Food Price Puzzle and Climatic Shocks Heightened Pakistan: An Application of Machine Intelligence

Abdul Subhan[1], Nabila Khurshid[1], Zarwa Shah[1] and Usman Shakoor[1]

[1]COMSATS University Islamabad

Abstract

This study aims to investigate how climate change (floods and droughts) affects the staple food crops prices in Pakistan. Extant studies on ramification of climate change vulnerabilities on food security are becoming areas of scientific ascertainment. The objective of present study is one step ahead by disaggregating the climatic shocks in different periods to assess the intensity of association with food price puzzle on food security. The current study has evaluated these immoderations on monthly time series data under vulnerable climatic conditions: first period is from January 2000 to December 2004 (droughts) and second period data is from January 2010 to December 2015 (floods). The correlation matrixes visualization which is an application of machine intelligence is applied to dataset. Results discovered that during the drought period 2000 to 2004 rainfall has a negative association with wheat, rice, and maize prices, meanwhile, temperature has a positive association. Furthermore, during the flood period of 2010 to 2015, rainfall has a positive linkage, meanwhile, temperature has negative association with wheat and maize prices except rice prices. To cope and mitigate the adverse impacts of climate change, there is need for the development of heat and drought resistant crop varieties to ensure food security in the country.

Keywords: Pakistan, climate change, price puzzle, staple crops, food security, machine intelligence

1.Introduction

Climate change has been caused mainly by a persistent rise in greenhouse gases, which includes carbon dioxide, nitrous oxide, methane and fluorinated gases that lead to variations in temperature and rainfall patterns. Though climate change is a global issue, its effects are more drastic in case of developing countries that are more vulnerable and possess lesser capacity to curtail its adverse effects. Most of the developing countries, Pakistan included, are based on agriculture as the mainstay of their economies, and this sector is directly exposed to nature hence bearing most of the negative effects. Pakistan is the 5th most vulnerable country to climate change (Eckstein et al. 2019). Agriculture makes up 18.7% of GDP and 60% of the population employed in this sector. A large proportion of the population obtains its income from this sector. Pakistan's total fertile land is 34.54 million hectares, and the cultivated area is 24.4 million hectares (Government of Pakistan 2019). The major staple food crops of Pakistan are wheat, rice, and maize. There are inherently two agricultural seasons namely Kharif and Rabi season. The Kharif season crops are those having crop season from May to November, also called the summer crops. While Rabi season refers to the crops cultivated in winter, having crop season from November to April.

[1]Department of Economics, COMSATS University, Islamabad 45550, Pakistan; subhan2142@gmail.com (A.S); nabilakhurshid@comsats.edu.pk (N.S); szarwashah@gmail.com (Z.S); usman.shakoor@comsats.edu.pk (U.S)
*Correspondence: subhan2142@gmail.com; Tel.: (+92 334-5286286)

Climate change causes variations in temperature and rainfall patterns, droughts, floods, and adverse impacts on agricultural production (Kurukulasuriya et al. 2006; Men-delsohn 2018). Novel research in developing countries like Africa and Asia, has investigated the effects of climate change about agricultural production and agricultural food prices (Kurukulasuriya et al. 2006; Mendelsohn 2018). Most climate models anticipated a rise in rainfall during summers (Mirza 1997). The glaciers in the Himalayas are melting at a rapid pace and are likely to vanish by 2035. A fall or rise in intensity is likely to cause either floods or droughts respectively (Misra 2014). Crop productivity will be affected because of climate change, and this may lead to problems with regard to food security and agricultural food prices (Splash 2007; Kirby et al. 2016). Global warming is expected to cause a rise in yields owing to the fertilizer effect, however farmers will be adversely affected.

For instance, countries that lie near the equator may face a reduction in production (Droogers and Aerts 2005). If agricultural production and food prices are affected by climate change in lower income Asian and African countries, many populations will be exposed, and food insecurity will rise. In developing economies, the driving force regarding food security is climate change, as it has major impacts on agricultural productivity, food prices as well as elements of the food system, such as storage, accessibility and utilization (Wheeler and Von Braun, 2013). In general, climate change does not affect the global production of food in a major way, however these impacts have an uneven distribution in terms of geography. Lower income countries, especially the ones in sub humid and arid South Asia and Africa, suffer the most losses. These areas depend on subsistence agriculture, not possessing enough technical soundness or financial strength to deal with the adverse effects that come with changes in climate. There is next to no potential about adaptation (Kurukulasuriya et al. 2006). The population of these countries suffer negative impacts as they mostly rely on agriculture to earn their living.

The Food & Agriculture Organization (FAO) estimates that the number of people that are undernourished around the globe stands at 795 million. These numbers show that over the last two decades, there has been a decline of around 200 million people (Food and Agriculture Organization, 2020). Most of the people facing hunger around the world reside in Sub-Saharan Africa and South Asia (Vermeulen 2012). South Asia is the region most exposed to climate change (Banda-ra and Cai 2014). Above 70 percent (nearly 1.1 billion) of South Asia's population live in rural areas and depend on agriculture, nearly 75% of them are poor people (World Bank 2012a). About 18 percent of the GDP of the region depends on agriculture, which provides employment to more than half of the region's population (World Bank 2012b). Aside from this, agriculture and food security can be threatened because of changes in spatial as well as temporal rainfall distribution, capital, land, availability of water, terrestrial resources and biodiversity due to climate change. About 9 billion people could become food insecure owing to fluctuations in agricultural production by 2050. Research has also found that rising temperatures and alteration in rainfall patterns has tremendous impacts with regard to food production (Kirby et al. 2016; Janjua et al. 2010). It is expected that South Asia's wheat production will fall by half by 2050, which amounts to nearly 7 percent of the world's production of crops (de Fraiture et al. 2007). According to the Peterson Institute, developing countries will suffer a 10 to 25 percent decline in agricultural production, and if global warming continues unabated, it will lead to a 40 percent decline in India's agricultural capacity. Therefore, food security is seriously threatened by climate change (Spash 2007; Bandara 2014), adverse effects on crop productivity and prices (Arnell 2004; Rosenzweig and Parry 1994), as well as costs of adoption with respect to changes in climate are very high (Kandlikar and Risbey 2000).

Hence, Pakistan's government has focused upon food security in its policies. Pakistan's prominent food crops are rice, wheat, and maize. The food security policy therefore mainly concentrates on the aforementioned crops. In view of these considerations, this research work has been done to investigate the interconnection among climate change in terms of temperature and rainfall patterns, and agricultural food prices in context of Pakistan. Moreover, we take this study analysis one step further by disaggregating the climatic shocks in different periods to get a more understandable look at the root of the issue.

