Impact of Climate Change on Wheat Production

A Case Study of Pakistan

Dr. Pervez Zamurrad Janjua, Ghulam Samad and Nazakat Ullah Khan[1]

Abstract:

Climate change is an emerging issue of agricultural production and geographical location of Pakistan makes it vulnerable to climate change. Climate change is basically due to the increase in the concentration of greenhouse gases (GHGs) like carbon dioxide, methane and nitrous oxide through anthropogenic activities. These gases trap the sunlight and increase the earth's overall temperature. This higher temperature may negatively affect the growth process of wheat and hence decreases the productivity of wheat. The objective of this study is to look at the impact of climate change on wheat production which is the main food crop of Pakistan. The study uses Vector Auto Regression (VAR) model to evaluate the impact of global climate change on the production of wheat in Pakistan. The study considers annual data from 1960 to 2009. On the basis of this historical data the study captures trends for the impact of climate change on wheat production for the period 2010-2060. The results of estimation reveal that global climate change may influence the wheat production in Pakistan. Therefore, appropriate adaptative and mitigative techniques as well as measures like timely cultivation, better irrigation system, new technology and utilization of drought resistant seeds are recommended to cope with or at least to reduce this newly emerging hazard of global climate change on wheat production in Pakistan.

Keywords: Climate Change, Global Warming, Greenhouse Gases (GHGs), C3& C4 Crops

[1] Dr. Pervez Zamurrad Janjua <dr.pervezzamurrad@iiu.edu.pk> is cruntly working as Foriegn Professor at International Institute of Islamic Economics, International Islamic University (IIUI), Islamabad, Pakistan.

Ghulam Samad <ghulamsamad@hotmail.com> is currently working as, Research Economist at Pakistan Institute of Development Economics, Islamabad, Pakistan

Nazakat Ullah Khan <nazakatkhan_82@yahoo.com> is Student of M.Phil. Economics & Finance at International Institute of Islamic Economics, International Islamic University (IIUI), Islamabad, Pakistan

1. INTRODUCTION

Atmospheric condition which remains for some days is called weather, whereas, if such condition prevails for a season, decade or a century, it is termed as climate. To keep the pace of growth fossil fuel has been used in order to meet the energy requirement. However, fossil fuel adds some gases in the atmosphere which are altering the climate with the passage of time.

1.1 Climate Change

Climate change refers to “change in climate due to natural or anthropogenic activities and this change remain for a long period of time.” (IPCC 2007)

The gases responsible for the global warming are known as Greenhouse Gases (GHGs), which are comprised of Carbon Dioxide CO_2, Methane CH_4, Nitrous Oxide N_2O and water vapors. These gases are produced by a number of anthropogenic activities (Motha and Baier). CO_2 is mainly produced during the combustion of wastes, carbon, wood and fossil fuels. Methane is produced during the mining of coal, gas and oil and during their transportation, whereas, Nitrous Oxide is produced during agricultural and industrial activities.

Man is responsible for this newly emerging CO_2 enriched world because since the pre industrial time CO_2 concentration has increased from 280ppm[2] to 380ppm due to deforestation, massive use of fossil fuels etc. (Stern 2006) Concentration of GHGs as a result of anthropogenic activities are increasing at a rate of 23ppm per decade, which is highest rise since the last 6.5 million years. Percentage contribution of different sectors in the atmospheric concentration of GHGs is from energy sector 63%, agriculture 13%, industry 3%, land use and forestry 18% and waste 3% (Rosegrant et al, 2008). Climate change is an externality which is mainly caused by particular economic activities, and the geographical position of many developing countries makes them very much vulnerable to climate change. According to the IPCC prediction, in the absence of any policy to abate the GHGs emission, GHGs would increase from 550ppm to 700ppm at the mid of current century and this level of GHGs would cause to accelerate the temperature from 3^oC since the pre industrial era to 6^oC. (Stern 2006)[3]

Earth gains solar energy from sun in the form of sun light and atmosphere, which is composed of different GHGs, hold these energy rays and pass them on to the earth and then let them to go back into the space. So the atmosphere plays a vital role to maintain the earth average temperature at level of 15^oC (Edwards 1999).

Global warming is a real issue which is directly caused by the higher level of CO_2 in the atmosphere, whereby GHGs trap the sun rays and do not let them go back to space. Higher level of GHGs especially CO_2 produced by anthropogenic activities, intensify concentration of GHGs, trap more light and cause to increase earth’s overall temperature (Brown 1998). Some of the consequences of global warming may appear in the form of more frequent floods and drought, food shortage, non supporting weather conditions, newly born diseases, sea level rise, etc. (Tisdell 2008). The concentration of these GHGs are mounting in the atmosphere through

[2] PPM means parts per million. It is used to measure the level of pollution in air. It is a ratio between pollutant components and the solution.

[3] For international efforts to abate GHGs see Appendix-1

number of ways like anthropogenic activities, deforestation etc. It is expected that up to 2100 this concentration would become 3 times as much as the pre-industrial time causing 3 to 10^{o}C hike in temperature.

1.2 Possible Effects of Climate Change on Agriculture:

Agriculture is the most vulnerable sector to climate change. Agriculture productivity is being affected by a number of factors of climate change including rainfall pattern, temperature hike, changes in sowing and harvesting dates, water availability, evapotranspiration[4] and land suitability. All these factors can change yield and agricultural productivity (Harry M. et al 1993). The impact of climate change on agriculture is many folds including diminishing of agricultural output and shortening of growth period for crops. Countries lying in the tropical and sub tropical regions would face callous results, whereas regions in the temperate zone would be on the beneficial side.

CO_2 is regarded as the driving factor of climate change, however its direct effect on plant is positive (Warrick 1988) CO_2 enriches atmosphere positively and affects the plants in two ways. First, it increases the photosynthesis process in plants. This effect is termed as carbon dioxide fertilization effect. This effect is more prominent in C3 plants because higher level of CO_2 increases rate of fixed carbon and also suppresses photorespiration[5]. Second, increased level of CO_2 in atmosphere decreases the transpiration[6] by partially closing of stomata and hence declines the water loss by plants. Both aspects enhance the water use efficiency of plants causing increased growth.

The crops which exhibit positive responses to enhanced CO_2 are characterized as C3 crops including wheat, rice, soybean, cotton, oats, barley and alfalfa whereas, the plants which show low response to enhanced CO_2 are called C4 crops including maize, sugarcane, sorghum, millet and other crops.

Warrick study for USA, UK and Western Europe regarding the impact of increase in temperature on the wheat productivity indicates that impact of increase in temperature is catastrophic in terms of yield losses because higher temperature accelerates the evapotranspiration process creating moisture stress (Warrick 1988). It also shorten the growth period duration of wheat crop and this becomes more severe regarding yield losses if it occurs during the canopy formation because less time will be available for the formation of kernels. Wetter conditions are beneficial for wheat yield whereas drier are harmful and cause to decrease the productivity.

In Pakistan wheat is sown in winter season, preferably in November. Estimated land, on which wheat is cultivated in Pakistan, is 9045 thousand hectare and per hectare wheat yield is 2657 kg. (Zia Khan et al). Per head consumption of wheat in Pakistan is about 120 kg which makes the importance of this food crop. The water available for the cultivation of wheat in Pakistan is 26 MAF (million acre feet) which is still 28.6% lower than the normal requirement of water (Rosegrant et al, 2008). Almost all the models predict that climate change will stress the

[4] The sum of evaporation and plant transpiration from the surface of the earth to atmosphere
[5] A process that displaces newly fixed carbon
[6] Loss of water by plant during exchange of gases

wheat yield in South Asia region. According to the 4th IPCC report cereal yield could decrease up to 30 percent by 2050 in South Asia along with the decline of gross per capita water availability for South Asia from $1820m^3$ in 2001 to $1140m^3$ in 2050. Water supply is scarce in many part of the country. In near future a dramatic decline in the water availability would cast a sharp decline towards the production of agricultural productivity.

1.3 Objectives of Study

The primary purpose of this study is whether the global warming negatively affects the wheat production in Pakistan. More specifically, what has been the impact of change in temperature and precipitation on the wheat production in Pakistan? How far possible future changes in temperature and precipitation may affect the level of wheat production in Pakistan? Moreover, along with core variables of temperature, precipitation, water and land under wheat cultivation, the study also aims to investigate the role of a number of explanatory variables on the wheat production of Pakistan.

