Regulatory Quality and Agricultural Value Added in Pakistan: Roles of FDI, Innovation, Employment, and Energy

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ABSTRACT: Agriculture value added is an important aspect for the agrarian economies like Pakistan. This research caters the state of agriculture value added in the presence of Foreign Direct Investment (FDI), technological innovation, employment in agriculture sector, and usage of renewable energy. For the observance of in-depth outcomes of the selected variables, the variables are constructed with the interaction of regulatory quality. The data was collected from 1990 to 2025. The analysis is done via Autoregressive Distributed Lag (ARDL). The results confirm that FDI and technological, innovation positively, employment in agriculture, and renewable energy consumption post a positive effect on agriculture value added in Pakistan. Policy option is to effort for better regulatory quality together with consistent FDI inflows, adaptation of technology, rich employment opportunities in agriculture, and usage of a renewable energy for achieving desired agriculture growth targets.

KEYWORDS: Regulatory Quality, Agriculture Value Added, Technological Innovation, FDI, ARDL, Pakistan

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Introduction

The adoption of measures for favoring the agriculture sector performance are to be in-line with the regulatory quality. The regulatory quality measures the ability of government to formulate as well as implement sound policies and regulations. These regulatory measures permit and promote the sectoral development in respective country. regulatory quality, especially in agriculture sector, dictates the enforcement and creation of the sound policies which allow the businesses and the farmers to struggle for the public health, food security, and the environmental protection measures. The sustainable land management and reliable market accesses are possible in the presence of good governance and regulatory setup (Xie & Tao, 2026).

Agriculture sector is crucial for food security in Asia (Montesclaros & Teng, 2021). It enjoins economic activities in a region and a source of employment creation in the rural areas. According to Montesclaros and Teng (2021), 81 % of Asian population relies upon agriculture sector for its livelihood. Food security, economic growth, employment, and sustainable development, to Shah et al. (2024), depend upon agriculture value addition, particularly in Asian economies. But it is essential to consider the regulatory quality to improvise the agriculture value added. Agrarian productions also degrade the resources and also contribute to the greenhouse gas emission thereby drive towards the global warming. The technological innovation is recognized to be a crucial factor in the tackling of the climate related challenges. The digital technologies like remote sensing, artificial intelligence, and precision of agriculture cultivation techniques along with the advanced biotechnology and renewable energy provide the solution towards the optimum resource usage together with the development of climate-resilient crops and a noticeable reduction in greenhouse gas emission (Venturini, 2025).

FDI is of a vital role in enchanter of productivity and the introduction of the advanced technologies in order to improvise the agriculture related infrastructure. In context of food demand, the proper utilization of FDI capital is crucial to favor the agriculture productivity at wider spectrum. Study of Sabir et al. (2019) found that positive impact of FDI on agriculture productivity is reliant upon regulatory quality, rule of law, and the government effectiveness. Without these governance indicators, the capacity of a region to capture the external investment gains remains depressed (Gelgo et al., 2023). Since FDI favored firms are largely export-oriented, directing their capital into high-tech agricultural ventures can amplify both the volume and market value of farm exports, thereby strengthening the sector's international competitiveness.

Academic perspectives on this impact remain divided. Research by Rahman et al. (2024) indicates that FDI inflows play a statistically significant role in expanding agriculture's contribution to total GDP, leading to recommendations for more aggressive government incentives to attract foreign investors. Conversely, Sultana and Sadekin (2023) observed a negative correlation between FDI and domestic agricultural health. Their findings suggest that capital alone is insufficient; they argue that the state must prioritize human capital development—specifically through farmer training and skill enhancement—to ensure that foreign investment actually translates into higher productivity rather than displacing local industry.

Agriculture sector of Pakistan's contributes around 23 % into the GDP and engages employment opportunities for around 37.4 % of the national labor force. United Nations' Agriculture and Food Organization (2026) confirms that about 70 % of Pakistan's exports are derived from the agriculture sector. Covering an area of above 30 million hectares, the 47 % of the national land is agriculture-based, that is greater than global average of 38 %. In an agriculture sector, livestock has an irresistible involvement of 62 %, tracked by central crops (4.1 %), other crops (3.3 %), fisheries (0.3 %) and forestry (0.5 %).