2. Review of Literature and Background of Previous Studies

A sparse amount of research and studies have deliberated footprints of food price puzzle idiosyncrasy. It is anticipated that there will be noticeable changes in temperature and average precipitation on regional and global levels. Research has predicted significant effects of rainfall patterns and temperature around the globe over the next hundred years owing to climate change (Intergovernmental Panel on Climate Change). These alterations in the climatic system are likely to have severe impacts on agricultural production over the next hundred years. A rise in climate change has been considered as an anomaly on a global level which may have lasting consequences, including increased frequency of extreme weather events. These changes in climate are likely to have impacts on those who live in agricultural communities and developing countries (Maskery et al. 2007). Climate change has severe impacts on the population of countries in South Asia, as these countries depend upon agriculture as their main source of livelihood. As a result, their economic, ecological, and social systems are seriously threatened (Ahmed and Schmitz 2011). South Asia Climate Change Strategy by the World Bank has made the announcement that owing to limited resources, geographical conditions and more dependence upon sources of income that are sensitive to climate, the region's poor people are likely to bear the most severe consequences of climate change. Climate change is the reason why countries like India and Pakistan were exposed to frequent extreme weather episodes such as flash floods, causing poor people to be stuck in poverty trap (Mendelsohn and Dinar 1999).

As the agriculture sector is most vulnerable to climate change, it is likely to be affected the most (Mendelsohn 2001). The fluctuations in climate change are an important hurdle in agricultural production and a great challenge in terms of a rise in agricultural food prices, affecting nearly two and a half billion of population that rely on agriculture fully or in part. Variability in climate greatly affects the agriculture sector therefore it is a risky activity (Ji-kun 2014; Ullah et al. 2016). Climate change poses threats to agricultural production on a global scale (Godfray et al. 2010). Different regions and various crops are affected differently by climate change, however agricultural productivity is likely to fall (Musser 2002). Some of the fall in agricultural production is evident. A calculation shows that global maize yield was reduced by 3.8% from 1980 to 2010 due to climate change (Drollette 2009). Farmers felt less threatened in comparison with crops, however they were exposed and endangered due to climate change (Yousuf et al. 2014).

Climate change is causing extreme weather conditions resulting in economic losses (Ali and Erenstein 2017). Rainfall patterns are likely to be altered and average temperature is projected to rise. Furthermore, more extreme events as well as floods are likely to occur over the next decades. Climate change has significant effects on productivity of crops as well as implications in terms of food security (Spash 2008). Yields are hypothesized to be boosted due to global warming, as rising atmospheric carbon gives off the effect of a fertilizer, however the effects are adverse in case of poor countries. An example of this is that food production will be reduced in countries that lie close to equator owing to global warming (Droogers and Aerts 2005). Food shortages as well as droughts are likely to extend in African and Asian countries. As Indonesia and Pacific islands rely upon imports, there will be increased poverty and social problems therein. A study by International Water Management Institute has forecasted that there is likely to be a 50% decline in wheat production by 2050 (de Fraiture et al. 2007). Fluctuations in climate pose a serious risk to food systems and agriculture, thus causing a rise in food prices. As extreme weather events become more frequent and severe, agriculture has been increasingly flawed (Ji-kun 2014). Natural disasters such as pests and capricious rainfall are regularly befalling farmers. These farmers face floods, heavy rainfall, diseases, and pests (Ullah et al. 2016), as well as fluctuations in market prices and droughts (Iqbal et al. 2016). A report related to production reveals that marketing, financial, environmental, legal as well as human resources pose significant risks to agriculture (Drollette 2009). Five important causes of risk are: production risks associated to variation in crop yields as well as livestock from different sources (for example, unanticipated weather episodes, incidence of disease, as well as pests). Next, financial risks including the inability of a farmer to pay bills for sustainable farming. Third factor is marketing risks that involve fluctuating prices in terms of agricultural goods. Fourth factor is environmental and legal risks. Lastly, human resources are narrow, for example there may be few family members that may be involved in farm management and labor. Resultantly, prices are negatively affected. Price risks must therefore be perceived and regulated appropriately.

Pakistan's weather constitutes of freezing winters and hot, dry summers. The country has diverging geographical characteristics, with deserts, plains and coastline towards the southwest, the center is characterized by plateaus, and high mountains in the center, southwest, north and northwest. There are different climatic conditions in different geographical locations; some of the areas a very hot while others are very cold, and some are moderate throughout the year. Historical data reveals that this region receives less precipitation in comparison with adjacent regions. The country is characterized by river water systems that is a main source of water supply to agriculture (Yousuf et al. 2014). Agriculture plays a very important role in reducing poverty and maintaining food security. Agriculture can also be affected because of rise in temperatures and its impacts on cropping seasons, rise in heat stress with respect to crops and rise in evapotranspiration. The adverse impacts of these climatic threats can be diminished if crop varieties of short duration are introduced or if sowing time of crops is modified (Ali and Erenstein 2017).

Owing to differing climatic conditions, Pakistan stands at a high susceptibility index in terms of climate change in comparison with a lot of countries in the world. Pakistan has recently gone through changes in climate including increased temperatures, fluctuations in patterns of precipitation, shifts in weather, earthquakes, floods etc. Pakistan does not contribute significantly to emissions that caused the situation of climate change to worsen, however it still stands at a high vulnerability index. There is high requirement to adapt to the changes (Yousuf 2014). Pakistan's agriculture sector has experienced three huge floods since 2010 that has had serious negative effects on the entire economy, specifically the agricultural sector. Owing to monsoon floods in 2010, 2011 and 2014, agriculture crops, forestry, livestock, fisheries were destroyed on a massive scale and important infrastructure like tube wells, houses, fertilizers, animal shelters, people, agricultural equipment, seed stocks and water channels were also damaged. The flood occurred just before the main crops such as rice, maize, wheat, vegetables, and sugarcane were to be harvested. Yield loss related to the main crops caused approximate production loss standing at 13.3 million tons. 1.2 million livestock, poultry included, were killed because of the 2010 flood, as well as the destruction of 2 million hectares worth of standing crops (World Food Program 2010). The huge flood of 2011 that occurred in the Sindh and Baluchistan province had severe adverse impacts on the population of these provinces in terms of lives lost, and loss of agricultural activities. Nearly 80% of rural Sindh's population that lives in rural areas is dependent on agriculture such as crops, fisheries, livestock, and forestry for their economic survival (National Disaster Management Authority 2011). There were heavy losses due to the floods of 2011, including loss of precious lives and destruction of standing crops including sugar cane, rice, sorghum, pulses, vegetables, cotton as well as livestock. The livestock that was killed stood at 115500, while 5 million man-aged to survive, however they faced dislocation and diseases. The total loss was predicted to be $1840.3 million in terms of US dollars. The direct damage was 89% while indirect victims were 11%. The agricultural sector was damaged to the maximum extent, amounting to US dollars 1.84 billion, specifically to fisheries and livestock. The floods of 2011 caused damage worth US$3.7 billion. The cost for rehabilitation and revival is estimated to be US$2.7 billion (Government of Pakistan 2020). Floods and heavy rains affected 2.5 million people, causing the death of 367 people in the September 2014 floods. Cultivated land worth 1 million acres, 129880 houses as well as 250,000 farmers were affected. 439.7 million US$ and 56.2 million US$ were spent on recovery as well as building resilience respectively (National Disaster Management Authority 2011). The previously mentioned numbers reveal that floods affected the agriculture sector most severely in Pakistan.

