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FORECASTING TOMATO PRODUCTION UNDER CLIMATE VARIABILITY IN PAKISTAN

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ABSTRACT

Pakistan contributes the lowest to per capita greenhouse gas (GHG) emissions but is among the five worst affected countries in the world. This paper forecasts tomato production under climate variability in Pakistan. Time series data were collected from Government of Pakistan (GOP), Food and Agriculture Organization (FAO) and World Bank's online sources. Both quantitative and qualitative techniques were applied to analyze the data. For quantitative analyses, dynamic forecasting techniques were used, and qualitative analyses were carried out using the rapid appraisal method. The results concluded that temperature shocks have adverse dynamics on tomato production as well as prices. An ambiguous role of rainfall was found i.e., in some areas it had positive impact while in other areas had negative impacts. Several issues were identified including limited area of production, low yields, pests and disease stresses, labor shortage, poor water management and lack of modern information. It is suggested that value chain industry of tomato must be developed in tomato growing areas Furthermore, the access of farmers to reliable information about weather dynamics must be ensured.

Keywords: Climate variability, dynamic forecasting, Pakistan, price volatility, tomato production

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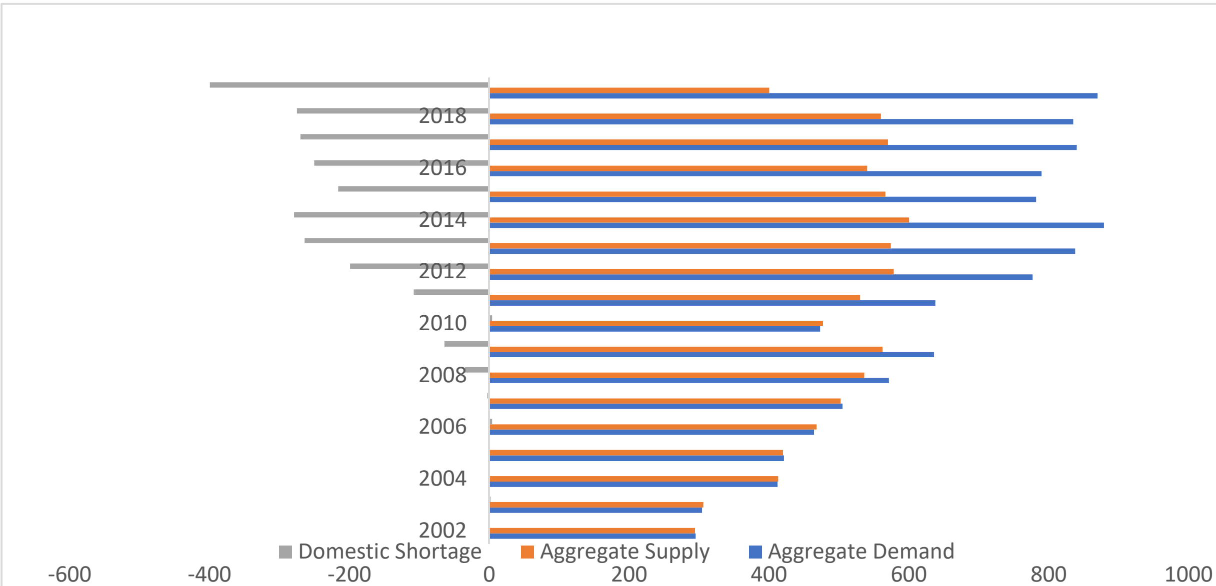
INTRODUCTION