This study contributes into the literature by several key objectives by considering the role of regulatory quality which enables to explore the key aspects such as FDI, technological innovation, employment, and renewable energy consumption for their profound effects on the agriculture productivity of Pakistan after interacting with regulatory quality.

The study is arranged in 5 Sections; Section 1 is the Introduction; Section 2 reviews the Literature. Methodological Framework is given in Section 3. Whereas, the Section 4 and Section 5 are allocated for Results and Discussions and Conclusion and Policy Recommendations, respectively.

Literature Review

The recent researches on agriculture value added and productivity emphasize on the transition from the traditional to the data centric paradigms in view of analyzing the impacts of macroeconomic shift and climate change without considering the dynamic effect of regulatory quality.

Researchers have indicated that use of fertilizer and FDI significantly contribute in the agriculture value added (Sansika et al., 2023). In this regard, the green finance also improvises the agricultural value added via sustainable development-based funding for the agriculture productivity (Epor and Akande, 2025).

Empirical researches indicate FDI to positively influences agricultural efficiency, employment, and trade balance. However, with its impact being mediated by factors like regulatory quality and the business climate (Pascal & Wijaya, 2023a; Pascal and Wijaya, 2023b). In precise, better regulatory quality that reduces structural barriers is crucial for attracting FDI towards agriculture. Such FDI inflows then in turn lead to an increased value addition and productivity. However, the moderating effects of FDI and regulatory quality sometimes be negative as well, thus emphasize the significance of context-specific policy measures (Pascal & Wijaya, 2023; Pascal & Wijaya, 2023).

Overall, ensuring regulatory quality, fostering a conducive business environment, and addressing structural obstacles are key strategies for leveraging FDI to favor agricultural value addition, especially in emerging economies (Patel et al., 2025).

Agriculture productivity increases by the reduction of latency and costs (Samanta & Saha, 2026). Digitalization is a way to producing more with the cleaner environment, though it's on ground actual impact remains dependent on the context of its usage and adoption (Manta, 2026).

Analytics such as Sansika et al. (2023), Sinha (2024), Epor (2025), Padda (2026), and Cloete et al. (2025) distinguished with the macroeconomic variables, green finance, climate change, infrastructure energy, and globalization and FDI on the agriculture value addition, employment, and productivity (Sansika et al., 2023, Sinha, 2024, Epor, 2025, Padda, 2026, & Cloete et al., 2025). For instance, FDI and agriculture employment are found linear in relation (Sansika et al., 2023). Trade openness, economic growth, and agriculture value addition are long term cointegrated (Sinha, 2024). Moreover, Epor and Akande (2025) found that mitigated green finance and financial inclusion prove to advancing the agriculture productivity. The power shortages and outages (load shedding) disrupt the agriculture productivity and does cause to significantly lower the agriculture value addition of specific sectors like fruit and farming (Cloete et al., 2025).

Contrary to that, literature also points out that the properly scaled and aligned FDI are inadequate for substantial growth (Sangulla et al., 2025). Similarly, empirical analysis showed no significant effect of FDI on agriculture's contribution to GDP, nevertheless increasing FDI levels, suggesting inefficiencies within the sector and limited direct paybacks from FDI in furthering the productivity (Epaphra & Mwakalasya, 2017). Such inefficiencies are of weak regulatory quality. Conversely, larger analyses emphasized that FDI enhances agriculture productivity and export volume in African agriculture when it is combined with the efforts to improve infrastructure and land use (Gunasekera et al., 2015). In the Indian context, analytics viewed FDI as a catalyst for technological advancement, productivity developments, and employment creation although the sectoral growth remains reliant on effective policy implementation and sector-specific strategies (Gopalakrishna, 2019). Overall, the empirical evidences suggest that FDI has the potential to improve agricultural productivity, but the effectiveness of FDI inflows do hinge due to non-addressing of infrastructural, targeted policies, sector-specific investments, and institutional constraints. The literature underscores that deprived of strategic alignment and loyal policies, impact of FDI on agriculture productivity remains partial, despite its documented benefits in technology transfer and resource mobilization.