Adaptation is a matter of great interest leading to the formulation of many definitions related to climate adaptation. The Intergovernmental Panel on Climate Change has termed it to be "The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Broader definitions have been formulated by others, together with actions that improve the society's situation due to climate change (Iqbal et al. 2016). Past literature has indicated that if land is not used properly and if drought occurs, this may have effects on local agriculture, while losses caused by disaster may be diminished through rational management related to use of land (Fu et al. 2013). An example of this is that Malaysia needed a long-term policy related to land use so that the adverse effects of climate change could be mitigated (Alam et al. 2012). Likewise, there are many ways in which climate change can be tackled including use of hybrid seeds (Deressa et al. 2009), planting on different dates as well as altering type of farming such as in South Africa (Bryan et al. 2009). Over the last decade, the government of China attempted at adaptation to climate change by means of nationwide reforestation programs that lead to huge environmental benefits (Zhou and Turvey 2014). There are serious challenges to the sustainability of food systems due to the vulnerability of agriculture to climate change. The rise in temperature as well as fluctuations in rainfall caused by climate change may reduce the advantages related to agricultural production (Walthall et al. 2012). IPCC and the Kyoto Protocol are of the view that there are various forms of adaptation (Adger et al. 2003). The term adaptation is used about climate change related vulnerability. The perception related to climate change is what determines the adaption. That is how people may respond to climate change. Perceptions are shaped by an individual's knowledge, experience and observed effects of a change in climate. An example of this is the change in variety of crops, more water conservation, and a switch towards non-farm activities by farmers in eleven African countries due to temperature changes (Maddison 2007). If precipitation changed, they changed the dates for plantation. Likewise, it was found that commonly used strategies by farmers in Ethiopia and South Africa include planting various varieties of crops, conserving the soil, tree cultivation, and altering the dates regarding plantation as well as irrigation (Bryan et al. 2009). It was found that farmers who lacked credit, had little access to land or information could not adopt any strategy for adaptation to climate change because of these hurdles (Bryan et al. 2009).

Pakistan is one of the country's most highly vulnerable to changes in climate. For the period 2020, the Global Climate Risk Index ranked Pakistan at 5th position about the fact that it was exposed to extreme weather episodes. The World Bank termed Pakistan as the 12th most vulnerable country regarding change in climate (Nomman and Schmitz 2011). Pakistan's economy has its basis in agriculture, contributing 19.8% to gross domestic product and employing 42.3% labor force, giving sustenance to about 62% rural populace (Abid et al. 2011). Aside from being extremely important for Pakistan, the agriculture sector faces problems due to climate change, for example yield losses, food price instability, droughts, floods and increase in temperature (Nomman and Schmitz 2011). The past few decades have seen the impacts of climate change to become obvious, affecting lower income countries in particular. Pakistan faces extreme climate episodes such as floods, high temperature, droughts, water shortages, and more diseases as well as pest attacks (Smit 2002). The droughts that continued from 1999-2003 and the floods that continued 2010-2014 are some of the examples regarding Pakistan's climate related events. Climate change is expected to have negative effects on Pakistan's economy because of the occurrence of extreme weather episodes, including droughts, changes in patterns of rainfall and floods. As Pakistan relies on natural resources and so it is especially exposed to climate change. As a result, adaptation measures are necessary (Abid et al. 2015).

Thus, considering the recent and anticipated climate changes in the near future, this research work investigates the association of climate change with regard to temperature and rainfall pattern on agricultural food prices in Pakistan. The significance of this study lies in the fact that Pakistan is severely exposed to climate change and as a result, the situation of its food security is not satisfactory.

3. Material and Methods

Ensuring Food Security has been an international commitment since the Millennium Development Goals and has been further reaffirmed by the Sustainable Development Goals in 2015. Yet the situation of food price puzzle on food security is a rising concern with excessive importance headed for its wide socio-economic implications. Scientists, policymakers and economists have been making struggles to examine the potential paraphernalia of food price instability to fortify the objectives of sustainable agriculture development of United Nations' by 2030. Given the bulging population growth, Pakistan is also faced with an ongoing crisis of food price puzzle. Therefore, the contribution of the present study highlights climatic shocks as a key reason for the food price puzzle in the agricultural economy of Pakistan. This analysis is one step ahead by disaggregating the climatic shocks in different periods to get a more rigorous look at the underlying issue. This study is a pioneer in that the nature of it is to take a lead and address this important issue for the major agricultural commodity prices for Pakistan and using state of the art machine learning technique Matrices Visualization.

3.1. Correlation Matrixes Visualization

The correlation matrixes visualization was invented by American Statistician Michael Friendly in 2002. Correlogram is a graph of correlation matrix. It is very useful to highlight the most correlated variables in a data table. In this plot, correlation coefficients are colored according to the value. Correlation matrix can be also reordered according to the degree of association between variables. This method helps to visualize and analyze data, also indicative for advanced analysis. It also advantages in dimensionality reduction, better decision making, time saving and cost-effective means to investigate that bring off Artificial Intelligence (AI). This study is pioneer in that the nature of it is to take a lead and address this important issue for the major agricultural commodity prices for Pakistan and using state of the art machine learning technique Matrices Visualization.

Furthermore, to develop the Matrix's Visualization, world high-level programming language Python is used. Python is a mass-market coding linguistic and very easy to acquire. It is progressively used in technical fields and accessible for all main operating systems. The principal linguistic can be prolonged to numerous packages. A multitude of those packages is appropriate for scientific research, of which widely used are Numpy (Walt et al. 2011) and Pandas (McKinney 2010).