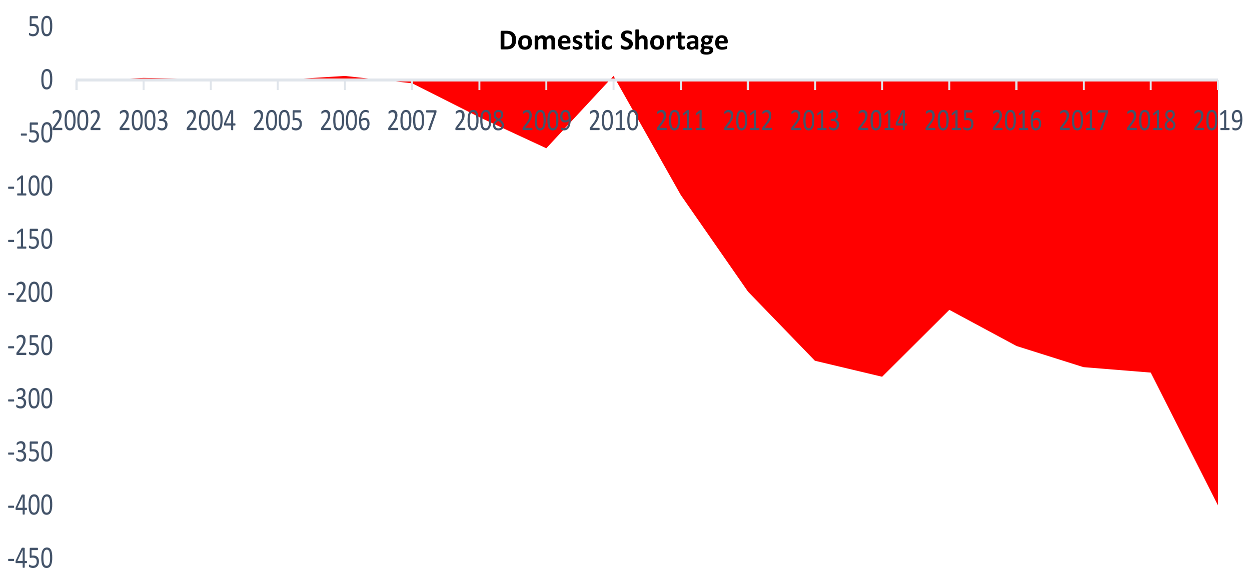
Climate change adversely affects the economy that was involved in subsistence farming. Lack of financial and technical resources are responsible to slow adaptation to these changes (Paltasingh and Goyari, 2013). Pakistan is one of the lowest contributors to per capita GHG emissions in the world but is among the top 5 worst affected countries in the world (CCPI, 2017). Pakistan's agricultural economy is most vulnerable to climate change as nearly 18% of the GDP and agro based industry is dependent on this sector. In addition, climatic stress also poses dangers to national food security by changing the pattern of rainfall, temperature and water availability. There is strong evidence that the changing pattern of rainfall and increasing temperature have a substantial impact on crops production (Bakhsh, 2007; FAO, 2013; GOP, 2016). Weather stress had a serious negative impact on food supply (IPCC, 2012; Christensen *et al.*, 2007) and productivity of different crops (Attoh *et al*. 2014; Cinco *et al*. 2014). Major agricultural crops in Pakistan are Wheat, Cotton, Rice and Sugarcane. However, some crops like tomato, pulses, and vegetables are cultivated on smaller areas but have huge importance due to their central role in food culture and national food security. Tomato is an important crop for both consumers and farmers that is most affected by weather fluctuations due to its perishability and cause social and political turmoil due to production fluctuations. Pakistan ranks at 34th position in terms of tomato production and 11th in terms of area of production (GOP, 2015a). Most of the tomatoes are grown by small farmers having 1-2 hectares of land. The tomato crop is sensitive to climate variability which results into reduction in number of plants, average yield, and farmer's income (Schlenker *et al.*, 2005; Furuya *et al.*, 2009). Lack of processing facilities in almost all the provinces negatively impacts producers and consumers. Farmers often get low prices in peak seasons and must face post-harvest losses. On the other hand, consumers must pay exorbitant prices during off seasons and during the periods of low production (Kirby *et al.*, 2016). The climate vulnerable events have adverse impacts on tomato production that is creating ambient conditions for diseases and pests' attacks, which negatively affect crop yield (Anley *et al.*, 2007). Trend in annual demand and supply scenario of tomato (Figure 1) shows a strong expansion of national tomato demand overtime, however supply was relatively stagnant in recent years.

Pakistan's demand for fresh and processed tomato products is expanding annually driven by substantial consumer demand for value added products like ketchup, sauces, fast foods and hotel chains (Khan and Ghafar, 2013). Furthermore, consumer market is witnessing food diversification with expansion into ready-to-eat food products like pizza, curry gravies and processed foods as compare to traditional use like puree, ketchup, sauces, dried tomato and juices (Noorani *et al.*, 2015, GOP, 2015b). Although the value-added tomato products' demand is expanding, Pakistan's tomato processing industry is usually confronted with the issues of limited supply of tomatoes due to low yields that increase cost and risk (climatic variability) of growing tomatoes at large scale. As a result, the imports of fresh tomato increased enormously since 2008 (Figure 2).



Data Source: GOP 2016 and 2020

Figure 1: Annual demand, supply of tomato and domestic shortage (000 tons)