A novel approach to judging energy utilization in agriculture includes calculating the value of produced output per unit of energy input, which enables comparisons across regions, systems, and the over time. Doing that way aids in the policy formulation and identifying comparative advantages (Singh, 1993). Efficient energy use is related to better governance and regulatory quality. In the manufacturing, energy intensity serves as a surrogate for the energy efficiency, with reductions indicating potential efficiency gains, however it is also subject to external influences such as market conditions (United States Office of Energy Markets and End Use. (1991). Additionally, energy efficiency policies also generate manifold benefits beyond energy savings, including the economic growth, environmental sustainability, and social wellbeing, which strengthen the reputation of a wide-ranging evaluation framework (International Energy Agency, 2014). Overall, integrating measures of energy productivity with assessments of manifold benefits can bring sustenance towards effective policies—aimed at improving the energy utilization in manufacturing and agriculture sectors.

Technological innovation also adds into the agriculture value addition. Yang et al. (2024) and Huang and Ping (2025) signified that technological innovations engage sustainable development in agriculture productivity. In this regard, adoption of technological innovation that is agriculture specific contribute in addressing the climate challenges and price volatilities.

Empirical analyses validate those perfections in governance indicators, counting regulatory quality, are meaningfully associated with augmented agricultural productivity and the epoch of market-based reforms (Petrov, 2025; Azmat & Coghill, 2005). Operative regulatory quality guarantees fair market practices, reduce of corruption, and promotion of transparency, those are vital for sustainable agricultural development.

Moreover, importance of regulatory mechanisms is adapted to technological advancements such as AI and blockchain, fostering transparency and accountability (Cao & Tao, 2025). Additionally, governance and regulatory quality influence land use and environmental sustainability. Where, better governance and regulation scores enable sustainable intensification and land sparing, reduce environmental degradation and ultimately increase productivity (Ceddia et al., 2014).

Overall, the literature underscores that regulatory quality as pivotal component of governance. It directly impacts agricultural efficiency, sustainability, and resilience. Therefore, advocates for integrated, data-driven, and multi-stakeholder approaches to governance in agriculture.

Methodological Framework

This study computes the relationship of FDI, technological innovation, employment, and renewable energy consumption having interacted with regulatory quality on the agriculture value added of Pakistan. The chosen time period is from 1990 to 2025. The time series data is gathered from The World Bank Development Indicators. Table 1 represents measurements of the variable. And Figure 1 highlights the stages of empirical analyses.