1.4 Scope and Limitation of Study

This study assumes Pakistan as a homogenous region. It considers two basic variables of climatic change, namely temperature and precipitation. It does not consider the impact of climatic change on wheat production through CO_2 and humidity due to non-availability of wide range of time series data about the level of CO_2 and humidity in Pakistan. In context of dependent variable, scientists sometimes consider yield (per unit output) in place of total output to investigate the impact of various independent variables. However, this study does not consider yield due to non-availability of data on various factors (including different features of soil, etc.) that may influence yield.

2. LITERATURE REVIEW:

Warrick (1988) investigated that at higher level of CO_2 in the atmosphere, C3 crops specially wheat would show improvement in water use efficiency through less transpiration, in such case at 2×CO2 concentration level (680ppm) wheat production would be increased 10% to 50% for mid and high latitude region of Europe and America. However, 2^oC increase in temperature would decrease the production by 3% to 17% which might be offset by higher level of precipitation. He analyzed that for each ^oC increase in temperature would cause to shift the geographical location for crops production to several hundred kilometers towards mid and high latitude.

Lobell et.al (2005) used CERES-Wheat simulation model for the climate trend effect on wheat production in the Mexico region. They studied the climate trend and wheat yield for the last two decades from 1988-2002. They found that the climate had favored during the two decades and resulted in 25% increase in wheat production. It means climate was having positive effect on the wheat yield for this region. However 25% increase is less as compared to the previous studies which predicted higher increase in wheat productivity for this region.

Xiao et al (2005) carried out the investigation in order to check the effect of climate variability on high altitude crop production and to check whether the wheat yield at high altitude could be affected by the climate variability. For this purpose they selected two sites, Tonguei Metrological station 1798m above the sea level and Peak of Lulu Mountains 2351m above the sea level. They investigated the effect for the time period of 1981 to 2005. Their results showed that yield of both the sites increased during this period bearing positive change in temperature and precipitation. Initially up to 1998 yield of two altitudes was high but after that yield of high altitude showed an increasing trend as compared to loss at low altitude. The simulated results up to 2030 also showed that the agriculture production of wheat for low altitude would increase by 3.1% and that of high altitude would increased by 4.0%.

Hussain and Mudasser (2006) used Ordinary Least Square (OLS) method to assess the impact of climate change on two regions of Pakistan, Swat and Chitral 960m and 1500m above the sea level, respectively. They investigated whether increase in temperature up to 3^oC would decrease the growing season length (GSL) of the wheat yield of this county. Their result showed that increase in temperature would create positive impact on Chitral district as its location on high altitude and negative impact on Swat because of its low altitude position. An increase in temperature up to 1.5^oC would create positive impact on Chitral and would enhance the yield by 14% and negative effect on Swat by decreasing its yield by 7%. A further increase in temperature up to 3^oC would decrease the wheat yield in Swat by 24% and increase in Chitral district by 23%. They suggested adaptation strategies of cultivating high yielding varieties for warmer areas of northern region of Pakistan because of expected increasing temperature in the future.

Tobey et al (1992) used SWOPSIM statistical world policy simulation based on General Circulation Model (GCM). The model used by them is static in nature in the sense that it presents only on spot effect of doubling of CO_2 on global agriculture. The model used 20 agriculture commodities. According to their result the negative impact of climate change on some region would not sabotage the world agriculture market rather this negative impact would be counterbalanced by agriculture yield of some other region which would experience positive impact of the global warming of climate change.

Zhang and Nearing (2005) used Hardley Centre Model (HadCM3) for their study about the wheat productivity in Central Oklahoma. They used three scenarios A2a, B2a and GGal for the current time period 1950-1999 and future time period 2070-2099. The simulations model projected that annual future precipitation would decrease by 13.6%, 7.2% and 6.2% for the three said scenarios respectively, whereas temperature would increase by 5.7^oC, 4^oC and 4.7^oC respectively. They concluded that the short of rainfall in summer and not in winter will affect the yield whereas effect of increased temperature will be offset by the carbon fertilization.

Paul Winters et al (1996) analyzed the impact of global warming on the archetype structure for Africa, Asia and Latin America. They used Comparable General Equilibrium (CGE) model for their study. They concluded that these entire three regions will face agriculture loss in cereal and export crops and hence income losses. They said that Africa would be the most negatively affected by this climate change because its economy is relying very heavily on agriculture output. They investigated that higher substitution possibility for increase in import cereal could do more to reduce income losses and development efforts regarding production of export crops in order to generate foreign exchange.

G. A. Gbetibouo and R. M. Hassan (2004) employed Ricardian model on wheat, sorghum, maize, sugarcane, ground nut, sunflower and soybean for the South African region. They found that temperature increase would be having positive impact on the agriculture production of maize, sorghum, sunflower, soybean whereas it would be having negative impact on sugarcane and wheat productivity. They said that this region is already having high temperature and any further increase in temperature in future due to climate change would havoc the wheat productivity. They suggested to replace wheat by maize and sorghum or other heat adapted crops in order to avoid possible loss of yield due to increased temperature.

Wolf et al (2005) compared five wheat models designed for Europe at different levels of agronomic conditions[7]. They concluded that almost all the models predicted the same results. Their results showed that temperature increase would result in yield reduction whereas increased level of precipitation and CO_2 fertilization would have positive impact on the production of wheat for Europe.

Anwar et al (2007) used the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO's) global atmospheric model under three climate change scenarios which were Low, Mid and High for the time period of (2000-2070) for South-East Australian location. Their results showed that for all the three scenarios the medium wheat yield declined by about 29%, however in the presence of elevated CO_2 affect reduced this decline in production from 29% to 25%. CO_2 fertilization affect offset a very small level of low rain fall and higher temperature. They suggested that higher yield productivity could be made through better agronomic strategies and breeds of wheat.

Cerri et al (2007) used simulation model for Central South region of Brazil up to 2050. They revealed that 3^oC to 5^oC increase in temperature and 11% increase in precipitation would cause to decrease the productivity of wheat to the level equal to one million ton by weight. They said that in Brazil wheat had already been cultivating at the threshold level of temperature and any further addition to this level of temperature would cause to decline agricultural production specially wheat. They further added that most of the developing countries lying on the tropical belt and relying on agriculture would, face losses in agricultural yield.

Zhai et al (2009) used comparable general equilibrium (CGE) model in order to examine the impact of climate change on agriculture sector of China in 2080. Their results showed that 1.3% decline of agricultural share in GDP. The CGE simulation results showed that in 2080 agricultural output would become slow which ultimately leads to output losses except wheat which showed enhancement in output because of increase in global wheat demand. The simulation results also showed that as compared to world average agricultural production the agricultural productivity in China would decline less.

[7] The models AFRCWHEAT2, CERES-Wheat, N-WHEAT, SIRIUS-WHEAT, and SOILN-wheat were designed for Rothamsted, UK and Sevelle, Spain.

Zhai and Zhuang (2009) made a study on Southeast Asian region to investigate the economic impact of climate change on the said region by suing CGE model. According to them impact is not consistent throughout the world and developing countries would face large losses. According to the simulation results made by them up to 2080 Southeast Asia would face 1.4% decline in GDP. Crop productivity would fall up to 17.3%, whereas, the agriculture productivity of paddy rice would fall 16.5% and that of wheat up to 36.3%. In future, the Southeast Asian countries' dependency on import of these agricultural products would increase creating more welfare losses and hence weakening the term of trade of this region.

3. METHODOLOGY:

3.1 Vector Auto Regression (VAR) Model:

Rational expectation acted as a base for forward-looking models. However, it was logically criticized by Lucas. Sim answered 'Lucas critique' through his model famed by Vector Auto Regression (VAR) model. Initially, VAR model was used in macroeconomics. Christopher Sim and Litterman urged that it is better to use VAR model for forecasting instead of structural equation model. VAR model superficially resembles simultaneous equation modeling in that we consider several endogenous variables together. But each endogenous variable is explained by its lagged or past values and the lagged values of all other endogenous variables in the model. Usually there is no exogenous variable in the model. Sim developed VAR model on the basis of true simultaneity among the exogenous and endogenous variables. VAR model is more suitable for forecasting. All variables used in this model are endogenous and believed to interact with each others. Estimation with VAR model is simple because we use OLS method to each equation. However, VAR model is not free from critique. VAR is a theoretical model. It summarizes the correlations in the data and does not explain the nature of intervention in the economic process. Forecasting through VAR may be correct but possible error can not be avoided. VAR is used for forecasting so it is less suitable for policy analysis[8].