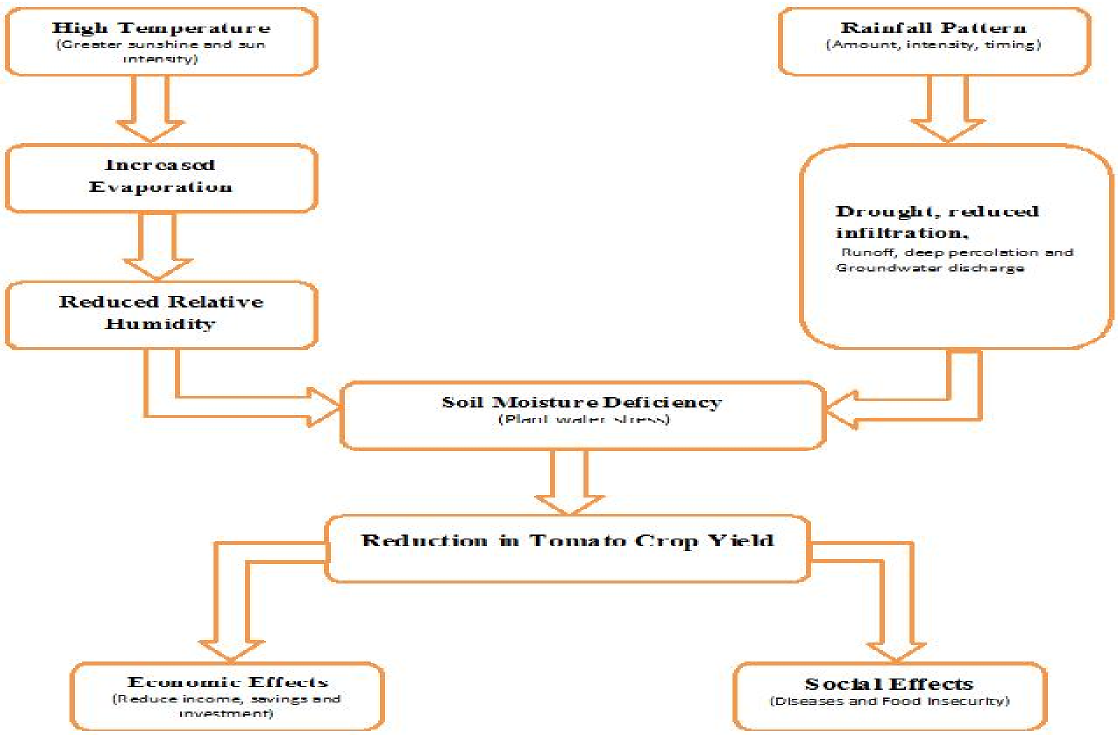


Data Source: GOP 2016 and 2020

Figure 2: Pakistan's domestic tomatoes shortage trend (000 Tons)

The low yield of tomato production mainly attributed to climate variability in Pakistan. In the hot-wet season, production shifts from lowlands to the relatively cooler and dryer highlands. Because highland production areas are limited, tomato supply decreases during the wet season which results in drastic price increases. Although there is plenty of evidence that climate change impacts agriculture growth (Afzal *et al.*, 2011; Arku, 2013; Attoh *et al.*, 2014; IPCC, 2012), but there is very little evidence to tie this issue with respect to perishable commodities like tomato and other vegetables in Pakistan (Ali, 2000; Tahir *et al.*, 2012). The aim of the study is to identify the origin and seasonality of tomato production in Pakistan; assess the short and long run relationship of environmental variables with tomato production; forecast the future trends of these impacts; identify the issues faced by the farmers and commission agents.

Theoretical framework: The available literature revealed that, there is a two-way causation between temperature variability and change in rainfall pattern across the globe, particularly in developing countries and other variables such as the concentration of sunlight and carbon dioxide which all have an increasing trend over the period. It is established that, the climate variability has a great influence on vegetables' and crops' yields in all dimensions of the food security (food accessibility, availability and utilization).



Source: Inspired and designed from FAO (2012)

Figure 3. Climate variability impact on the tomato yield

MATERIALS AND METHODS

Data Collection: This study used the mixed method approach (quantitative and qualitative). Both secondary and primary data were collected. For quantitative approach, the monthly time series data were collected from the period 1991M1[1] to 2018 M1[2]. The data is obtained from "Government of Pakistan", "Food and Agriculture Organization" and "World Bank's climate change knowledge portal".

The rapid appraisal method was used to collect primary data from farmers and commission agents of three fruits and vegetables markets (Lahore, Faisalabad and Multan) in April and August 2018. Telephonic interviews were conducted with 50 farmers and commission agents.

Data Analysis: The first objective was to identify the origin and seasonality of tomato production in Pakistan. To meet this objective, ArcGIS Software was used for mapping the national and regional supply lines of tomato in Pakistan. The prices of tomato were considered endogenous variable and as a proxy for tomato production, and average monthly temperature and rain are taken as exogenous variables. To explain the long and short run relationship of the tomato prices with the climate change by using the ARDL[3] model (equations 1 and 2, respectively).

[1] Month one(January)

[2] Month 12 (December)

[3] Autoregressive distributed lag model

$$\Delta PT_t = \alpha + \sum_{i=1}^{m}\beta_{1i}R_{t-i} + \sum_{i=1}^{m}\beta_{2i}T_{t-i} + \sum_{i=1}^{m}\beta_{3i}\Delta PT_{t-i} + \sum_{i=1}^{m}\beta_{4i}\Delta R_{t-i} + \sum_{i=1}^{m}\beta_{5i}\Delta T_{t-i} + \sum_{i=1}^{m}\beta_{6i}\Delta PT_{t-i} + \mu_t \quad (1)$$

$$\Delta PT_t = \alpha + \sum_{i=1}^{m}\beta_{1i}\Delta R_{t-i} + \sum_{i=1}^{m}\beta_{2i}\Delta T_{t-i} + \sum_{i=1}^{m}\beta_{3i}\Delta PT_{t-i} + \varepsilon_t \quad (2)$$

To forecast tomato prices and other climate change variables and future policy analysis of the explanatory variables changes, Vector Autoregressive Multivariate Forecasting Technique was applied.