Table 1

Variable's Description

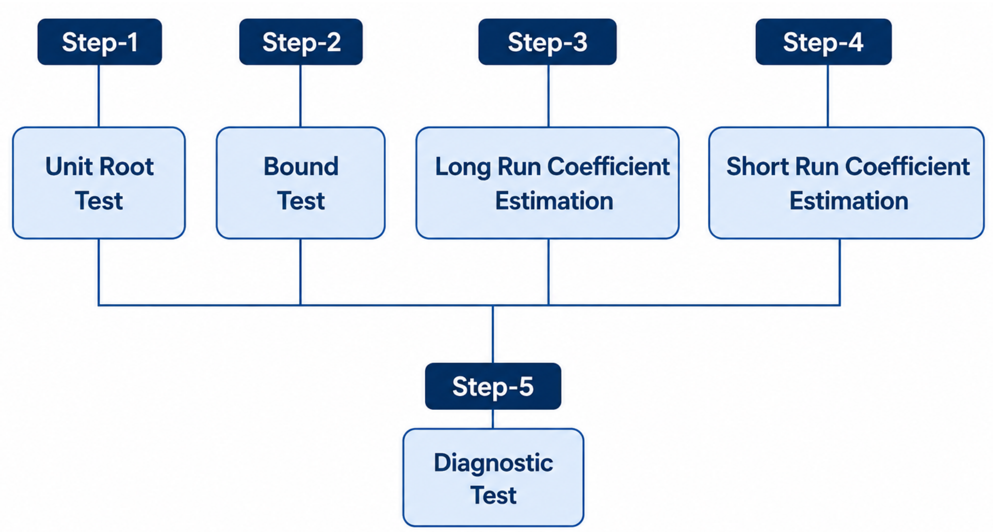
Variables	Symbols	Measurement
Agriculture Value Added (Million $)	AGR	"Agriculture, forestry, and fishing corresponds to ISIC (Rev. 4) divisions 01-03 and includes the exploitation of vegetal and animal natural resources, comprising the activities of growing of crops, raising and breeding of animals, harvesting of timber and other plants, animals or animal products from a farm or their natural habitats. Value added is the contribution to the economy by a producer or an industry or an institutional sector, which is estimated by the total value of output produced and deducting the total value of intermediate consumption of goods and services used to produce that output. This indicator is expressed in current prices, meaning no adjustment has been made to account for price changes over time."
Foreign Direct Investment (Million $)	FDI	"Foreign direct investment is a category of cross-border investment associated with a resident in one economy having control or a significant degree of influence on the management of an enterprise that is resident in another economy. Ownership of 10 % or more of the voting power is evidence of a direct investment relationship. This indicator is expressed in current prices, meaning no adjustment has been made to account for price changes over time."

Variables	Symbols	Measurement
Technological Innovation	TCI	"Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention--a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years."
Employment (In Percentage)	EMP	"Employment is defined as persons of working age who were engaged in any activity to produce goods or provide services for pay or profit, whether at work during the reference period or not at work due to temporary absence from a job, or to working-time arrangement. The agriculture sector consists of activities in agriculture, hunting, forestry and fishing, in accordance with division 1 (ISIC 2) or categories A-B (ISIC 3) or category A (ISIC 4)."
Energy Consumption	ENC	"Renewable energy consumption is the share of renewable energy in total final energy consumption."

Figure 1 shows the stages of empirical analyses which are based upon the Autoregressive Distributed Lag (ARDL).

Figure 1

Stages of Empirical Analyses



The econometric model of the research is specified below;

$$AGR_t = \beta_0 FDI \times RQ_t + \beta_1 TCI \times RQ_t + \beta_2 EMP \times RQ_t + \beta_3 ENC \times RQ_t + \mu_t \quad [1]$$

Where AGR denotes agriculture value added. FDI×RQ is a foreign direct investment. TCI×RQ indicates technological innovation. EMP×RQ is a notation of employment in agriculture sector. And ENC×RQ is a donation of renewable energy consumption. All the variables are constructed having interacted with regulatory quality. The μ_t is the error term.

This research evaluates the presence of long run relationship between agriculture value added and FDI×RQ, TCI×RQ, EMP×RQ, and ENC×RQ by utilizing ARDL technique of cointegration. Based on this objective, the model is stated as below;

$$\Delta AGR_{t-1} = \partial_0 + \partial_1 FDI \times RQ_{t-1} + \partial_2 TCI \times RQ_{t-1} + \partial_3 EMP \times RQ_{t-1} + \partial_4 ENC \times RQ_{t-1} + \sum_{i=1}^{p} \phi_1 AGR_{t-i} + \sum_{i=1}^{p} \phi_2 FDI \times RQ_{t-i} + \sum_{i=1}^{p} \phi_3 TCI \times RQ_{t-i} + \sum_{i=1}^{p} \phi_4 EMP \times RQ_{t-i} + \sum_{i=1}^{p} \phi_5 ENC \times RQ_{t-i} + \mu_t \quad [2]$$

The Δ represents first difference. It is based on Akaike Information Criteria. Optimal lag option is shown by *t-1*. The Δ and ϕ analyze he long term cointegration. The H_0 and H_1 hypotheses are of Bound Test, based on the following expressions;

$H_0 = \partial_1 = \partial_2 = \partial_3 = \partial_4 = 0$

$H_1 \neq \partial_1 \neq \partial_2 \neq \partial_3 \neq \partial_4 \neq 0$

Following Pesaran et al. (2001), the long run relationship exists if computed F-statistic is greater than upper bound threshold and converse is true. The result is to be inconclusive if the F-statistic lies between lower and upper bound threshold boundary.