3.2 General From of VAR Model:

The general form of VAR model in the matrix form is as follows:

$$\begin{array}{cccccccccccc} y_t & = & \mu & & \Gamma_1 & \Gamma_2 & --- & \Gamma_p & & y_{t-1} & & e_t \\ y_{t-1} & & 0 & + & I & 0 & & 0 & + & y_{t-2} & + & 0 \\ --- & & --- & & --- & --- & --- & 0 & & --- & & --- \\ y_{t-p+1} & & 0 & & 0 & --- & I & 0 & & y_{t-p} & & 0 \end{array}$$

[8] For details of advantages as well as disadvantages of VAR model see for example Greene 2002, Gujarati 2004, Eugen St. Pecician 2010

However, in the equation form the model can be expressed as follows:

$$y_t = \mu + \Gamma_1 y_{t-1} + \text{-------} + \Gamma_p y_{t-p} + e_t$$

Or

$$\Gamma (L) y_t = \mu + e_t$$

Where Γ (L) is matrix of polynomial in lag operator.

The specific form of the model which we used for our studies is as follows;

Wheat Production = f (Temperature, Precipitation, Agricultural Credit, Wheat Procurement Price, Fertilizers takeoff, Technology, Land under wheat cultivation, Water availability) + Ui

$$W_p = ß_1 – ß_2 T_{emp} + ß_3 Precip + ß_4 A_{crdt} + ß_5 W_{pp} + ß_6 F_{ert} + ß_7 T_{ech} + ß_8 Lw + ß_9 Wa + Ui$$

Wheat Production:

Wheat production data is collected by us from different editions of Economic Survey of Pakistan. We consider the amount of wheat in thousand ton.

Average Temperature:

Temperature assumed to be having negative impact on wheat productivity for the regions which lie on the tropical or near to the tropical regions. We consider temperature in Celsius degree centigrade. Data source is Metrological Department of Pakistan.

Average Precipitation:

Precipitation assumed to be having positive impact on the production of wheat. Our source of data for precipitation is Metrological Department of Pakistan. The gauge of precipitation is millimeter.

Explanatory Variables:

Explanatory variables are agricultural credit, wheat procurement price, fertilizers offtake, technology, land under wheat cultivation and water availability. The data source for these variables is different editions of Economic Survey of Pakistan.

4. RESULTS AND INTERPRETATION[9]:

Vector Autoregression (VAR) requires testing of the unit roots in the variables. Therefore in order to check whether the variables are stationary or integrated of some order, the Augmented Dickey-Fuller (ADF) is incorporated. The results of the units root test are reported below:

[9] PC application Eviews has been used for the purpose of estimation.

Table 1 Results of the ADF Unit Root Statistics:

S. No.	Variables	Level	1st Difference	Conclusion
1	Wheat Production	0.9349	0.0000	I(1)
2	Avg. Temperature	0.4602	0.0000	I(1)
3	Avg. Precipitation	0.0116	0.0000	I(1)
4	Land under wheat	0.1565	0.0000	I(1)
5	Water Availability	0.0000		I(0)
6	Technology	0.9512	0.0000	I(1)
7	Wheat procurement price	0.0900	0.0000	I(1)
8	Fertilizers offtake	0.9512	0.0000	I(1)
9	Agriculture credit	0.9959	0.0000	I(1)

The results of the ADF test show the non stationarity of the variables of our model at conventional levels of significance. Thus values in the table indicate that all the variables are stationary at first difference, which shows that all the variables are integrated of order 1, whereas water availability data is already in the stationary form.

4.1 Results from Vector Autoregression (VAR) model:

The results of VAR model estimation to our core variables, namely wheat production (Wp), average temperature (Temp), average precipitation (Precip), agricultural land under wheat cultivation (Lw) and water availability (Wa), are shown in the following table[10]:

Table 2 Results through VAR model:

Sample(adjusted): 1963-2009
Included observations: 47 after adjusting endpoints
Standard errors & t-statistics in parentheses

	Wp	Lw	Temp	Precip	Wa
Wp(-1)	0.378517	0.209512	0.000291	-0.000130	-0.003238
	(0.22769)	(0.09316)	(0.00023)	(0.00170)	(0.00611)
	(1.66240)	(2.24905)	(1.29084)	(-0.07642)	(-0.53034)
Wp(-2)	0.355467	-0.033830	7.21E-06	0.000398	-0.011903
	(0.22217)	(0.09089)	(0.00022)	(0.00166)	(0.00596)
	(1.60000)	(-0.37219)	(0.03277)	(0.23990)	(-1.99801)
Lw(-1)	0.297277	0.009830	-0.000982	0.000611	0.017136
	(0.61505)	(0.25163)	(0.00061)	(0.00460)	(0.01649)
	(0.48334)	(0.03906)	(-1.61264)	(0.13284)	(1.03902)
Lw (-2)	0.200009	0.170954	0.000171	0.001734	0.027766
	(0.60060)	(0.24572)	(0.00059)	(0.00449)	(0.01610)
	(0.33301)	(0.69572)	(0.28691)	(0.38616)	(1.72409)

[10] VAR model estimation results to explanatory variables, namely agricultural credit (Ac), fertilizers offtake (Fr), technology (Te) and wheat procurement price (Wpp), are given in appendix-2.

Temp(-1)	-62.17562	-10.37793	0.500886	-0.140987	-2.531763
	(161.483)	(66.0669)	(0.15982)	(1.20739)	(4.33000)
	(-0.38503)	(-0.15708)	(3.13408)	(-0.11677)	(-0.58470)
Temp(-2)	242.9269	72.48890	0.308464	-0.229359	-1.188558
	(157.887)	(64.5958)	(0.15626)	(1.18051)	(4.23358)
	(1.53861)	(1.12219)	(1.97404)	(-0.19429)	(-0.28075)
Precip(-1)	29.81109	13.21421	-0.000744	0.098245	1.209526
	(23.0053)	(9.41210)	(0.02277)	(0.17201)	(0.61687)
	(1.29583)	(1.40396)	(-0.03266)	(0.57116)	(1.96076)
Precip(-2)	-15.24816	-0.814147	0.000676	0.288965	0.484826
	(24.7400)	(10.1218)	(0.02449)	(0.18498)	(0.66338)
	(-0.61634)	(-0.08044)	(0.02759)	(1.56215)	(0.73084)
Wa(-1)	15.90099	-4.064487	0.004756	-0.067453	0.587948
	(14.6807)	(6.00626)	(0.01453)	(0.10977)	(0.39365)
	(1.08312)	(-0.67671)	(0.32734)	(-0.61451)	(1.49359)
Wa(-2)	-12.47152	1.820005	-0.007814	0.037746	1.006996
	(14.4909)	(5.92860)	(0.01434)	(0.10835)	(0.38856)
	(-0.86065)	(0.30699)	(-0.54488)	(0.34838)	(2.59162)
C	-4017.236	2396.269	6.089071	13.16633	-175.0879
	(3716.34)	(1520.46)	(3.67806)	(27.7867)	(99.6501)
	(-1.08096)	(1.57602)	(1.65551)	(0.47384)	(-1.75703)
R-squared	0.975264	0.901506	0.900114	0.300028	0.972362
Adj. R-squared	0.968392	0.874146	0.872368	0.105591	0.964685
Sum sq. resids	35851231	6000953.	35.11640	2004.230	25776.73
S.E. equation	997.9316	408.2807	0.987652	7.461438	26.75856
F-statistic	141.9349	32.95039	32.44117	1.543062	126.6564
Log likelihood	-384.9915	-342.9862	-59.84035	-154.8825	-214.9065
Akaike AIC	16.85070	15.06324	3.014483	7.058830	9.613042
Schwarz SC	17.28372	15.49626	3.447496	7.491843	10.04606
Mean dependent	12454.49	7058.340	18.40398	35.76338	132.4143
S.D. dependent	5613.135	1150.869	2.764549	7.889592	142.3912
Determinant Residual Covariance		8.68E+14			
Log Likelihood		-1141.793			
Akaike Information Criteria		50.92737			
Schwarz Criteria		53.09244			

The statistical values of t-statistics for our variables are not significant enough but the higher value of F-statistics makes all the lag terms of our model statistically significant. The coefficient of determination R-squared values of our variables is lying in between 0 to 1 which shows the goodness of fit of our model. We consider VAR model with lag 2 because the values of Akaike AIC and Schwarz Sc for the data using lag 2 is smaller than that of lag 3, lag 4 and lag 5, so the lower values Akaike AIC 16.85070 and Schwarz Sc 17.28372 for lag 2 make the model more parsimonious. Therefore VAR model for lag 2 for the study is more preferable as compared to other lag values.