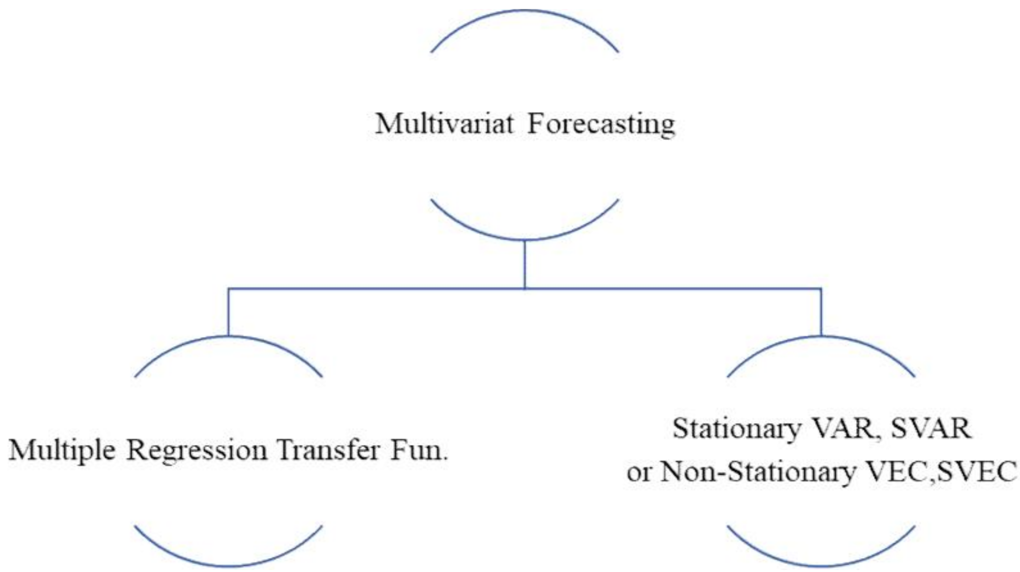


Figure 4: Forecasting technique

General structure of the vector autoregressive (VAR) model for Cotton lint Production:

$$CL_t = \mu + A_1 CL_{t-1} + \ldots + A_p CL_{t-p} + \mu_t \quad (3)$$

Where $A_t \ldots A_p$ are the parameter matrices, and μ_t assume to be normally distributed with zero mean and constant variance?

$$CL_t = \mu + A_1 CL_{t-1} + \ldots + A_{p\max} CL_{t-p\max} + \mu_t \quad (4)$$

The VAR with only $p \leq p_{\max}$ lags (5)

The order p is selected by minimizing the lag order via Akaike information criterion (AIC)

$$AIC(m) = \ln\left|\sum_{\mu}(m)\right| + \frac{2}{T}mK^2 \quad (6)$$

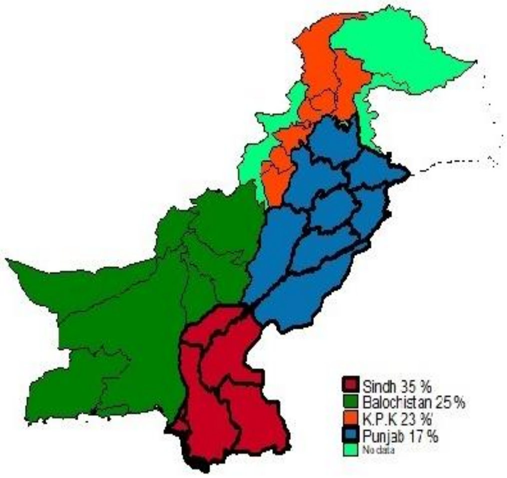
And

$$BIC(m) = \ln\left|\sum_{\mu}(m)\right| + \frac{\ln T}{T}mK^2 \quad (7)$$

At the end in Section II rapid appraisal method was used to collect primary data from farmers and commission agents of three fruits and vegetables markets. Both open and closed ended questions were asked. The telephonic interview was deemed suitable because majority of the respondents (commission agents) were easily accessible on phone call instead of face to face interview.

RESULTS AND DISCUSSION

Origin and seasonality of tomato production in Pakistan: Local production of tomato comes from almost all the provinces of Pakistan at different times of the year. Figure 5 explains the origin and season (time) of tomato supply in Pakistan.



Province	Major Areas of Production	Sowing Season	Availability
Balochistan	Bolan, KharanLasbella, Turbet, Sibi.	Rabi	Nov-March
	Quetta, Loralai, QilaSaifullah, Mastung, Khuzdar, Pishin.	Kharif	Jul- October
Khyber Puktunkhwa	Mardan, Swat, Deer, Malakand, Chitral,Mansehra, Haripur, Charsada	Rabi	Nov – March
	Peshawar, Charsada, Noshera, Mardan,Malakand, Swat, Tanak, D.I.Khan.	Rabi	Nov – March
Punjab	Southern Punjab, Central Punjab,	Rabi	April – May
	Rahim Yar Khan, Khushab		May – June
			Nov – Decembe
			Jan – March
Sindh	Badin, Thatha, Karachi, Noshera Feroze,Nawabshah, Umerkot, Hyderabad, Nasrpur,Mirpurkhas,	Rabi	Nov-March

Figure 5: Tomato Availalablity Clander & Provincewise Production Share (2018) Short and Long Run Relationship Analysis

It is prerequisite to check the stationarity order of all the series before analyzing the time series. Therefore, we used ADF unit root test and the ADF unit root test estimated results at level with and without trend, at first difference with and without trend are presented in table 1. The depicted results of the table 1 shows that we can reject the null hypothesis in case of tomato prices (PT) and Rain fall (R) series at level with trend and concluded prices of tomato (PT) and Rain fall (R) are stationary at level with trend. The temperature series are non-stationary with and without trend at 5%, 10 level of significance and stationery at 1st difference with and without trend.

Table 1: Result of Unit Root.

		at Level		
Variables	Without Trend	Prob. Values	Trend & Intercept	Prob. Values
PT_t	-1.223	0.666	-8.987	0.000
R_t	-4.170	0.001	-4.177	0.005
T_t	1.657	1.000	0.756	1.000
		1st Difference		
Variables	Without Trend	Prob. Values	Trend & Intercept	Prob. Values
T_t	-20.164	0.000	-20.323	0.000

PT=Price of Tomato, R= Rainfall, and T= Temperature.