For the comparison and interpretation of multiple years of fluctuating climatic conditions with food price puzzle on food security, firstly, this study standardized the dataset. By standardizing the data, it is easy to compare and interpret results on the same scale. For standardization, the z-score approach is used. In machine learning, z-score is then several standard deviations that measure the value of raw score above or below the average value of what is being measured. Its value is either 0 or 1, where 0 represents raw score which is equal to mean value and 1 represents the raw score which is 1 standard deviation greater than the mean value. Its value is computed by the following formula as given in equation (1).

$$\text{Z- Score} \quad z = \frac{x - \mu}{\sigma} \text{-------------- (1)}$$

Where, x = Raw Score, μ = Population Mean, σ = Population Standard Deviation

The Pandas package (McKinney 2012) is used for the import and export of data. Moreover, the "2-dimensional labeled data structure" pandas' data-frame is used for the storage and handling of data. Thus, we exported standardized data-frame to CSV file, to have a machine and human-readable that can serve as a basis for further work.

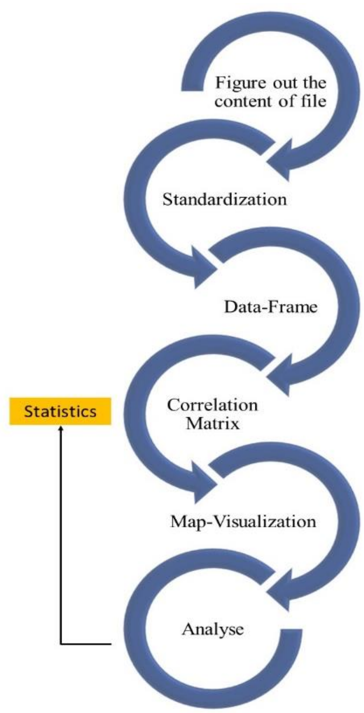
The key feature of the data-frame is the capability to certainly create a correlation matrix from it. Therefore, this study easily obtained Pearson Correlation Coefficients for every time series paring. Pearson Correlation Coefficients measure the strength between variables and relationships. It ranges from -1.00 to +1.00. If the value is negative it means variables have an inverse relationship or an increase in one causes another to decrease. If the value is positive, it means variables have a direct relationship or an increase in one causes the other to also increase, and vice versa. Its value is computed by the following formula as given in equation (2).

$$r = \frac{n.\sum(xy) - \sum(x)\sum(y)}{\sqrt{[n.\sum x^2 \;\; \sum(x)^2] - [n.\sum y^2 \;\; \sum(y)^2]}} \text{------------------------ (2)}$$

n = Number of Pair of Scores, $\sum(xy)$ = Sum of the Products of Paired Scores, $\sum(x)$ = Sum of *x* Scores, $\sum(y)$ = Sum of *y* Scores, $\sum(x^2)$ = Sum of squared *x* Scores, $\sum(y^2)$ = Sum of squared *y* Scores

In contrast to single correlation coefficients, the map representation of correlation matrix visualization allows a convenient approach. For map visualization of data, python seaborn packages are used [Hunter, 2007]. The planned research method is described in Figure 1. Our dataset consists of wheat, rice, maize crop prices, temperature, and rainfall. The dataset consists of floods and drought periods in context of Pakistan. Under vulnerable climatic conditions: the first period consists of January 2000 to December 2004 (droughts) and second-period data from January 2010 to December 2015 (floods). The data of wholesale crop prices has been taken from Index Mundi Data and Statistics (Index Mundi Data and Statistics 2019). The data of rainfall and temperature has been collected from the Pakistan Meteorological Department Government office in Islamabad. The description of selected periods is extensively provided in introduction and literature review sections. After figuring out the content of the file, we standardized all period's data and framed it into a "2-dimensional labeled data structure" pandas' data-frame. Then we analyzed the correlation between wheat, rice, maize crop prices puzzle with different subsets of climatic conditions of Pakistan and finally, map visualization. Matrixes used multiple colors to show the magnitude of correlation. In case of positive correlation, lighter the color higher the magnitude of correlation and darker the color, lower the magnitude of correlation while in case of negative correlation, lighter the color, lower the magnitude of correlation and darker the color, higher the magnitude of correlation.

Figure 1: Planned Research Method Matrix Visualization



(Source: Author Created)

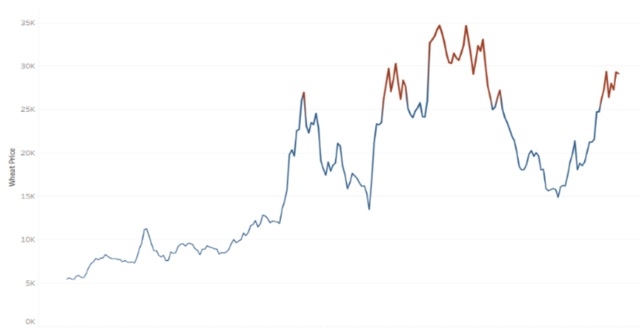
3.2. Data Description

Given the presumable increase in climate change in the coming decade, are reputed as a threat to consummating the goal of food price stability for Sustainable Agriculture Development of United Nations' by 2030. Pakistan has already a long history of food price puzzles. Most of the previous literature has pointed out the issue of food insecurity concerning agricultural production and yield in the context of Pakistan. The literature focused on the food price puzzle in connection with climatic shocks is somewhat limited. Therefore, this study would guide policymakers and the painstaking leaders of the country to identify how climatic vacillating conditions affect food prices. Moreover, this analysis will help the acting bodies to device climatic strategies, to secure food price stability in Pakistan. All the more, the study will prove as a stepping-stone for the researchers and economists to carry out further investigation for crops in Pakistan. This section illuminated data, its sources, and time-frequency with the complete information about measuring units of chosen variables along with the graphical view of the collected data. For a graphical view of data this study uses American insightful and intuitive data visualization TABLEAU software. The data of crop prices have been taking out from Index Mundi Data and Statistics. The data of rainfall and temperature have been collected from the Pakistan Meteorological Department Government office in Islamabad.

3.2.1. Wheat, Rice and Maize Prices

The main objective of this study is to see the influence of climatic shocks on food price puzzle on food security. Wheat, rice and maize are the major staple crops of Pakistan and directly associated with food security. Price explosiveness has a strong influence on food security because it affects purchasing power. Simply put, the higher the price, the more robust the welfare concerns of volatility for buyers. This relation implies that concentrating only on productivity will not address overall welfare concerns. Thus, this study addresses the price behavior.