4.2 Forecasting for 2010 using VAR model:

By suing the coefficient of variables from VAR results table 2 we can forecast for wheat production of 2010. The calculation for forecasting is as follows;

E (Wheat $_{2010}$) = -4017.236 + 0.378517 (wheat$_{2009}$) + 0.355467 (wheat$_{2008}$) + 0.297277 (wheat area$_{2009}$) + 0.200009 (wheat area$_{2008}$) – 62.17562 (Avg. Temp$_{2009}$) + 242.9269 (Avg. Temp$_{2008}$) + 29.81109 (Avg. Precip$_{2009}$) – 15.24816 (Avg. Precip$_{2008}$) + 15.90099 (water available$_{2009}$) -12.47152 (water available$_{2008}$)

= -4017.236 + 0.378517 (24033) + 0.355467 (20959) + 0.297277 (9046) + 0.200009 (8550) – 62.17562 (22.6) + 242.9269 (23) + 29.81109 (39.2) - 15.24816 (35.3) + 15.90099 (142.9) -12.47152 (142.4)

= 22,237.932

So the estimated value for 2010 wheat production is 22,237.932 thousand ton.

4.3 Impulse Response Function:

Cholesky impulse response function checks the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. The results of the impulse response function for our variables are shown in Table 3:

Table 3 Results of the Impulse Response Function:

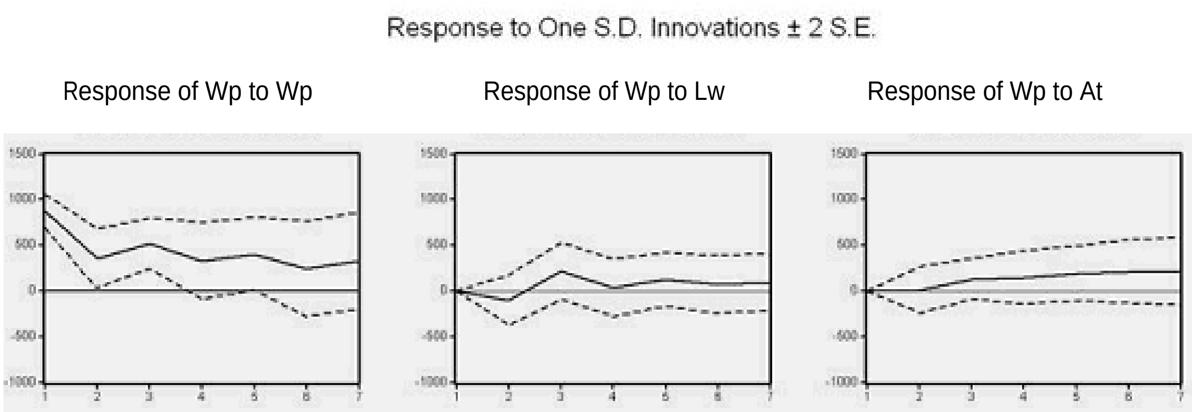
Response of Wheat Production:

Period	Wheat Production	Wheat Land	Avg. Temp	Avg. Precipitation	Water Available
1	8.733.797	0	0	0	0
	-900.822	0	0	0	0
2	3.543.272	1.016.809	7.877.232	2.555.733	3.427.293
	-160.766	-137.998	-128.706	-146.84	-279.181
3	5.230.332	2.176.983	1.307.476	1.339.713	-1.333.332
	-138.398	-155.56	-110.241	-199.347	-178.191
4	3.298.733	3.339.831	1.448.506	2.935.221	3.727.726
	-210.558	-157.789	-145.063	-225.499	-335.294
5	4.040.547	1.249.241	1.900.457	2.692.408	106.476
	-200.177	-144.849	-148.685	-268.452	-297.188
6	2.423.849	6.794.647	2.092.394	350.503	4.325.677
	-260.997	-158.762	-172.165	-313.903	-407.455
7	3.278.869	9.151.978	2.133.493	3.713.913	2.372.797
	-264.965	-154.496	-182.565	-355.042	-418.252

Ordering: Wheat, Wheat growing area, Avg. Temp, Avg.Precip, Water Available

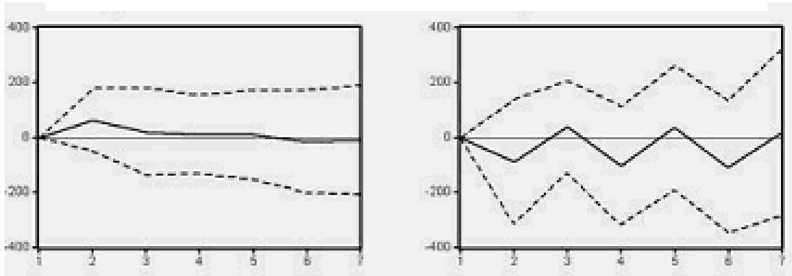
The results of panel (a) in Fig 1 shows that a shock of one standard deviation in wheat production in period one increases the wheat production up to 873.3797 points, in second period a shock of one standard deviation also creates positive impact and increase the wheat production to 354.3272 points but at this time increase is lower as compared to the shock in period one. However, third shock of one standard deviation once again increases wheat production up to 523.0332 points. After that each period shock is creating increasingly positive impact on wheat production. The response of wheat production to land under wheat cultivation, shown in the panel (b), demonstrates that one standard deviation shock of land under wheat cultivation in period one creates no change in wheat production. However, shock in period two decreases wheat production to 101.6809 points. In period three one standard deviation shock again increases the wheat production to 217.6983. The results in the panel (c) show that the shock of one standard deviation of average temperature in period one slightly increases wheat production to 7.877232 points but after that second shock increases the production to 130.7476 units, third shock increases production by 144.8506 units and rest of shocks also creates increasingly positive impact on wheat production. Panel (d) of the impulse response function demonstrates that first shock of one standard deviation of average precipitation creates no change in land under wheat cultivation. However, in second period shock of one standard deviation increases land under wheat cultivation to 63.18267 points. Shock of one standard deviation in third, fourth and fifth period also create increasingly positive impact. However, in sixth and seventh period shock of one standard deviation decreases land under wheat cultivation by 15.77849 and 10.65688, respectively. Panel (e) shows the results of the water availability shock on land under wheat cultivation. Here, it can be seen that the negative impact is dominating.