ARDL long run and short run c-integration relationship between prices of tomato with other climate change variables (Rain Fall and temperature) are presented in Table 2. First part of the table explains the long-term and second part of the table is the short-term relationship between prices of tomato with another climate change.

The volatility of the temperature affects the pattern of crop yield, fruit maturation and time of fruit ripening. The estimated coefficient of temperature shows that there is a positive relationship between tomato prices and temperature as suggested by Hurd and Graves (1984, 1985) that higher air temperature responsible for the higher tomato production. The reported elasticities of the temperature shows that one percent change in temperature lead to increase tomato prices 87.6 percent and statistically significant at 1%,5% and 10% level of significance. One percent change in the rail fall increase the tomato prices 5 percent, but the coefficient of the rain falls statistically insignificant.

The results of short-term relationship between tomato prices with climate change variables (rainfall and temperature) are presented in Table 2. To determine the short-term relationship between the variables the study used the Error Correction Model (ECM). The empirical results indicated that there is a short-term relationship between prices of tomato with climate change variables. The results of Error Correction Model (ECM) explain the convergence pace which is about 62 percent in one year.

Table 2: Results of ARDL

Long-Term Co-integration Forms			
Variable	**Coefficient**	**t-Statistic**	**Prob.**
LNT	0.876	3.749	0.000
LNR	0.050	1.347	0.179
C	3.836	5.427	0.000
TREND	0.006	15.552	0.000
Short-Term Co-Integrating Form			
$\Delta lnPT_{t-1}$	0.134	2.239	0.026
$\Delta lnPT_{t-2}$	-0.101	-1.850	0.065
ΔlnT	-0.106	-0.701	0.484
ΔlnT_{t-1}	0.494	1.997	0.047
ΔlnT_{t-2}	-0.026	-0.111	0.912
ΔlnT_{t-3}	-0.572	-3.838	0.000
ΔlnR	0.031	1.384	0.167
$\Delta TREND$	0.003	7.638	0.000
ECM_{t-1}	-0.616	-9.086	0.000

Adjusted R^2 0.741 F-statistic 92.120*** Durbin-Watson: 1.942
Dependent variable: PT (Monthly tomato price)

Table 3 presented the results of the estimation test after the ARDL boundary which explains the existence of the long-term relationship between tomato prices with climate change variables.

Table 3: ARDL Bounds test.

Test Statistic	Value	K
F-statistic	45.09885	2
	Critical Value Bounds	
Significance	**I0 Bound**	**I1 Bound**
10%	4.19	5.06
5%	4.87	5.85
2.50%	5.79	6.59
1%	6.34	7.52

Null Hypothesis: No long-run relationships exist

The empirical results of the ARDL bounds test verified the existence of long-term relationship between prices of tomato with climate change variables. We can reject the null hypothesis based on F-Statistics value which is grater then upper and lower bounds.

Forecasting Analysis: The forecasted results and future policy prospects of the tomato prices with respect to climate change shock are presented in figure 7. The forecasted results of the study were estimated by using the Vector autoregressive (multivariate analysis) technique. Due to nature of crop "tomato" and data limitation it is reliable that to forecast only for next three years.