The ARDL model is employed when the regressor are integrated of order I(0) and I(1). The long run coefficients are found by the mean of following equation;

$$\Delta AGR_t = \partial_0 + \sum_{i=1}^{p} \phi_1 AGR_{t-i} + \sum_{i=1}^{p} \phi_2 FDI \times RQ_{t-i} + \sum_{i=1}^{p} \phi_3 TCI \times RQ_{t-i} + \sum_{i=1}^{p} \phi_4 EMP \times RQ_{t-i} + \sum_{i=1}^{p} \phi_5 ENC \times RQ_{t-i} + \mu_t \quad [3]$$

The ϕ denotes the long run coefficient.

The error correction model for short run ARDL model is given below;

$$\Delta AGR_t = \partial_0 + \sum_{i=1}^{p} \delta_1 AGR_{t-i} + \sum_{i=1}^{p} \delta_2 FDI \times RQ_{t-i} + \sum_{i=1}^{p} \delta_3 TCI \times RQ_{t-i} + \sum_{i=1}^{p} \delta_4 EMP \times RQ_{t-i} + \sum_{i=1}^{p} \delta_5 ENC \times RQ_{t-i} + \gamma ECT_{t-1} + \mu_t \quad [4]$$

The δ is short run coefficient of the regressors and γ is the coefficient of Error Correction Term (ECT) which illustrates the speed with which the system gets back to the original equilibrium after the shock. The computed coefficient of ECT has to be significant and negative in sign.

Results and Discussion

The descriptive statistics results are given in Table 2. Findings show that noticeable dispersions are evident in all the variables. AGR and FDI×RQ are positive in skewness. EMP×RQ and ENC×RQ are platykurtic. Jarque-Bera results is satisfactory on at TCI×RQ.

Table 2

Descriptive Statistics

	AGR	FDIXRQ	TCIXRQ	EMPXRQ	ENCXRQ
Mean	43438.14	1072.94	-584.57	-27.97	-33.29
Median	38764.53	881.46	-547.15	-26.98	-33.56
Maximum	89245.90	3223.77	-299.64	-18.55	-22.73
Minimum	9229.23	149.55	-1076.53	-45.46	-56.21
Std. Dev.	26833.13	874.03	204.13	5.72	7.13
Skewness	0.25	0.90	-0.46	-0.84	-0.92
Kurtosis	1.58	2.86	2.25	3.99	4.28
Jarque-Bera	3.41	4.92	2.14	5.68	7.56
Probability	0.18	0.09	0.34	0.06	0.02

The correlation results are presented in Table 3. High correlation is found between EMP×RQ and ENC×RQ. Most of the variables are evident for the negative correlation among one another. AGR is moderately correlated with FDI×RQ and ENC×RQ.

Table 3

Correlation

	AGR	FDIXRQ	TCIXRQ	EMPXRQ	ENCXRQ
AGR	1				
FDIXRQ	0.58	1			
TCIXRQ	-0.03	-0.39	1		
EMPXRQ	-0.48	-0.30	0.53	1	
ENCXRQ	-0.25	-0.09	0.43	0.93	1

Moving towards the empirical results, the unit root test is given in Table 4. the conclusion is drawn in a way that I(1) order of integration is found on the selected variable thus, ARDL is considered viable regression technique to compute the regression analyses (Pesaran et al., 2001).