Fig. 1 Standardized Impulse Response Function:



Panel (a) Panel (b) Panel (c)

Response of Lw to Ap Response of Lw to Wa



Panel (d) Panel (e)

4.4 Variance Decomposition:

The objective of variance decomposition is to separate the variation on endogenous variables into the component shocks to the VAR. Table 4 demonstrates similar results as established by impulse response function:

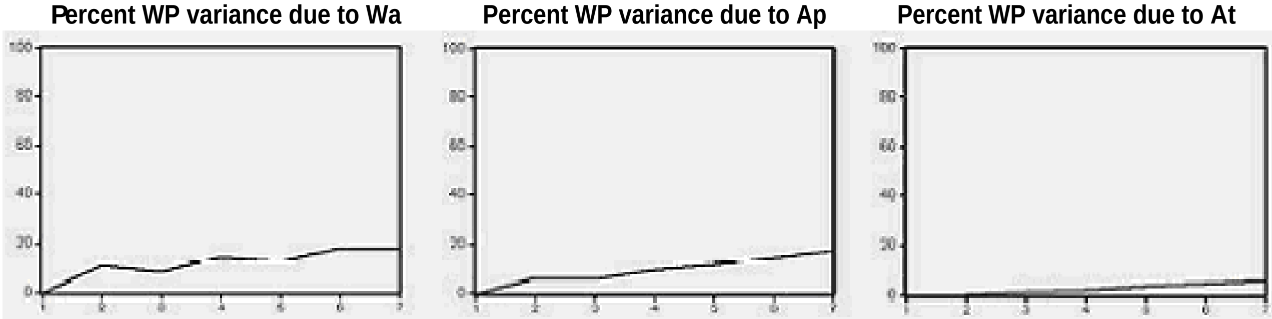
Table 4 Percentage response of Variance Decomposition:

Percent change in wheat production due to

Period	S.E.	Wheat Prod	Wheat Land	Avg. Temp	Avg. Precip	Water Available
1	8.733.797	100	0	0	0	0
2	1.039.963	8.213.794	0.955968	0.005737	6.039.424	1.086.093
3	1.199.041	8.081.687	4.015.552	1.193.364	5.791.616	8.182.597
4	1.339.301	7.084.242	3.280.711	2.126.225	9.445.206	1.430.544
5	1.446.561	6.852.825	3.558.025	354.861	1.156.069	1.280.443
6	1.584.189	5.947.953	3.150.624	4.703.325	1.453.444	1.813.208
7	1.692.717	5.584.914	3.051.894	5.708.151	1.754.431	178.465

As shown in Panel (a) and (b) in Fig 2, the role of water availability and precipitation is quite positive as compare to average temperature. The second shock of average precipitation and water availability increases the wheat production by 6.039424 and 10.86093 percent, respectively and after that third shock of both variables shows slightly less but positive impact on wheat production. After that almost every shock of average precipitation and water availability shows higher percentage increase in wheat production. Panel (c) demonstrates that first shock in temperature creates no change in wheat production, however second shock causes a nominal increase of wheat production by 0.005737 percent, whereas, third shock increases the wheat production by 1.193364 percent. Similarly fourth and fifth shock show positive impact of increase in temperature on wheat production by 2.126225 and 3.54861 percent, respectively.

Fig. 2 Cholesky Variance Decomposition:



Panel (a) Panel (b) Panel (c)

Almost all the results of our study are showing positive impact on the wheat production in Pakistan up to 2010. These results might appear contrary to the theoretical as well as empirical consideration of possible negative impact of global warming on the agricultural (wheat) production in the tropical and sub-tropical regions. However, following factors might be positively affecting the wheat production in Pakistan:

1) Pakistan is near to the glaciers therefore melting of these glaciers due to higher temperature makes more water available for wheat production. The relevant data is also showing increasing trend in the availability of water.
2) Land under wheat cultivation is also increasing due to increased water supply and other factors which may be creating positive impact on the production of wheat.
3) The pattern and direction of rain is changing worldwide due to climatic change. More rain and higher level of precipitation in the areas of wheat cultivation may have positively impacted the wheat production.
4) Improvement in technology regarding new ways of cultivation, hybrid seeds, fertilizers, extension services and attractive procurement prices are also creating positive impact on the production of wheat.

4.5 Simulation of Wheat Production 2060:

We are considering three simulation scenarios for the year 2060. In first scenario we are assuming that both the temperature and precipitation increase in Pakistan and in second scenario we assume that temperature increase and precipitation remains constant whereas, in third scenario we assume that temperature increase and precipitation decrease. We are considering three alternative increases in temperature, namely 2^oC, 4^oC and 5^oC. Moreover, we assume 10 % increase or decrease in precipitation.

Scenario 1:

If both the temperature and precipitation increase:

Case 1: If temperature increases by 2^{o}C and precipitation increases by 10%	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 (wheat$_{2059}$) + 0.355467 (wheat$_{2058}$) + 0.297277 (wheat area$_{2059}$) + 0.200009 (wheat area$_{2058}$) – 62.17562 (Avg. Temp$_{2059}$) + 242.9269 (Avg. Temp$_{2058}$) + 29.81109 (Avg. Precip$_{2059}$) – 15.24816 (Avg. Precip$_{2058}$) + 15.90099 (water available$_{2059}$) -12.47152 (water available$_{2058}$) = -4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.21) + 0.200009 (119016.6) – 62.17562 (24.6) + 242.9269 (25) + 29.81109 (43.12) – 15.24816 (38.8) + 15.90099 (316) -12.47152 (311) = **134936.67 thousand ton**
Case 2: If temperature increases by 4^{o}C and precipitation increases by 10%	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 (wheat$_{2059}$) + 0.355467 (wheat$_{2058}$) + 0.297277 (wheat area$_{2059}$) + 0.200009 (wheat area$_{2058}$) – 62.17562 (Avg. Temp$_{2059}$) + 242.9269 (Avg. Temp$_{2058}$) + 29.81109 (Avg. Precip$_{2059}$) – 15.24816 (Avg. Precip$_{2058}$) + 15.90099 (water available$_{2059}$) -12.47152 (water available$_{2058}$) = - 4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (26.6) + 242.9269 (27) + 29.81109 (43.12) – 15.24816 (38.8) + 15.90099 (315) -12.47152 (311) **= 140533.20 thousand ton**
Case 3: If temperature increases by 5^{o}C and precipitation by increases by 10%	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 (wheat$_{2059}$) + 0.355467 (wheat$_{2058}$) + 0.297277 (wheat area$_{2059}$) + 0.200009 (wheat area$_{2058}$) – 62.17562 (Avg. Temp$_{2059}$) + 242.9269 (Avg. Temp$_{2058}$) + 29.81109 (Avg. Precip$_{2059}$) – 15.24816 (Avg. Precip$_{2058}$) + 15.90099 (water available$_{2059}$) -12.47152 (water available$_{2058}$) = - 4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (27.6) + 242.9269 (28) + 29.81109 (43.12) – 15.24816 (38.8) + 15.90099 (315) -12.47152 (311) **= 146312.29 thousand ton**

In this scenario the production of wheat increases with simultaneous increases in temperature and precipitation. It means in this situation global warming has a positive impact on the output of wheat. The situation is conceivable for Pakistan because this region lies near to glaciers and in case of higher temperatures more ice may be melted into water and the water, in the presence of higher temperature, may lead to higher precipitation.

Scenario 2:

If temperature increases but precipitation remains constant:

Case 1: If temperature increases by 2^oC and precipitation remains constant	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 ($wheat_{2059}$) + 0.355467 ($wheat_{2058}$) + 0.297277 (wheat $area_{2059}$) + 0.200009 (wheat $area_{2058}$) – 62.17562 (Avg. $Temp_{2059}$) + 242.9269 (Avg. $Temp_{2058}$) + 29.81109 (Avg. $Precip_{2009}$) – 15.24816 (Avg. $Precip_{2008}$) + 15.90099 (water $available_{2059}$) -12.47152 (water $available_{2058}$) = -4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.21) + 0.200009 (119016.6) – 62.17562 (24.6) + 242.9269 (25) + 29.81109 (39.2) – 15.24816 (35.3) + 15.90099 (316) -12.47152 (311) =154872.54 thousand ton
Case 2: If temperature increases by 4^oC and precipitation remains constant	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 ($wheat_{2059}$) + 0.355467 ($wheat_{2058}$) + 0.297277 (wheat $area_{2059}$) + 0.200009 (wheat $area_{2058}$) – 62.17562 (Avg. $Temp_{2059}$) + 242.9269 (Avg. $Temp_{2058}$) + 29.81109 (Avg. $Precip_{2009}$) – 15.24816 (Avg. $Precip_{2008}$) + 15.90099 (water $available_{2059}$) -12.47152 (water $available_{2058}$) = - 4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (26.6) + 242.9269 (27) + 29.81109 (39.2) – 15.24816 (35.3) + 15.90099 (315) -12.47152 (311) = 159777.69 thousand ton
Case 3: If temperature increases by 5^oC and precipitation remains constant	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 ($wheat_{2059}$) + 0.355467 ($wheat_{2058}$) + 0.297277 (wheat $area_{2059}$) + 0.200009 (wheat $area_{2058}$) – 62.17562 (Avg. $Temp_{2059}$) + 242.9269 (Avg. $Temp_{2058}$) + 29.81109 (Avg. $Precip_{2009}$) – 15.24816 (Avg. $Precip_{2008}$) + 15.90099 (water $available_{2059}$) -12.47152 (water $available_{2058}$) = - 4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (27.6) + 242.9269 (28) + 29.81109 (39.2) – 15.24816 (35.3) + 15.90099 (315) -12.47152 (311) **=** 164863.6 thousand ton

In this scenario increasing temperature with constant level of precipitation may also lead to higher level of wheat production. In case of Pakistan the historical data revealed a low growth rate in the level of precipitation. If the growth in the level of precipitation becomes insignificant in future, even then it may not negatively affect the level of wheat production.