Figure 2: Wheat Price January 2000 – January 2019



From above Figure 2, the general pattern of wheat price series across the time-period can be observed. It is noticed that prices were inconsistent and going up in June 2007 to September 2008 because of global financial crisis, along with the decrease in prices and upswing in May 2010 to July 2011 owing to reduction in wheat crop productivity due to extreme floods and increase in oil prices. Further, with the drop in prices which later started increasing in 2013 January to February 2014 by reason of extreme climatic factors and Punjab government's failure to reach a desired target. Again, it is noticed that prices were changing and growing in December 2018 to January 2019 due to government's inefficient polices and currency depreciation. However, red color in wheat prices series highlights the price hikes across the time-period.

Figure 3: Rice Price January 2000 – January 2019

From above Figure 3, the general pattern of rice price series across the time-period can be observed. It is noticed that prices were changing and going up in June 2017 to September 2008 because of global financial crisis and were on the decrease in 2010-11. Further, there was a drop in prices which then started increasing in January 2013 to February 2014 owing to increase in export supplies. Again, it is observed that prices were changing and increased in December 2018 to January 2019 due to government's inefficient polices and currency depreciation. However, red color in rice prices series highlights the price hikes across the time-period.

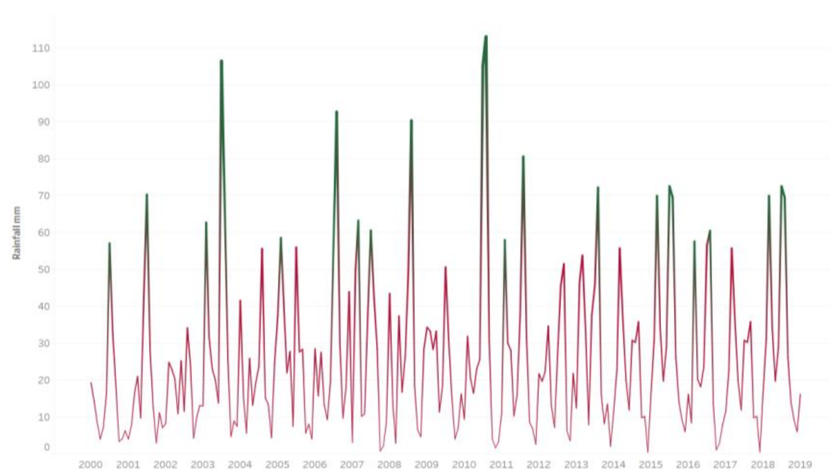
Figure 4: Maize Price January 2000 – January 2019

From above Figure 4, the general pattern of maize price series across the time-period can be observed. It is seen that prices were inconsistent and going up in June 2007 to September 2008 because of global financial crisis, along with the decrease in prices and growing in May 2010 to July 2011 due to increase in oil prices. Further, there was w drop in prices which then started increasing in January 2013 to February 2014 due to projected decrease in imports by five million bushels. Again, it is noticed that prices were changing and increased in December 2018 to January 2019 owing to government's inefficient polices and currency depreciation. However, red color in maize prices series highlights the price hikes across the time-period.

3.1.2. Rainfall

The mean monthly rainfall used as first climatic variable in this study to analyze the impact of climatic shocks on food price puzzle. Changes in rainfall have linear or non-linear impact on food production leading to puzzle in food price (FAO 2011). A certain amount of rainfall is required for crop to survive and to increase its productivity. However, extreme natural events like irregular rain, floods and droughts have serious influence on regional and global food security which raises food price.

Figure 5: Rainfall January 2000 – January 2019

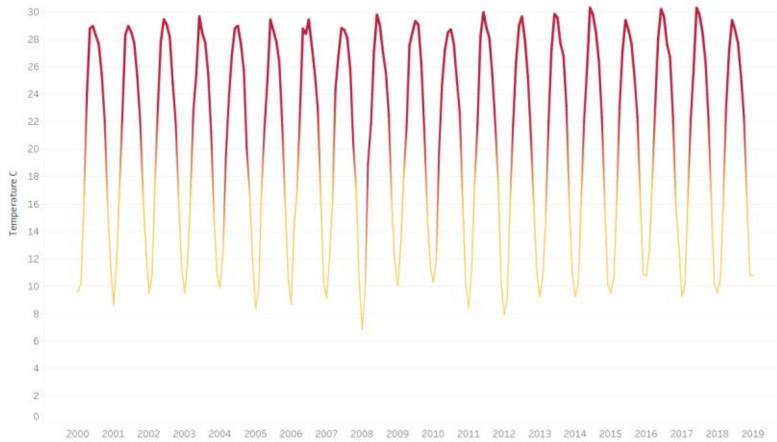


From above Figure 5, the general pattern of rainfall series across the time-period can be observed. The figure shows that rainfall data is rising and declining on seasonal basis. Further, it becomes easy to understand that rainfall is maximum during monsoon months from June to September as classified in green color.

3.1.3. Temperature

To assess the impact of climatic shocks on food price puzzle, mean monthly temperature is also incorporated as second climatic variable in this study. Variability in temperature has symmetric and asymmetric impact on agriculture production leading to puzzle in food prices (FAO 2012). Like rainfall, a definite volume of temperature crop is needed to go through the photosynthetic process for subsistence and increased productivity. However, extreme climatic events like heat spells and periods of frosts could cause serious threats for food productivity and prices.

Figure 6: Temperature January 2000 – January 2019



From above Figure 6, the general pattern of temperature series across the time-period can be observed. It is found that temperature data is rising and declining on seasonal basis. Further, it becomes distinct that temperature is maximum during summer months from April to July as classified in red color.

4. Results and Discussions

This section explains descriptive statistics of all the selected variables to get a basic idea of the existence of any pattern in the series. Then the empirical results based on the ultramodern approaches Matrix's Visualization. Moreover, shadowed by a comprehensive explanation and interpretation of empirical findings. The evaluation of empirical findings with the remaining studies is also presented. For descriptive statistics influential statistical STATA 16 software is used. Furthermore, to develop the Matrix's Visualization world high-level programming language Python is used.