Table 4

Unit Root Test

Variable	Constant	First Difference	Conclusion
AGR	-3.62	-6.55*	I(1)
FDI×RQ	-1.81	-6.06*	I(1)
TCI×RQ	-3.63	-4.04*	I(1)
EMP×RQ	-1.29	-5.66*	I(1)
ENC×RQ	-0.86	-5.03*	I(1)

Table 5 clarifies that the H_0 of no long run relationship is rejected. The cointegration between the AGR and selected variables does exist in the long run. The value of computed F-statistic is greater than the upper bound critical value.

Table 5

Bound Test

Model	*F*-Statistics	Upper Bound Critical Value	Conclusion
Model I *AGR = f (FDI*×RQ, *TCI*×RQ, *EMP*×RQ, *ENC*×RQ*)*	3.84	3.09	Co-integration exist

Long run coefficient estimates are given in Table 6. FDI×RQ possesses positive impact on AGR. By accelerating agriculture productivity through injecting modern capital, technology, and a strong and delivering organizational structure, FDI×RQ improvises the farming. The results move in line with Joseph (2025), Pascal and Wijaya (2023a). Pascal et al. (2025), and Wabwile et al. (2024). TCI×RQ also have positive effects on agriculture productivity since affect the farmers' wellbeing and productivity. The results of this research also fetch positive relationship of the two. Efficient use of resources especially by small farmers, support of education, access to credible education adds to the value addition in the agriculture (Danda, 2023; Dimitrova, 2022; Bagri, 2024; Andrianarison, 2022; Petrov, 2025; Azmat & Coghill, 2005). Variable of employment based on agriculture is found significant but negative. It is also significant to note that the impact of renewable energy usage is found significant and positive in effecting ARG. Any good combination of ENC and regulatory quality is of appraisable results on agriculture value addition. Alone, ENC can also hold a negative relationship with AGR. In the absence of strong government policies and high regulatory quality, the effect of transition of renewable energy advertently disrupts agriculture productivity, akin to Wang et al. (2023) and Situma (2025).

Table 6

Estimates of Long-run Coefficients

Variable	Coefficient	Std. Error	*t*- Ratio	Prob.
FDI×RQ	1.84	0.74	2.49	0.00
TCI×RQ	70.71	10.70	6.61	0.00
EMP×RQ	-16484.10	2785.08	-5.92	0.00
ENC×RQ	11999.92	1961.06	6.12	0.00
C	23505.94	28300.91	0.83	0.44

The short run coefficient estimates are presented in Table 7. Short run coefficient of FDI×RQ are jumbled in impacting ARG. At lag of 3 and 4, the results are significant but negative. Therefore, it is concluded that better picture needs to be detected in case of long run. The same results are visible in case of TCI×RQ. All the values are significant and negative in affecting AGR. It TCI together with regulatory quality is negative in short run due to postponement of some of the essential government tasks but the short run results turn significant and positive in long run. It is interesting to note that in paradoxical to long run, EMP×RQ possesses positive effects on AGR in short run. The result are highly significant at lag of 1 to 3. ENC×RQ holds mixed results too. AGR is half way negative in response to ENC×RQ in short run. It is very much neglectable. Economic policies do not rest on short run but on long run. Therefore, the long run impacts are to be considered authentic and relevant for the policy making. The coefficient of error term is found significant and correctly signed indicating the reversal towards the long run equilibrium at 55%. The study also passes the diagnostics of serial correlation, heteroskedasticity, residuals' normality, and of the correct model specification.