Scenario 3:

If temperature increases and precipitation decreases:

Case 1: If temperature increases by 2^oC and precipitation decreases by 10%	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 ($wheat_{2059}$) + 0.355467 ($wheat_{2058}$) + 0.297277 (wheat $area_{2059}$) + 0.200009 (wheat $area_{2058}$) – 62.17562 (Avg. $Temp_{2059}$) + 242.9269 (Avg. $Temp_{2058}$) + 29.81109 (Avg. $Precip_{2059}$) – 15.24816 (Avg. $Precip_{2058}$) + 15.90099 (water $available_{2059}$) -12.47152 (water $available_{2058}$) = - 4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (24.6) + 242.9269 (25) + 29.81109 (35.28) – 15.24816 (31.8) + 15.90099 (315) -12.47152 (311) = 162549.2 thousand ton
Case 2: If temperature increases by 4^oC and precipitation decreases by 10%	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 ($wheat_{2059}$) + 0.355467 ($wheat_{2058}$) + 0.297277 (wheat $area_{2059}$) + 0.200009 (wheat $area_{2058}$) – 62.17562 (Avg. $Temp_{2059}$) + 242.9269 (Avg. $Temp_{2058}$) + 29.81109 (Avg. $Precip_{2059}$) – 15.24816 (Avg. $Precip_{2058}$) + 15.90099 (water $available_{2059}$) -12.47152 (water $available_{2058}$) = - 4017.236 + 0.378517 170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (26.6) + 242.9269 (27) + 29.81109 (35.28) – 15.24816 (31.8) + 15.90099 (315) -12.47152 (311) = 157438.2 thousand ton
Case 3: If temperature increases by 5^oC and precipitation decreases by 10%	
E (Wheat $_{2060}$) =	- 4017.236 + 0.378517 ($wheat_{2059}$) + 0.355467 ($wheat_{2058}$) + 0.297277 (wheat $area_{2059}$) + 0.200009 (wheat $area_{2058}$) – 62.17562 (Avg. $Temp_{2059}$) + 242.9269 (Avg. $Temp_{2058}$) + 29.81109 (Avg. $Precip_{2059}$) – 15.24816 (Avg. $Precip_{2058}$) + 15.90099 (water $available_{2059}$) -12.47152 (water $available_{2058}$) =- 4017.236 + 0.378517 (170795) + 0.355467 (164226) + 0.297277 (19307.2) + 0.200009 (19016.7) – 62.17562 (27.6) + 242.9269 (28) + 29.81109 (35.28) – 15.24816 (31.8) + 15.90099 (315) -12.47152 (311) = 151965.7 thousand ton

In this scenario the temperatures are increasing with decreasing precipitation which may ultimately negatively affect the level of wheat production. This is a worst scenario and it can be conceived for Pakistan if the level of precipitation decreases as a consequence of climatic change.

5. CONCLUSIONS AND RECOMMENDATIONS:

The Vector Autoregression (VAR) model is used in this study in order to check the impact of climate change on wheat production in Pakistan. The study used data of the last half century. The results reveal that up to now there is no significant negative impact of climate change on wheat production in Pakistan.

Wheat is main food crop of Pakistan. The newly emerging threat of climatic change may influence the level of wheat production in Pakistan. Being an agricultural country we should be capable to secure domestic consumption by increasing the level of wheat production and the surplus production can be exported abroad to earn foreign exchange. In order to cope with any type of emerging hazard of climate change the agriculture sector in Pakistan needs some adaptation strategies. In this regard some strategic measures are given below:

1) Main issue of climate change is global warming. Therefore, researchers have to produce heat resistant seeds.
2) Climate change may change the level of precipitation as well as pattern and directions of rainfall. Therefore, drought resistant seeds have to be developed in time.
3) The increasing population requires more cultivable land for wheat production.
4) Water conservation management and the irrigation system have to be improved.
5) Increasing temperature may shorten the period of growth for wheat canopy. Therefore, time of wheat cultivation shall be adjusted accordingly.

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APPENDIX-1:

International Efforts to Abate the GHGs:

In order to cope with the global warming, a globally emerging threat, UN formed a body known as United Nation Framework Convention on Climate Change (UNFCCC) in March, 1994. Most of the countries are members of this body. Purpose of this body is to share information regarding emission among signatories' countries (Tisdell 2008). It does not impose penalty on the countries, rather it provides a plate form for the member countries to negotiate and to formulate policies. It was the success of this body that Kyoto agreement was first negotiated in 1997 which was ultimately ratified in 2005. The basic motive of this protocol was to bring back the emission of GHGs, namely Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydroflorocarbon (HFCs), Perflorocarbons (PFCs) and Super hexafluoride (SF6) at 1990 level. For this purpose the protocol proposed different mechanism to abate the CO_2 emission. These include clean development mechanism, emission trading and joint implementation.

USA, being one of the main polluters, has not ratified the protocol yet. Countries like China and India are also increasingly contributing toward emission of GHgs, however, these countries are not obligated per Kyoto protocol to reduce the emission. In this scenario the perspectives for success of the Kyoto Protocol in abating GHGs are not quite promising.

APPENDIX-2:

Vector Autoregression Estimates

Sample (adjusted): 1964 2009

Included observations: 46 after adjustments

Standard errors in ( ) & t-statistics in [ ]

	WH	AT	AP	LW	WPP	AC	FR	WA	TE
WH(-1)	0.478933	0.255874	0.000267	-0.004065	-0.003106	3.426.817	0.031710	0.001286	0.013681
	(0.42595)	(0.19330)	(0.00079)	(0.00328)	(0.00627)	-167.865	(0.05036)	(0.00205)	-148.858
	[1.12438]	[1.32373]	[0.33789]	[-1.23982]	[-0.49523]	[2.04141]	[0.62973]	[0.62809]	[0.00919]
WH(-2)	-0.086876	0.273605	0.000253	-0.005973	-0.007102	-0.424279	-0.017249	-0.002607	3.055.296
	(0.47973)	(0.21770)	(0.00089)	(0.00369)	(0.00706)	-189.058	(0.05671)	(0.00231)	-167.651
	[-0.18109]	[1.25679]	[0.28453]	[-1.61753]	[-1.00529]	[-0.22442]	[-0.30415]	[-1.13082]	[1.82242]