4.1.Descriptive Statistics

This section provides the basic summary statistics to give a brief overview of the pattern (if any) in the variable series considered. The descriptive statistics include mean, standard deviation (SD), median, skewness, kurtosis along with the minimum and maximum values in each time series considered. These results of descriptive statistics are given in Table 1, below:

Table 1: Descriptive Statistics

Variable	Mean	SD	Median	Min	Max	Sk	Kurt
Wheat Price	17722.58	8395.433	17634.63	5443.88	34665.46	0.27	1.83
Rice Price	32419.16	16402.91	38815.13	9270.69	61146.25	-0.14	1.37
Maize Price	14039.97	7571.736	14017.31	3898.35	31461.29	0.43	2.14
Rainfall	25.0481	21.44328	20.0550	0.411470	113.1860	1.48	5.33
Temperature	20.63422	7.278660	22.29040	6.835780	30.30580	-0.31	1.60

Note: Sk = Skewness measure; Kurt = Kurtosis measure

Table 1 describes measures of central tendencies and variation or dispersion for each of the chosen data series. It can be noted that mean and median prices of wheat are near to one another signifying that the wheat series has symmetric distribution. The minimum price of wheat was 5443.88 PKR per metric ton in April 2000 while the maximum price was 34665.46 PKR per metric ton in November 2012. While the mean price of rice is less than the median price implying that the series is left-skewed and rice series has an asymmetric distribution, the minimum price of rice was 9270.69 PKR per metric ton in September 2000 and the maximum price was 61146.25 PKR per metric ton in May 2008. Further, the mean price of maize is close to the median price showing that series is symmetrically distributed. The minimum price was 3898.35 per metric ton in July 2000 and the maximum price was 31461.29 PKR per metric ton in July 2012.While the mean value of rainfall is greater than median value implying that the series is right-skewed and rain-fall series has an asymmetric distribution, the minimum value of rainfall was 0.411470 millimeter in December 2014 and the maximum value was 113.1860 millimeter in August 2010. Moreover, the mean value of temperature is less than the median value implying that the series is left-skewed and temperature series has an asymmetric distribution, the minimum value of temperature was 6.835780 centigrade in January 2008 and the maximum value was 30.30580 centigrade in June 2014. All variables have symmetric distribution except rice, rainfall, and temperature. Rice and temperature were negatively skewed. Statistics of kurtosis show that all variable series are platykurtic as their peak is lower than the benchmark normal distribution. This also implies that all variable series have shorter tails than normal curves except rainfall which is leptokurtic and has fatter tails as compared to normal.

4.2. Climatic Shocks (Droughts) on Wheat, Rice and Maize Prices 2000-04

Figure 7: Climatic Shocks on Wheat Prices 2000-04

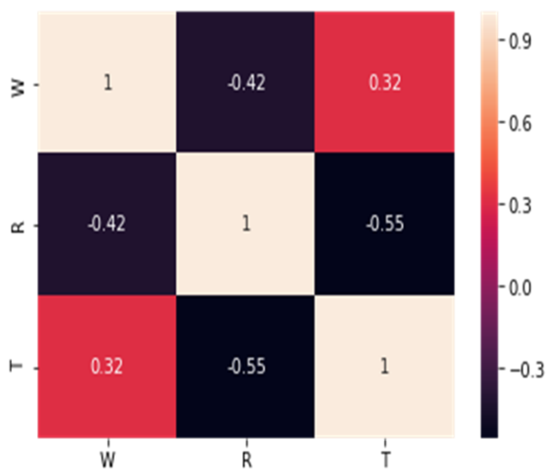


Figure 8: Climatic Shocks on Rice Prices 2000-04

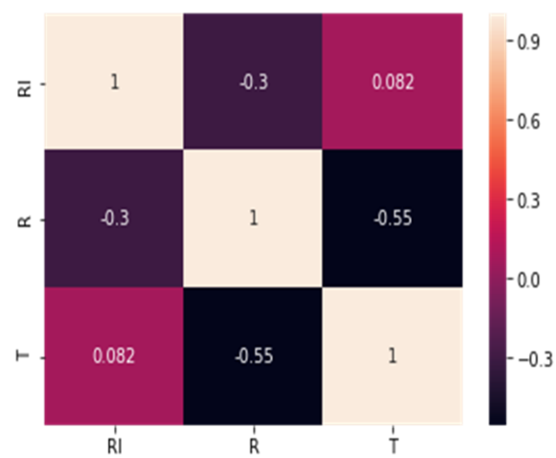


Figure 9: Climatic Shocks on Maize Prices 2000-04

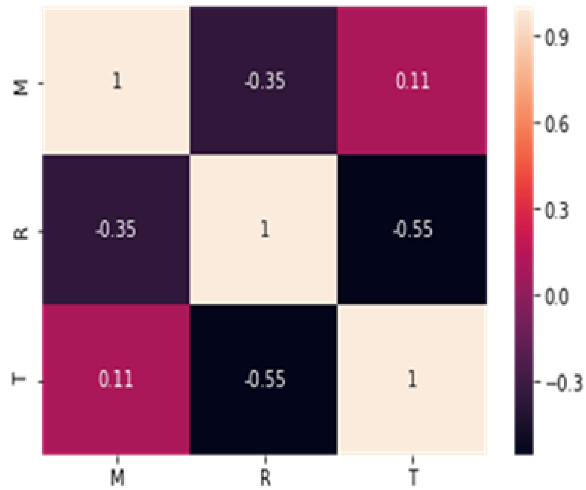


Table 2: Results of P-value Climatic Shocks (Droughts) on Wheat, Rice and Maize Prices 2000-04

Wheat Price (W)	0.0000***	0.0016***	0.03883**
Rainfall (R)	0.0016***	0.0000***	0.0000***
Temperature (T)	0.03883**	0.0000***	0.0000***
	Wheat Price (W)	Rainfall (R)	Temperature (T)
Rice Price (RI)	0.0000***	0.0163**	0.4115
Rainfall (R)	0.0163**	0.0000***	0.0000***
Temperature (T)	0.4115	0.0000***	0.0000***
	Rice Price (RI)	Rainfall (R)	Temperature(T)
Mazie Price (M)	0.0000***	0.0061***	0.3967
Rainfall (R)	0.0061***	0.0000***	0.0000***
Temperature (T)	0.3967	0.0000***	0.0000***
	Mazie Price (M)	Rainfall (R)	Temperature (T)

Note: *, ** and *** denote the significance at 10% (0.10), 5% (0.05) and 1% (0.01) levels, respectively.

A combination of three variables is used in each matrix. In Figure 7, 8 and 9 wheat, rice and maize prices are correlated with rainfall, and temperature during the droughts time of 2000-04 in Pakistan. However, the correlation coefficients and their probability values are shown in Table 2. The correlation coefficients have one value across the diagonal line which represents that each variable is perfectly correlated with itself and is displayed by light pink color. The one half of the correlation matrix is a mirror image of the aforementioned fact.

