0.919	0.445	-2.07	0.055*
Ln(TRANS)	-0.009	0.042	-0.24	0.814
Ln(TRANS) (-1)	-0.005	0.043	-0.12	0.905
Ln(LAB)	0.205	0.210	0.97	0.344
Ln(LAB) (-1)	-0.234	0.216	-1.08	0.295
Ln(LAB) (-2)	0.019	0.216	0.09	0.931
Ln(TECH)	-0.024	0.035	-0.68	0.507
Ln(TECH) (-1)	0.035	0.034	1.05	0.311
Ln(TECH) (-2)	-0.059	0.029	-1.99	0.064*
C	0.038	0.012	3.25	0.005***
Adjusted R^2	**Root MSE**	**F-Statistic**		**Prob(F-Statistic)**
0.4529	0.0381	2.85		0.0251

Note. *p<0.1, **p<0.05. ***p<0.01.

Consequently, the short-run and long-run association between dependent and independent variables is estimated by ARDL bound test (see Table 11). At 1% level of significance, the F-statistic estimated value 10.00 which is more than the upper critical value I(1) which is 4.68. Therefore, the alternative hypothesis is accepted that there is a long-run relationship between variables by rejecting the null hypothesis of no long-run relationship.

Table 11: ARDL Bound Test Results

Test Statistic	Value	K
F-statistic	10.00	5
Critical Values		
Significance level	**Lower Bound value**	**Upper Bound value**
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Now, we estimate ARDL Error-Correction Model (ECM) based on the following equation:

$$\Delta Ln(SY)_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\Delta \mathrm{Ln}(SY)_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta \mathrm{Ln}(FERT)_{1t-i} + \sum_{i=0}^{n} \beta_{3i}\Delta \mathrm{Ln}(IRLA)_{2t-i} + \sum_{i=0}^{n} \beta_{4i}\Delta \mathrm{Ln}(TRANS)_{3t-i} + \sum_{i=0}^{n} \beta_{5i}\Delta \mathrm{Ln}(\mathrm{LAB})_{4t-i} + \sum_{i=0}^{n} \beta_{6i}\Delta \sum_{i=0}^{n} \beta_{5i}\Delta \mathrm{Ln}(\mathrm{TECH})_{5t-i} + \lambda ECT_{t-i} + \varepsilon_{1t} \quad \text{..... (4)}$$

The ARDL ECM reveals technological growth has a short-run relationship with sugarcane yield (see Table 12). The ECM indicates the pace of convergence or correction in the long run. The error correction term ΔSY(-1) determines that if any shock arises in the short run, it adjusts by 194.7 percent within one year.

Table 12: ARDL ECM Model

Variable	Coefficient	Std. Error	T-Statistic	Prob.
LR (Long-Run)				
ΔLn(FERT)	0.015	0.069	0.22	0.831
ΔLn(IRLA)	-0.472	0.244	-1.93	0.071*
ΔLn(TRANS)	-0.007	0.025	-0.30	0.767
ΔLn(LAB)	-0.005	0.165	-0.03	0.975
ΔLn(TECH)	-0.024	0.032	-0.75	0.467
C	0.037	0.012	3.25	0.005***
ΔLn(SY (-1))	-1.947	0.288	-6.77	0.000***
SR(Short-Run)				
ΔLn(FERT)	0.067	0.071	0.94	0.363
ΔLn(TRANS)	0.005	0.043	0.12	0.905
ΔLn(LAB)	0.215	0.257	0.84	0.416
ΔLn(LAB) (-1)	-0.019	0.216	-0.09	0.931
ΔLn(TECH)	0.024	0.045	0.53	0.603
ΔLn(TECH) (-1)	0.059	0.029	1.99	0.064*
ΔLn(SY(-1))	0.539	0.176	3.06	0.008***
Adjusted R^2		**Root MSE**		
0.8024		0.0381		

Note. *p<0.1, **p<0.05. ***p<0.01.