WH(-3)	-0.681204	-0.010127	0.000288	-0.000437	-0.003507	-3.014.134	-0.122135	-0.000451	2.195.145
	(0.31869)	(0.14462)	(0.00059)	(0.00245)	(0.00469)	-125.592	(0.03767)	(0.00153)	-111.371
	[-2.13754]	[-0.07003]	[0.48744]	[-0.17801]	[-0.74723]	[-2.39993]	[-3.24183]	[-0.29466]	[1.97101]
WH(-4)	-0.589526	-0.212243	-2.06E-06	-0.003329	-0.004937	-0.207494	0.107189	0.002085	-2.084.824
	(0.53559)	(0.24305)	(0.00099)	(0.00412)	(0.00789)	-211.074	(0.06332)	(0.00257)	-187.173
	[-1.10070]	[-0.87324]	[-0.00207]	[-0.80744]	[-0.62595]	[-0.09830]	[1.69289]	[0.81003]	[-1.11385]
AT(-1)	-0.698948	-0.045861	0.000327	0.005805	0.015416	-7.169.618	0.020214	0.001879	-2.474.896
	-114.582	(0.51998)	(0.00213)	(0.00882)	(0.01687)	-451.563	(0.13546)	(0.00551)	-400.432
	[-0.61000]	[-0.08820]	[0.15366]	[0.65821]	[0.91358]	[-1.58773]	[0.14923]	[0.34116]	[-0.61806]
AT(-2)	0.163493	-0.527853	0.000291	0.014066	0.026036	-5.367.709	0.069998	0.003027	-8.452.483
	-124.668	(0.56575)	(0.00231)	(0.00960)	(0.01836)	-491.309	(0.14738)	(0.00599)	-435.678
	[0.13114]	[-0.93302]	[0.12560]	[1.46586]	[1.41814]	[-1.09253]	[0.47495]	[0.50508]	[-1.94008]
AT(-3)	1.086.864	0.363618	-0.001177	-0.010917	-0.027767	1.576.026	0.097341	-0.000416	-0.891495
	(0.99004)	(0.44928)	(0.00184)	(0.00762)	(0.01458)	-390.169	(0.11704)	(0.00476)	-345.990
	[1.09780]	[0.80933]	[-0.64027]	[-1.43259]	[-1.90445]	[4.03934]	[0.83168]	[-0.08742]	[-0.25767]
AT(-4)	0.690695	-0.226142	-0.001249	-0.002440	0.047150	-7.570.864	-0.278799	-0.007427	1.623.877
	-129.443	(0.58742)	(0.00240)	(0.00996)	(0.01906)	-510.128	(0.15303)	(0.00622)	-452.365
	[0.53359]	[-0.38498]	[-0.51969]	[-0.24488]	[2.47344]	[-1.48411]	[-1.82190]	[-1.19378]	[0.35897]
AP(-1)	8.516.057	1.991.439	0.343641	0.637459	2.264.486	6.223.358	2.339.213	1.621.462	1.003.821
	-225.613	-102.384	(0.41876)	-173.654	-332.251	-889.127	-266.717	-108.442	-788.449
	[3.77463]	[1.94508]	[0.82061]	[0.36709]	[0.68156]	[0.69994]	[0.87704]	[1.49523]	[1.27316]
AP(-2)	1.382.922	2.926.739	0.757613	0.146484	-1.065.039	-4.487.032	3.449.065	-0.739316	2.389.572
	-293.802	-133.328	(0.54533)	-226.139	-432.670	(1157.86)	-347.330	-141.218	(1026.75)

	[0.47070]	[2.19514]	[1.38928]	[0.06478]	[-2.46155]	[-0.38753]	[0.99302]	[-0.52353]	[2.32731]
AP(-3)	-5.785.916	-2.475.781	0.039959	6.535.342	4.500.649	-7.073.372	-6.697.482	0.263357	-5.223.719
	-374.947	-170.152	(0.69594)	-288.596	-552.169	(1477.64)	-443.258	-180.220	(1310.33)
	[-1.54313]	[-1.45504]	[0.05742]	[2.26453]	[0.81509]	[-0.47869]	[-1.51097]	[0.14613]	[-0.39866]
AP(-4)	6.223.364	-2.722.957	-0.060009	2.309.372	1.055.548	1.896.834	1.702.486	1.616.362	-2.247.997
	-282.998	-128.425	(0.52528)	-217.823	-416.760	(1115.28)	-334.557	-136.025	-988.994
	[0.21991]	[-2.12027]	[-0.11424]	[1.06020]	[2.53275]	[1.70077]	[0.50888]	[1.18829]	[-2.27301]
LW(-1)	-3.127.832	6.761.075	0.001494	-0.424552	-0.378613	-4.662.717	0.221634	-0.302755	1.493.867
	-404.575	-183.597	(0.07509)	(0.31140)	(0.59580)	-159.441	-478.284	(0.19446)	-141.387
	[-0.77312]	[0.36826]	[0.01990]	[-1.36336]	[-0.63547]	[-0.29244]	[0.04634]	[-1.55689]	[1.05658]
LW(-2)	-1.023.328	-2.429.114	-0.068095	0.000624	0.637149	-1.462.823	-1.632.603	-0.134539	-6.623.768
	-385.400	-174.895	(0.07153)	(0.29664)	(0.56756)	-151.884	-455.616	(0.18524)	-134.686
	[-2.65524]	[-1.38889]	[-0.95192]	[0.00210]	[1.12260]	[-0.96312]	[-3.58329]	[-0.72628]	[-0.49179]
LW(-3)	5.596.709	-2.234.852	-0.081303	-0.706552	0.412924	5.069.213	5.868.536	0.174145	-1.047.862
	-569.531	-258.455	(0.10571)	(0.43837)	(0.83872)	-224.449	-673.293	(0.27375)	-199.034
	[0.98269]	[-0.08647]	[-0.76911]	[-1.61178]	[0.49232]	[2.25852]	[0.87162]	[0.63615]	[-0.05265]
LW(-4)	3.384.161	2.893.833	-0.042746	-0.657214	0.220947	-3.077.894	-5.708.635	-0.418569	1.950.834
	-455.829	-206.856	(0.08461)	(0.35085)	(0.67128)	-179.640	-538.876	(0.21910)	-159.299
	[0.07424]	[1.39896]	[-0.50523]	[-1.87320]	[0.32914]	[-1.71337]	[-1.05936]	[-1.91043]	[1.22464]
WPP(-1)	2.095.287	-3.799.012	0.026333	0.266634	1.498.527	-2.398.802	0.974065	0.021049	-4.787.716
	-215.853	-979.545	(0.04006)	(0.16614)	(0.31788)	-850.663	-255.179	(0.10375)	-754.341
	[0.97070]	[-0.38783]	[0.65727]	[1.60486]	[4.71417]	[-2.81992]	[0.38172]	[0.20288]	[-0.63469]
WPP(-	-	-1.062.686	0.008403	0.432300	-0.539013	-1.900.754	-1.216.585	0.007636	2.332.857

2)	6.113.220								
	-534.839	-242.711	(0.09927)	(0.41167)	(0.78764)	-210.777	-632.281	(0.25707)	-186.910
	[-1.14300]	[-0.43784]	[0.08465]	[1.05012]	[-0.68434]	[-0.90178]	[-1.92412]	[0.02971]	[0.12481]
WPP(-3)	2.607.842	-2.034.770	-0.003975	-0.356286	0.776765	4.156.133	1.498.126	0.187998	-3.314.215
	-543.563	-246.670	(0.10089)	(0.41838)	(0.80048)	-214.215	-642.594	(0.26127)	-189.959
	[0.47977]	[-0.82489]	[-0.03940]	[-0.85158]	[0.97037]	[1.94017]	[2.33137]	[0.71956]	[-1.74470]
WPP(-4)	-1.062.276	2.656.919	-0.045441	-0.558496	-0.538397	2.990.020	-5.600.697	-0.403226	4.040.248
	-443.583	-201.299	(0.08233)	(0.34143)	(0.65325)	-174.814	-524.399	(0.21321)	-155.019
	[-0.02395]	[1.31989]	[-0.55191]	[-1.63578]	[-0.82419]	[0.17104]	[-1.06802]	[-1.89121]	[2.60629]
AC(-1)	0.171000	0.114774	-7.03E-06	-0.001723	-0.002803	2.669.942	0.056795	0.000398	0.650132
	(0.17308)	(0.07854)	(0.00032)	(0.00133)	(0.00255)	(0.68210)	(0.02046)	(0.00083)	(0.60487)
	[0.98797]	[1.46126]	[-0.02187]	[-1.29352]	[-1.09978]	[3.91428]	[2.77572]	[0.47863]	[1.07483]
AC(-2)	-0.138051	-0.056275	-4.39E-05	0.002725	0.002614	-2.419.390	-0.094224	-0.001228	0.525286
	(0.27213)	(0.12349)	(0.00051)	(0.00209)	(0.00401)	-107.244	(0.03217)	(0.00131)	(0.95100)
	[-0.50730]	[-0.45570]	[-0.08684]	[1.30092]	[0.65216]	[-2.25597]	[-2.92889]	[-0.93886]	[0.55235]
AC(-3)	-0.091023	-0.092165	0.000237	0.000780	0.004306	1.574.888	0.044750	0.001814	-1.572.056
	(0.21091)	(0.09571)	(0.00039)	(0.00162)	(0.00311)	(0.83117)	(0.02493)	(0.00101)	(0.73705)
	[-0.43158]	[-0.96297]	[0.60526]	[0.48027]	[1.38652]	[1.89479]	[1.79480]	[1.78954]	[-2.13290]
AC(-4)	-0.021586	-0.038902	-0.000230	-0.001243	0.000237	-0.891705	-0.023558	-0.000940	-0.363759
	(0.15289)	(0.06938)	(0.00028)	(0.00118)	(0.00225)	(0.60253)	(0.01807)	(0.00073)	(0.53431)
	[-0.14118]	[-0.56069]	[-0.80915]	[-1.05659]	[0.10530]	[-1.47993]	[-1.30337]	[-1.27846]	[-0.68081]
FR(-1)	-5.623.362	-3.866.114	-0.002072	-0.000467	-0.005151	-9.689.549	0.540429	0.000225	-1.461.612