From 2000 through 2004, Pakistan faced severe droughts. Droughts in Sindh and Baluchistan provinces have always been part of life. Both provinces suffered from the recent drought of 2000-2004, which affected humans/crops, livestock population and water resources. The drought resulted from a continuous lack of rainfall. The situation is particularly serious in areas where groundwater is either deep or brackish and no surface-water resource is available. Other factors that increase the adverse impact of droughts include overexploitation of ground water in violation of ground water regulations, deforestation, depletion of grazing pastures due to lack of management, poor farm water management and lack of controlled cropping patterns (Farooq et al. 2009). Throughout the period, the correlation of wheat, rice and maize prices with rainfall is -0.45, -0.3 and -0.35 respectively as reflected by the modest purple color in figure 7, 8 and 9. The statistics demonstrate the moderate negative relationship between prices and rainfall. However, the corresponding probability values are statistically significant at a 1% level of significance for wheat and maize and 5% level of significance for rice. The result is out of line with the prior expectations in the agricultural economy of Pakistan. Studies reported that droughts in summer cause an increase in crop prices owing to a decline in productivity. In contrast, winter drought has no impact on crop prices which is why on the national level, drought has a negative relationship with wheat prices (Schaub and Finger 2010). Moreover, in the Sindh province, failure of rainfall and reduced flow of water in rivers and canals has affected groundwater recharge resulting in lowering of the water table, which had a positive impact on the productivity of irrigated agriculture due to waterlogging in the pre-drought situation and reduced crop (Chandio 2012).

Like rainfall, a definite volume of temperature is needed for wheat crop to go through the photosynthetic process for subsistence and increased productivity. However, extreme climatic events like heat spells and periods of frosts could cause serious threats to wheat productivity and prices. The correlation of wheat, rice and maize prices with temperature is 0.32, 0.082 and 0.11 respectively as reflected by the modest pink color in figure 7, 8 and 9. The matrix found a weak positive relationship between crop prices and temperature. Meanwhile, the correlation coefficient of wheat prices with temperature is statistically significant at a 1% level of significance. In their study, (Asseng et al. 2013) identified that increase in maximum and minimum temperature during summer crop hurts crop yield leads to an upsurge in prices. Similarly, (You et al. 2009) reported that a 1% increase in growing season temperature brings an 8-10% decline in grain productivity which causes a sharp upsurge in final crop prices.

Rainfall and temperature are fundamental measurements for describing climate. In the meantime, it is discovered that rainfall and temperature have a moderate negative relationship i.e., -0.55 shown by dense black color and probability value is statistically significant at a 1% level of significance (See Figure 7, 8 and 9). (Cong and Brady 2012] identified that due to an increase in greenhouse gasses in the atmosphere, annual rate of increase in temperature is 0.0032°C and a decrease in rainfall is 0.007 mm per year. Similarly, there is a high possibility that an increase in temperature will lead to more evaporation and transpiration. Thus, there is risk of increase in agricultural drought as temperature increases (Hayees and Knox-Hayes 2014).

4.3. Climatic Shocks (Floods) on Wheat, Rice and Maize Prices 2010-15

Figure 10: Climatic Shocks on Wheat Prices 2010-15

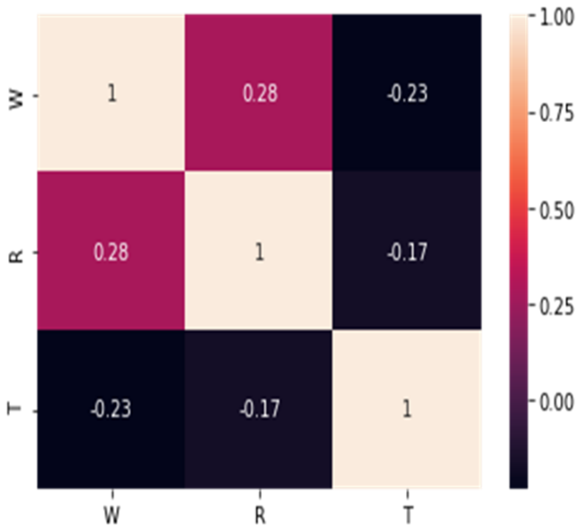


Figure 11: Climatic Shocks on Rice Prices 2010-15

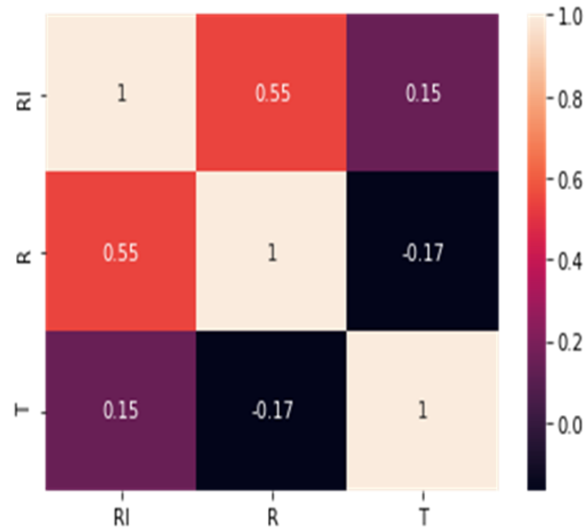


Figure 12: Climatic Shocks on Maize Prices 2010-15

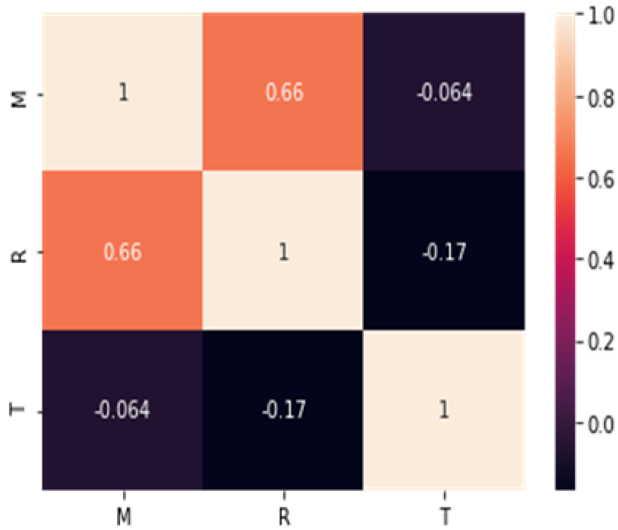


Table 3: Results of P-value Climatic Shocks (Floods) on Wheat, Rice and Maize Prices 2010-15