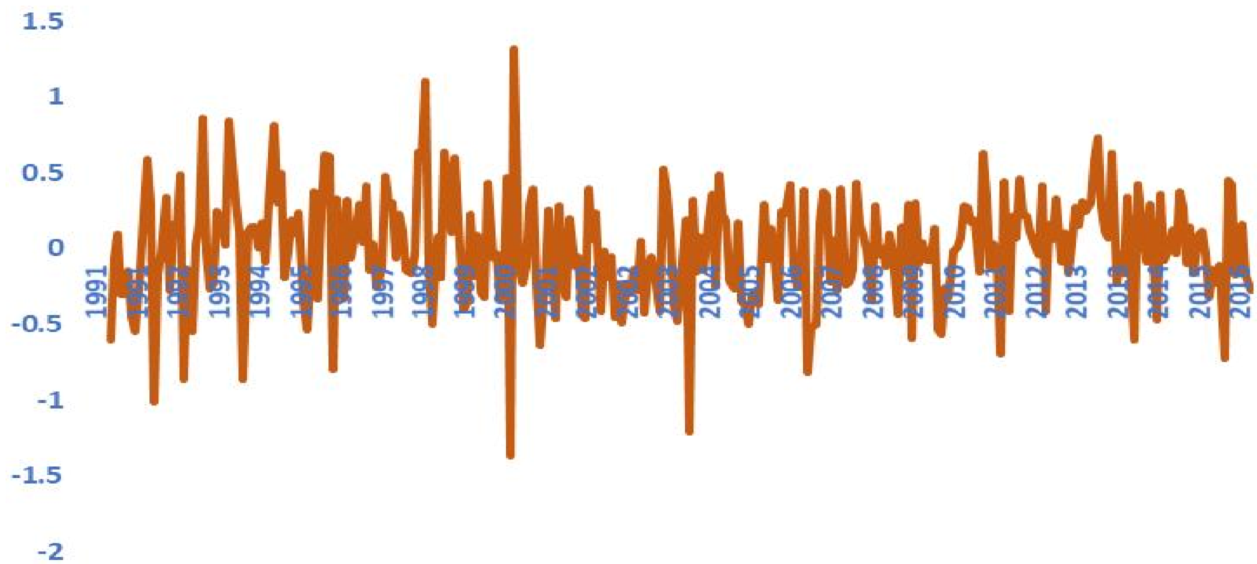


Figure 6: ECM Co-integration Graph

Figures 7 included three panel graphs show output of forecasted trend of tomato's prices, rain fall, and temperature for the period of year 2016 m1 to 2019 m12. Where year 2016m1 to 2019m12 shows the within sample, and 2017m1 to 2018 m12 out of sample forecasted trend of tomato's prices, rain fall, and temperature. The double pipe line shows the trend of actual data (including tomato's prices, rain fall, and temperature), and black line shows the forecasted trend of the data (including tomato's prices, rain fall, and temperature). The VAR forecasted results illustrated parallel trend just like the original series of the tomato's prices. The (Figure 8) shows future trends of average monthly tomato prices, rain fall, and temperature by adopting out of sample forecasting method for Pakistan. This provides useful information to understand the future dynamics about average wholesale tomato prices over the period 2016 and 2019. The (Figure 9) shows forecasted trend which illustrated the price's volatility was a great dis-incentive for both consumers and producers, especially in the context of the consistently low yields achieved by Pakistan tomato farmers as a result of temperature variability.