	-286.220	-129.888	(0.00531)	(0.02203)	(0.04215)	-112.798	(0.33837)	(0.01376)	-100.025
	[-1.96470]	[-2.97651]	[-0.39005]	[-0.02122]	[-0.12220]	[-0.85902]	[1.59717]	[0.01633]	[-1.46124]
FR(-2)	4.571.018	2.521.603	-0.001352	-0.035557	-0.113183	2.891.174	0.260601	0.000293	-7.922.703
	-357.610	-162.285	(0.00664)	(0.02753)	(0.05266)	-140.932	(0.42276)	(0.01719)	-124.974
	[1.27821]	[1.55382]	[-0.20365]	[-1.29180]	[-2.14917]	[2.05146]	[0.61642]	[0.01705]	[-0.63395]
FR(-3)	4.473.131	-0.952222	-0.001584	0.028272	0.146904	-4.551.582	0.236351	-0.001749	0.214908
	-382.076	-173.387	(0.00709)	(0.02941)	(0.05627)	-150.574	(0.45169)	(0.01836)	-133.524
	[1.17074]	[-0.54919]	[-0.22337]	[0.96136]	[2.61085]	[-3.02282]	[0.52326]	[-0.09522]	[0.01610]
FR(-4)	1.142.795	3.629.228	-0.000625	-0.025159	-0.138340	3.170.951	-0.137871	0.008817	2.887.491
	-397.796	-180.521	(0.00738)	(0.03062)	(0.05858)	-156.769	(0.47027)	(0.01912)	-139.018
	[0.28728]	[2.01042]	[-0.08471]	[-0.82169]	[-2.36148]	[2.02269]	[-0.29317]	[0.46113]	[2.07707]
WA(-1)	- 4.355.337	-4.208.479	-0.140208	0.328586	1.607.918	-1.423.155	-8.077.825	0.414428	-2.338.770
	-634.930	-288.133	(0.11785)	(0.48870)	(0.93504)	-250.222	-750.608	(0.30518)	-221.889
	[-0.06860]	[-1.46060]	[-1.18971]	[0.67236]	[1.71963]	[-0.56876]	[-1.07617]	[1.35797]	[-1.05403]
WA(-2)	1.064.764	1.872.821	0.045314	-0.150229	-0.796560	5.207.409	2.183.046	0.180423	5.729.499
	-767.543	-348.313	(0.14246)	(0.59078)	-113.033	-302.484	-907.381	(0.36892)	-268.233
	[1.38724]	[0.53768]	[0.31807]	[-0.25429]	[-0.70472]	[1.72155]	[2.40588]	[0.48905]	[2.13601]
WA(-3)	- 6.683.092	4.853.265	0.118100	1.800.717	-1.286.024	-4.618.034	-2.061.654	-0.131782	-1.726.636
	-107.092	-485.985	(0.19877)	(0.82428)	-157.710	-422.043	-126.603	(0.51474)	-374.254
	[-0.62405]	[0.99864]	[0.59414]	[2.18458]	[-0.81544]	[-1.09421]	[-0.16284]	[-0.25601]	[-0.46135]
WA(-4)	1.599.763	-3.209.755	0.148051	1.386.585	3.503.542	2.399.707	1.124.946	0.622154	-4.898.379
	-121.962	-553.466	(0.22637)	(0.93874)	-179.608	-480.645	-144.182	(0.58622)	-426.220
	[1.31169]	[-0.57994]	[0.65401]	[1.47707]	[1.95066]	[0.49927]	[0.78023]	[1.06130]	[-1.14926]
TE(-1)	0.095645	-0.026244	-3.90E-05	4.77E-05	0.001293	-0.131016	-0.006596	-0.000206	0.306466

	(0.09968)	(0.04524)	(0.00019)	(0.00077)	(0.00147)	(0.39283)	(0.01178)	(0.00048)	(0.34835)
	[0.95952]	[-0.58017]	[-0.21081]	[0.06220]	[0.88077]	[-0.33352]	[-0.55977]	[-0.42901]	[0.87976]
TE(-2)	-0.094425	0.024100	-6.81E-05	-0.001566	-0.003345	-0.108516	0.002869	-0.000266	0.370362
	(0.08826)	(0.04005)	(0.00016)	(0.00068)	(0.00130)	(0.34785)	(0.01043)	(0.00042)	(0.30846)
	[-1.06979]	[0.60167]	[-0.41596]	[-2.30505]	[-2.57303]	[-0.31197]	[0.27496]	[-0.62745]	[1.20069]
TE(-3)	0.082762	0.039135	0.000139	0.000961	0.000892	-0.358860	0.017002	0.000139	-0.066342
	(0.06969)	(0.03163)	(0.00013)	(0.00054)	(0.00103)	(0.27464)	(0.00824)	(0.00033)	(0.24354)
	[1.18759]	[1.23748]	[1.07252]	[1.79139]	[0.86877]	[-1.30665]	[2.06369]	[0.41595]	[-0.27241]
TE(-4)	-0.107189	0.020850	-8.81E-06	-8.44E-05	-0.000886	0.287142	-0.018329	0.000131	0.593091
	(0.10153)	(0.04607)	(0.00019)	(0.00078)	(0.00150)	(0.40012)	(0.01200)	(0.00049)	(0.35482)
	[-1.05574]	[0.45253]	[-0.04674]	[-0.10796]	[-0.59225]	[0.71764]	[-1.52707]	[0.26816]	[1.67155]
C	-14849.00	6.718.212	0.328828	-2.345.886	-5.464.261	-5.059.741	-5.934.352	-5.091.708	42125.17
	(13957.1)	(6333.75)	-259.058	-107.427	-205.540	(55004.0)	(1649.99)	-670.854	(48775.8)
	[-1.06391]	[1.06070]	[0.01269]	[-2.18370]	[-2.65849]	[-0.09199]	[-0.35966]	[-0.07590]	[0.86365]

R-squared	0.997254	0.985425	0.957901	0.918461	0.999452	0.999547	0.999133	0.996932	0.995013
Adj. R-squared	0.986269	0.927127	0.789504	0.592307	0.997258	0.997737	0.995666	0.984661	0.975066
Sum sq. resids	3917009.	806656.1	1.349.466	2.320.577	8.494.911	60835193	54742.99	9.049.475	47838214
S.E. equation	6.597.145	2.993.801	1.224.503	5.077.813	9.715.343	2.599.897	7.799.073	3.170.958	2.305.506
F-statistic	9.078.520	1.690.313	5.688.352	2.816.035	4.556.568	5.521.418	2.881.866	8.124.403	4.988.330
Log likelihood	-3.263.717	-2.900.274	-3.706.519	-1.024.931	-1.323.391	-3.894.570	-2.281.517	-8.083.413	-3.839.291
Akaike AIC	1.579.877	1.421.858	3.220.226	6.064.917	7.362.569	1.854.161	1.152.834	5.123.223	1.830.127
Schwarz SC	1.726.963	1.568.945	4.691.089	7.535.781	8.833.432	2.001.247	1.299.920	6.594.087	1.977.213
Mean dep	13069.50	7.192.239	1.870.007	3.598.804	1.553.163	31453.11	1.634.292	1.062.516	19748.52
S.D. dependent	5.629.965	1.109.021	2.668.933	7.952.620	1.855.416	54654.36	1.184.713	2.560.344	14600.72

Determinant resid covariance (dof adj.)	2.61E+27
Determinant resid covariance	1.09E+21
Log likelihood	-1.701.664
Akaike information criterion	8.846.364
Schwarz criterion	1.017.014