Wheat Price (W)	0.0000***	0.0302**	0.1098*
Rainfall (R)	0.0302**	0.0000***	0.1647
Temperature (T)	0.1098*	0.1647	0.0000***
	Wheat Price (W)	Rainfall (R)	Temperature(T)
Rice Price (RI)	0.0000***	0.0000***	0.0147**
Rainfall (R)	0.0000***	0.0000***	0.1647
Temperature (T)	0.0147**	0.1647	0.0000***
	Rice Price (RI)	Rainfall (R)	Temperature(T)
Mazie Price (M)	0.0000***	0.0000***	0.0079*
Rainfall (R)	0.0000***	0.0000***	0.1647
Temperature (T)	0.079*	0.1647	0.0000***
	Mazie Price (M)	Rainfall (R)	Temperature (T)

Note: *, ** and *** denote the significance at 10% (0.10), 5% (0.05) and 1% (0.01) levels, respectively

A combination of three variables is used in each matrix. In Figure 10, 11 and 12, wheat, rice and maize prices are correlated with rainfall, and temperature during the floods time of 2010-15 in Pakistan. However, the correlation coefficients and their probability values are shown in Table 3. The correlation coefficients have one value across the diagonal line which represents that each variable is perfectly correlated with itself and is displayed by light pink color. The one half of the correlation matrix is a mirror image of the aforementioned fact.

A certain amount of rainfall is required for crops to survive and to increase their productivity. However, extreme natural events like irregular rain, floods, and droughts have a serious influence on regional and global food security which causes food price puzzles (Field et al. 2012). Floods also result in the displacement of people, infrastructure damage (such as destruction of roads), loss of crops, cattle, and livestock and these losses delay ongoing development and political processes (Ali and Rahut 2020) which in turn have serious implications for food security, particularly in poor and developing countries. Between 2010 and 15, Pakistan faced severe floods which submerged 300,000 acres of wheat, 200,000 acres of rice and 170,000 acres of maize crop which made 7.8 million people food insecure during the same years (Rehman and Khan 2015). During the period, the correlation of wheat, rice and maize prices with rainfall is 0.22, 0.55 and 0.66 respectively as reflected by the modest pink and modest orange colors in figure 10, 11 and 12. The statistic demonstrates weak positive relationship for wheat while moderate positive relationship for rice and maize crop with rainfall. However, the corresponding probability values are statistically significant at a 5% level of significance for wheat while 1% level of significance for rice and maize prices. (Zhu et al. 2013) reports that Pakistan's grain prices kept rising and falling and so did the incomes of farmers due to extreme monsoon floods. Floods have a strong negative effect on commodity markets. As noted, weather shocks that reduce harvests cause food availability decline (FAD). Since the demand for food is highly price inelastic (food being a basic necessity), a relatively small shortfall in marketed supplies can cause a major increase in food prices (Devereux 2007).

However, in 2010-11 Pakistan was projected to be self-sufficient and to be a net exporter of wheat and maize with favorable world prices.

In context of temperature, the correlation of wheat, rice and maize prices with temperature is -0.23, 0.15 and -0.064 respectively as reflected by the modest pink color for wheat, strong purple color for rice and dense purple color for maize prices in figure 10, 11 and 12. Matrix found a weak positive relationship for wheat and maize prices while a weak positive relationship was found for rice prices with temperature. The correlation coefficient of wheat and maize prices with temperature is statistically significant at a 1% level of significance while 10% level of significance for rice. In their study, Wu et al. (2016) reasoned that temperature has an impact on yield as well as quality (length, weight, and shape). Increases in temperature beyond 30^{o} C adversely affect the crop quality which causes a decline in prices. However, Asseng et al. (2013) identified that increase in maximum and minimum temperature during summer crop hurts crop yield which leads to an upsurge in prices. For instance, Nozawa et al. (2016) reported that high rainfall during maturity and critical stages lowers the solar radiations to crop, causes yield reduction and upsurge in crop prices.

Meanwhile, it is discovered that rainfall and temperature have an extremely weak negative relationship i.e., -0.17 as reflected by the dense purple color. In their study, Zhang et al. (2014) discovered that during summers, temperature and rainfall have negative correlation while positive correlation was found in winter. However, the probability value is statistically insignificant.

5. Conclusions

Every economic sector is exposed to the environmental threats globally, particularly the agricultural sector. Extreme weather conditions such as flash floods and droughts have been experienced by Pakistan which has caused severe harm to the properties as well as major crops of farmers. This situation is expected to be further worsened due to climate change. Numerous literatures have pointed out the issue of food insecurity in the context of Pakistan. However, not a single study is available on detecting the association of climatic shocks with food price puzzle in Pakistan. The current study has evaluated these immoderations on monthly time series data under vulnerable climatic conditions: first period is from January 2000 to December 2004 (droughts) and second period data is from January 2010 to December 2015 (floods). By exploring in different time periods by fitting the correlation matrixes visualization to the data, the results show a significant association of climatic shocks with food price puzzle. Results exposed that during the drought period 2000 to 2004, rainfall has a negative association with wheat, rice and maize prices, meanwhile, temperature has a positive association with prices. Furthermore, during the time of floods 2010 to 2015, rainfall has a positive association with wheat, rice and maize prices, meanwhile, temperature has a negative association with prices except rice prices. The study recommends following policy recommendations based on the study's discoveries. Government should provide farm advisory services and weather forecasting about temperature extremes and rainfall pattern via radio, text messages and coordination meetings. Farmers should change the timing and date of crop sowing and choose suitable cultivars which diminish the probability of price puzzle. Further, government should provide better access of crop insurance schemes to farmers in case of crop loss. Lastly, alternative crops for Wheat like Quinoa, Rice like Direct Seeded Rice (DCR) and Maize like Tanseed International (TAN250) having more heat and drought tolerance should be grown. This will help to reduce the impact of drought on price puzzle.

6. Future Research

The present study can further extend for future work in many ways by using more climatic variables (humidity, soil moisture, solar radiations, water availability). Secondly, our proposed model may be used as guiding principle for other crops as well, such as cotton, sugar and barely. Lastly, future analysis can be extended at district level.

7. Funding: This research received no external funding.

8. Data Availability Statement: The data of wholesale crop prices has been taken from Index Mundi Data and Statistics https://www.indexmundi.com/. The data of rainfall and temperature has been collected from the Pakistan Meteorological Department Government Office in Islamabad.

9. Conflicts of Interest: The authors declare no conflict of interest.

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