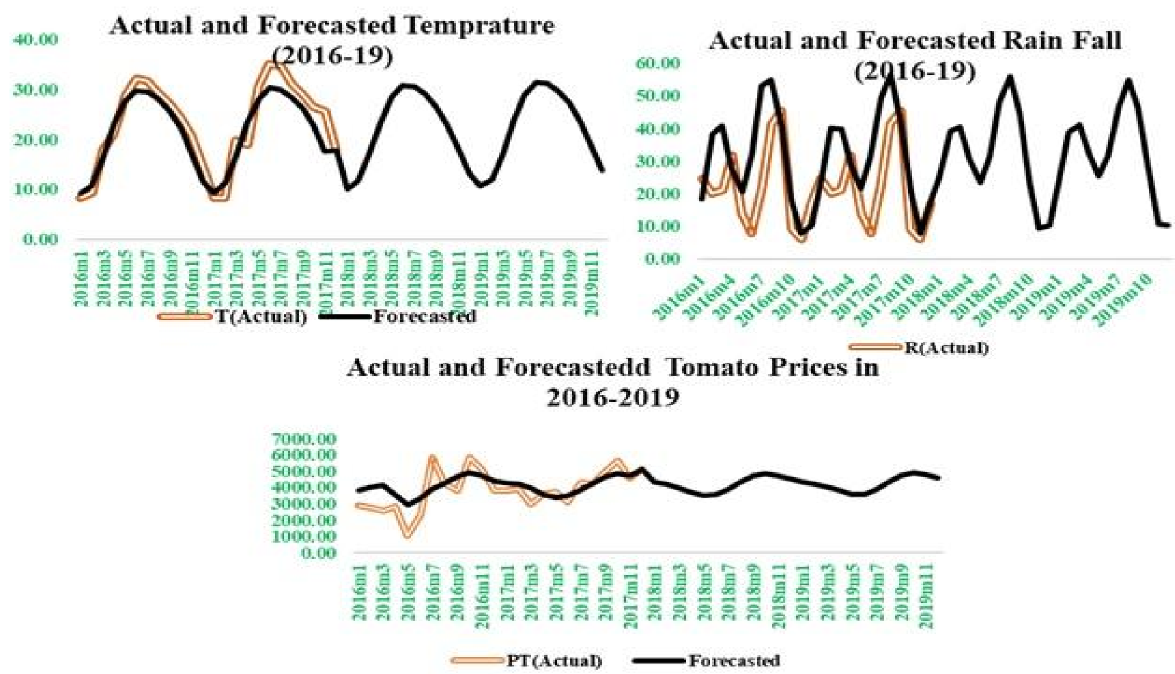


Figure 7 Forecasting results

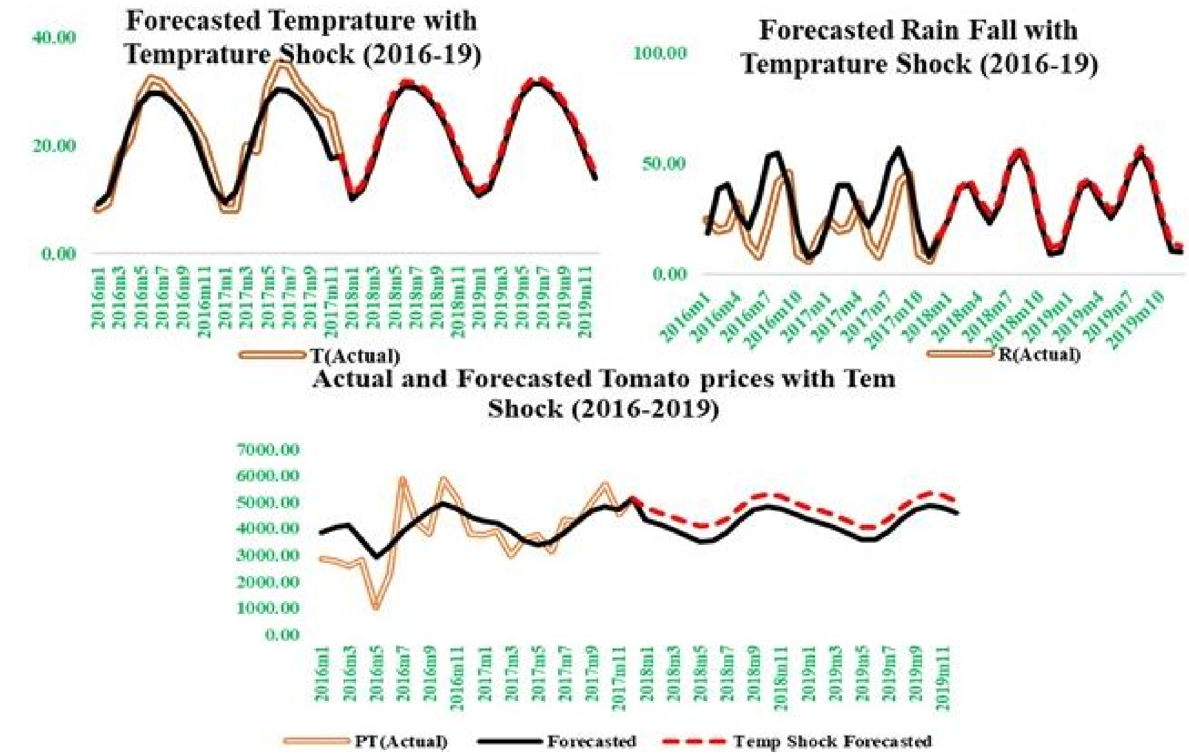


Figure 8: Forecasting results with Temperature Shock

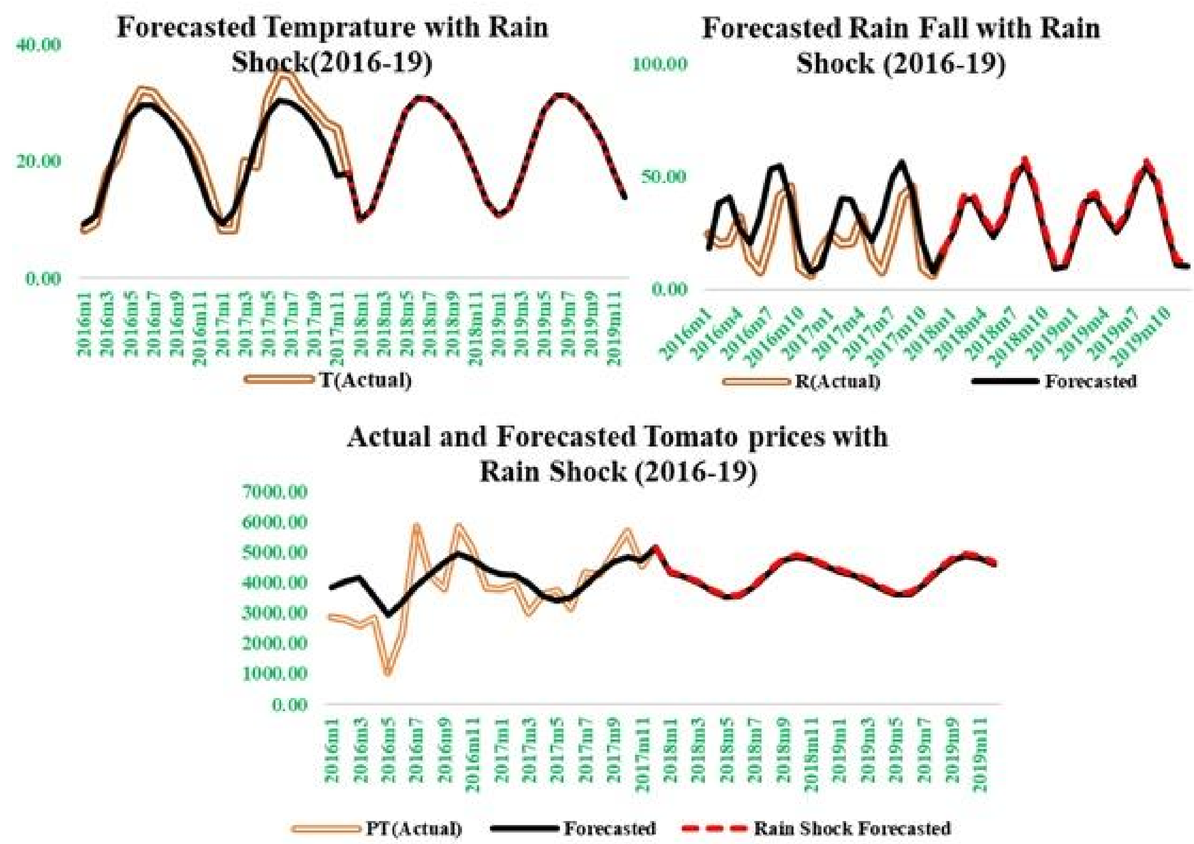


Figure 9: Forecasting Results with Rain Shock

From the forecasting series, there was apparent that temperature variability ~~had~~ adverse impact on tomato yield instead of rainfall. While the impact of temperature on tomato yield has temporal and spatial with respect to prices and the future tomato yield will depend on climate situation and farmer's crop management practices. To increase or maintain tomato yields under climate variability an appropriate adaptation package is required to support tomato cropping systems in near future.

Qualitative analysis

Tomato production issues in Pakistan: A summary of key tomato production issues raised by farmers and commission agents of fruits and vegetables markets after interviewing them and suggested by some responses/solutions are summarized in Table 4.

Table 4: Problems, consequences and possible solutions.