The Granger Causality Wald Test results also estimated, and these results advocate that there is unidirectional causality from transport growth to sugarcane yield, sugarcane yield to labor growth, transport growth to fertilizer growth, fertilizer growth to labor growth, and irrigation land growth to labor growth. On the other hand, there is a bi-directional relationship between fertilizer growth and transportation growth and transportation growth and labor growth. Though there is no relationship between irrigation growth and technology growth, transport growth, and labor growth, but probability value stated irrigation growth still can explain and cause technology growth by 83.5 percent, technology growth can cause transport growth by 81.8 percent and labor growth can cause technology growth by 81.9 percent (see Table 13).

Table 13: Granger Causality Test

Hypothesis			Chi-Square Statistic	Probability	Direction
Ln(SY)	➔	Ln(TRANS)	4.9829	0.083*	Unidirectional causality between Sugarcane Yield Growth and Transport Growth
Ln(TRANS)	➔	Ln(SY)	3.9651	0.138	
Ln(SY)	➔	Ln(LAB)	1.1643	0.559	Unidirectional causality between Sugarcane Yield Growth and Labor Growth
Ln(LAB)	➔	Ln(SY)	11.387	0.003***	
Ln(FERT)	➔	Ln(TRANS)	7.8667	0.020**	Bi-directional causality between Fertilizer Growth and Transport Growth
Ln(TRANS)	➔	Ln(FERT)	4.9567	0.084*	
Ln(FERT)	➔	Ln(LAB)	.43782	0.803	Unidirectional causality between Fertilizer Growth and Labor Growth
Ln(LAB)	➔	Ln(FERT)	5.0299	0.081*	
Ln(IRLA)	➔	Ln(LAB)	2.487	0.288	Unidirectional causality between Irrigation Growth and Labor Growth
Ln(LAB)	➔	Ln(IRLA)	11.361	0.003***	
Ln(IRLA)	➔	Ln(TECH)	.38109	0.827	No causality between Irrigation Growth and Technology Growth
Ln(TECH)	➔	Ln(IRLA)	3.6053	0.165	
Ln(TRANS)	➔	Ln(LAB)	11.711	0.003***	Bi-directional causality between Transport Growth and Labor Growth
Ln(LABGR)	➔	Ln(TRANS)	5.7006	0.058*	
Ln(TRANS)	➔	Ln(TECH)	3.4128	0.182	No causality between Transport Growth and Technology Growth
Ln(TECH)	➔	Ln(TRANS)	2.6012	0.272	
Ln(LAB)	➔	Ln(TECH)	2.1224	0.346	No causality between Labor Growth and Technology Growth
Ln(TECH)	➔	Ln(LAB)	3.4221	0.181	

Note. *p<0.1, **p<0.05. ***p<0.01.

Stability Test

The plot of the cumulative sum of squares and recursive cumulative sum lies inside the critical bounds at 5% level of significance, so we do not reject the null hypothesis and it establishes that the Autoregressive Distribution Lag (ARDL) model was established over the period of time.

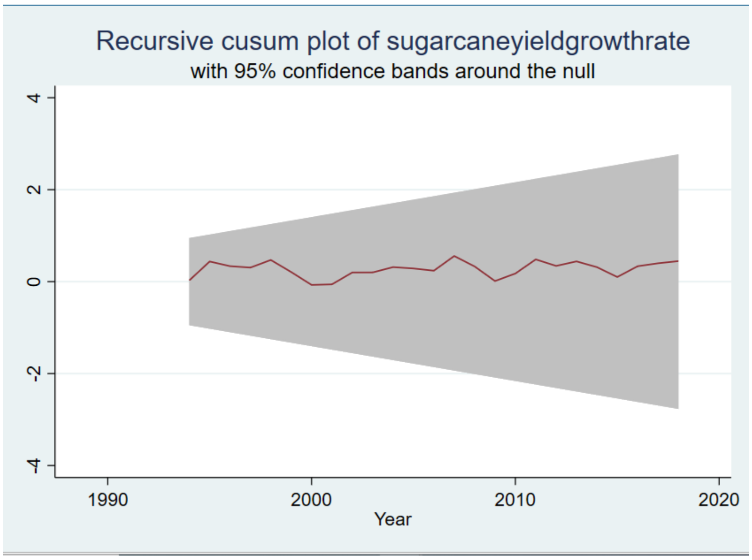

Figure 4: Recursive Cusum Plot perfomed in Stata

Discussion and Conclusion

This paper investigated two policies, zoning and de-zoning policies, of the sugar industry of Pakistan that were implemented from the 1960s to 2019. The paper also contributes to the literature because few studies have attempted to find out zoning policy benefits. The paper employed the ARDL model to ascertain the short-run and the long-run impact of fertilizer, irrigation land, transport, labor, technology, temperature, and rainfall on sugarcane yield from 1960 to 2019. The Granger Causality Wald Test also ran to determine the causality direction among variables.