Table 7

Estimates of Short-run Coefficients

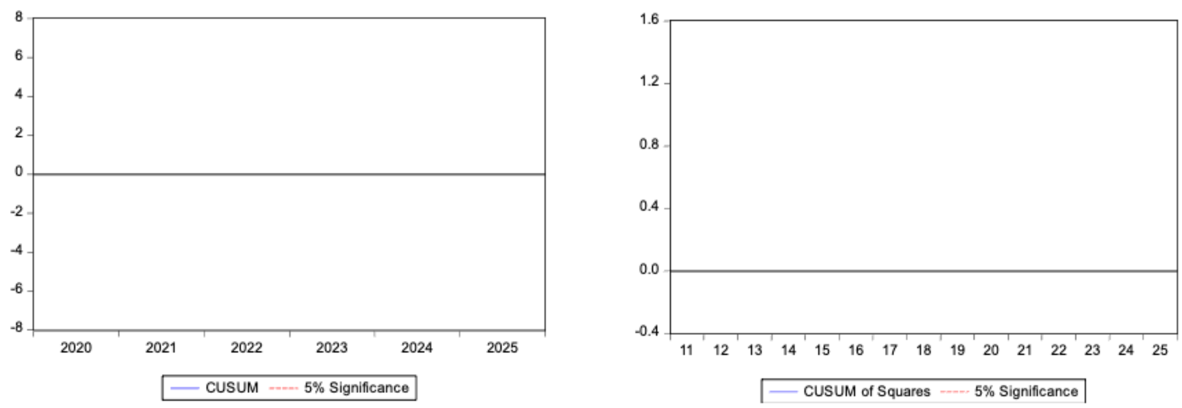
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(FDIXRQ)	2.40	1.34	1.79	0.12
D(FDIXRQ(-1))	-0.42	1.02	-0.41	0.69
D(FDIXRQ(-2))	-2.75	1.03	-2.66	0.04
D(FDIXRQ(-3))	-3.26	1.29	-2.53	0.04
D(TCIXRQ)	-20.68	8.22	-2.52	0.05
D(TCIXRQ(-1))	-35.75	11.16	-3.20	0.02
D(TCIXRQ(-2))	-34.20	10.77	-3.18	0.02
D(TCIXRQ(-3))	-61.22	13.22	-4.63	0.00
D(TCIXRQ(-4))	-40.31	12.92	-3.12	0.02
D(EMPXRQ)	907.67	568.04	1.60	0.16
D(EMPXRQ(-1))	5856.14	1609.16	3.64	0.01
D(EMPXRQ(-2))	4343.51	1060.13	4.10	0.01
D(EMPXRQ(-3))	5279.53	1058.76	4.99	0.00
D(EMPXRQ(-4))	1687.37	944.34	1.79	0.12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ENCXRQ)	-550.85	456.41	-1.21	0.27
D(ENCXRQ(-1))	-4106.56	1204.51	-3.41	0.01
D(ENCXRQ(-2))	-3055.87	736.77	-4.15	0.01
D(ENCXRQ(-3))	-4152.74	759.65	-5.47	0.00
D(ENCXRQ(-4))	-1006.35	671.91	-1.50	0.18
ECT	-0.55	0.08	-6.50	0.00
Diagnostic Test (F-statistics with prob. in parentheses)				
LM Test of Serial Correlation				0.18(0.84)
Breusch-Pagan-Godfrey Heteroskedasticity Test				1.64(0.28)
Jaque-Bera Test of Normality				0.33(0.84)
Ramsey RESET Test				0.65(0.54)

The structural stability test of CUSUM and CUSUM Sq is given in Figure 2. It reflects the stability of the model variance.

Figure 2

CUSUM and CUSUM Sq.



Conclusion and Policy Recommendation

Agriculture value added is crucial aspect particularly for the agrarian economies like Pakistan who rely upon it for their economic growth targets. On the other side, it is essential to have a sophisticated and delivering regulatory quality to achieve the desired macroeconomic objectives. This research observed the agriculture value added against the core variables such as FDI, technological innovation, employment, and renewable energy consumption having all of them interacted with regulatory quality. The Bound Test results confirmed the long run relationship. However, long run and short run coefficients were found to have different state of beings. In case of long run, FDI, TCI, and ENC were found to positively affect agriculture value added during the selected time span from 1990 to 2025. In case of short run, mixed results are observed at different scales. The coefficient of ECT was found significant.

As a policy recommendation, the government and the other stakeholders need to strengthen the vision of favoring agriculture productivity together with regulatory quality. Through the better use of FDI, technological innovation, employment, and renewable energy, the desired objectives are achievable in agriculture sector. Government is considered to take measures for analyzing these outcomes in relation with regulatory quality to observe better functioning of the agriculture sector.

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