Problem	Reason/Causes	Consequences	Possible Solutions
Limited Area/Production	less profitability, Markets	Price Volatility	Vibrant Market System, Processing & Value chain, crop diversification
Low Yield	Climate Variability (Temperature, Rainfall)	High Price for consumer, High cost for Producer	Appropriate Adaptation, Climate Resistant Seeds
Pest Diseases, Abiotic Stress	Climate Variability, Low Quality Seed	Risk Production cost, Pesticides use	protected cultivation, Resistant crop, IPM, grafting
Labor Shortage	Low MPN, Low income	Labor unavailable, Expensive	Labor Saving Technologies, long Shelf life, Mechanization
Poor Water management	Climate Variability (Temperature, Rainfall)	Low water tables, Water Shortage	Plastic mulches, drip Irrigation
Lack of Modern Information	Illiteracy, Limited Reach of Institutions	Bad crop Management	Private extension services, Technical Training & Workshop, establish link between academia and field

Tomato production decisions is normally linked expected profitability which depends on expected tomato prices. However, due to market imperfections the local farmers could not able to get optimal prices of its output. Similarly, low yield allied with climate conditions and non-availability of hybrid & climatic resistant seed, declining the production area and less profit margins are major causes of deploring production lines. Therefore, an appropriate solutions and responses are listed in Table 4 to mitigate the impact of climate variability and market imperfections.

Conclusion: This study examined the dynamics of climate variability such as rainfall and temperature on tomato production. The forecasting results from the present study could be used as a baseline to understand the consequences of climate variability on fruits and vegetables production. The study came up with conclusion that the temperature shocks had adverse dynamics on tomato production by using monthly time series data for this purpose from 1991M1 to 2018 M1. However, it is observed there was an ambiguous role of rainfall, sometime it was helpful to increase the tomato yield and vice versa. These results could not be too optimistic for Pakistan agriculture system because it is based on a labor-intensive system with very little adaptive capacity. Regarding the climate variables used in this study, particularly temperature, there is sufficient evidence to conclude that agriculture could be affected by future climate change and climate variability, because the results demonstrate a correlation between temperature and tomato production in Pakistan.

The results of the effect of high temperature on tomato production indicates that farmers face production losses. Since Pakistan is highly vulnerable to climate variability and agriculture is the major source of livelihood for more than 60% of total population, therefore it is important to develop the climatic resistant seeds and varieties which can mitigate the climate variability and help to increase productivity. To improve the financial capacity of tomato growers, it is important to develop allied tomato value chain industry that will motivate the farmers to enter into tomato production which will help to reduce poverty in rural areas. The access of reliable information about weather dynamics to enable tomato farmers that could improve the adaptive strategies and planning activities. The pre information about weather conditions will be useful to mitigate the adverse effects of climate variability. Government should take appropriate measures to provide help to vegetables growers such as tomato growers in availability of subsidies inputs (e.g. pesticides, insecticides, climatic resistant seeds and fertilizer).

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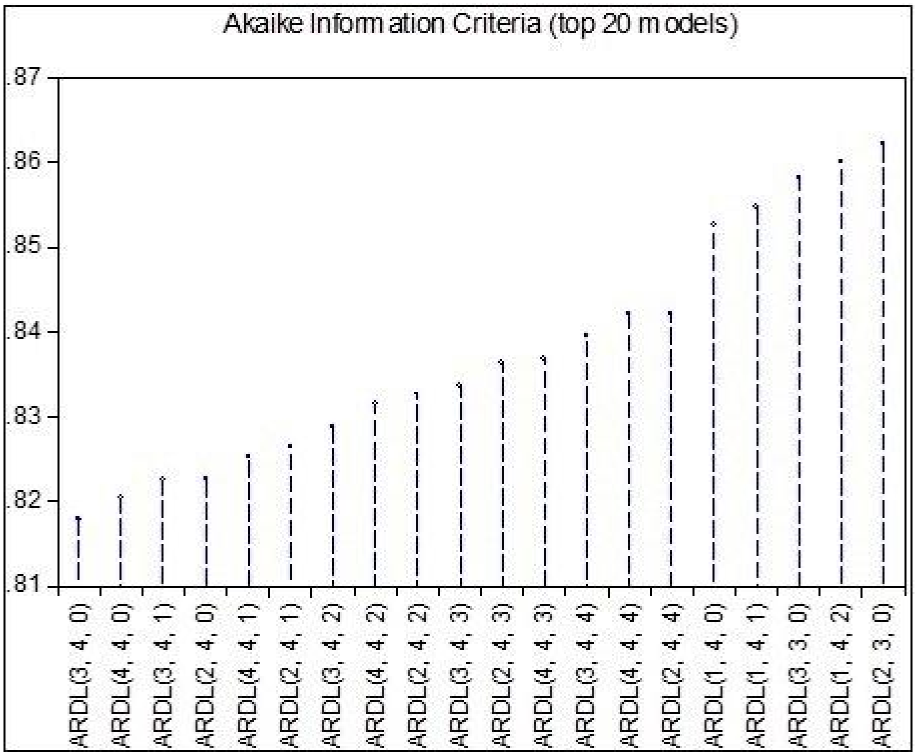

Appendix Lag selection Graph: The lag section criteria are based on the Akaike information criteria (AIC) which are used to select the lag structure of the ARDL model. The results of the graph indicate that out of the different models estimated by using Akaike info criterion, the chosen model with lag order ARDL (3, 0, 4, 4).