The ARDL bound test has established a long-term cointegration association among fertilizer, irrigation land, transport, labor, and technology for both policies. This long-run relationship was also established in previous studies (Ali et al., 2021; Shabbir & Yaqoob, 2019). The bound test has also established the long-run positive association of maximum and minimum temperatures with sugarcane yield for the zoning policy. The study found a negative insignificant association of rainfall with sugarcane yield. This is in the contrast with the study of Jan et al. (2021) where they found minimum temperature has a long-run insignificant impact on cereal crops and the maximum temperature has the long-run negative impacts on cereal crops. The study also estimated the short-run positive association of the technological impacts with lag effect on sugarcane yield in de-zoning policy. Instead, Ali et al. (2021) estimated the negative short-run impact of technology on sugarcane yield while Chandio et al. (2020) estimated the positive short-run and long-run impact of technology on agriculture production.

The study found unidirectional causality for zoning policy from labor growth to sugarcane yield; sugarcane yield to technology growth; minimum temperature to sugarcane yield; and transport growth and labor growth. It also estimated unidirectional causality from transport growth to sugarcane yield, sugarcane yield to labor growth, fertilizer growth to labor growth, and irrigation land growth to labor growth for de-zoning Policy.

These results also suggest that fertilizer growth, irrigation growth, labor growth, transport growth, maximum and minimum temperatures, and rainfall had bi-causality to impact on sugarcane yield while technology had bi-directional causality with irrigated land, fertilizer, labor, and transport and indirectly supported to sugarcane yield during zoning policy. Results also suggest that labor indirectly improves sugarcane yield through transportation growth and fertilizer growth during the de-zoning policy. These results also matched with previous studies (Ayinde & Adewumi, 2010; Gul et al., 2022; Oniki, 2001; Singh & Borrok, 2019).

Hence, results prove that the zoning policy was implemented and supported by the subsidized seed-fertilizer-water package, and farmers were given the incentive to produce the quality of seed and fertilizer by the sugar mills while it also supported increased irrigation system to improve the fertility of the land (Qureshi & Afghan, 2005; Khushk, 2010). Results also confirm that labor-intensive technology was adopted during this policy to enhance labor skills and support the livelihood of the rural community. In addition to it, better-mechanized farming also supported irrigated land productivity and supports the quality of sugarcane, eventually, farmers got good prices for their product. The positive point of the policy was that it eliminated the role of middlemen and established a direct link between sugarcane farmers with sugar mills also improved farm gate prices (Pirzada et al., 2022). The quality of sugarcane coupled with quality premium also declined the sugarcane loss during weighing at the sugar mills gate (Lodhi et al., 1988; Pirzada et al., 2022). Another positive point of zoning policy was that it also considered climate change impact and rising temperature or temperature below from minimum threshold can decline the sugarcane yield as indicated by the study results. In addition, though rainfall was insignificant, it declines the crop yield if more than or less than the required rainfall occurred in sugarcane areas.

For policy implication, the government should revive the zoning policy and provide subsidies to small farmers to produce the quality of sugarcane. Water availability should be ensured and mechanized farming with new technology should be adopted to reduce water consumption by the crop. Road infrastructure should also be built to reduce the transportation cost of sugarcane, it will also decline post-harvest losses during commuting from farmgate to sugar mill. Farmers should be trained for the application of seeds, fertilizer, and pesticides. Being a labor-intensive crop, corporate farming is not better solution and technology should be adopted that does not displace more labor from farm.. Sugarcane price should be calculated based on sucrose content, and byproducts of sugarcane like bagasse, molasses, and press mud. Farmers can also make climatic and agroecological zones in order to reduce the climate's impact on sugarcane crops.

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