Agricultural Productivity and Climate Change in the Greater Middle East

Zahra Tayebi
Department of Food and Resource Economics
University of Florida
ztayebi@ufl.edu

Lilyan Estela Fulginiti
Department of Agricultural Economics
University of Nebraska-Lincoln
lfulginiti1@unl.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association's 2016 Annual Meeting, San Antonio, Texas, February, 6-9, 2016

Agricultural Productivity and Climate Change in the Greater Middle East

Abstract

The main purpose of this research is to determine the potential impact of weather variables on agricultural productivity for Afghanistan, Iran, Pakistan, Turkey and Syria. A translog production function was used in estimating TFP growth in agriculture over the period 1980-2010. Precipitation, temperature, drought and irrigation were included in the analysis. The results indicate increasing agricultural productivity during the period with innovations contributing approximately 30% to agricultural output growth. Temperature and precipitation play a significant role in agricultural production and most frequent extreme drought episodes and irrigation affect, substantially, agricultural productivity growth in the region.

Key words: Agricultural productivity; Climate change; Greater Middle East; Stochastic frontier

1. Introduction

Total Factor Productivity (TFP) growth in agriculture represents how efficiently the agricultural industry uses the resources that are available to turn inputs into outputs. It is a key measure of the economic performance of agriculture and an important driver of farm incomes.

In this study the focus is on agricultural productivity growth in the Greater Middle East, specifically in Iran, Afghanistan, Turkey, Pakistan and Syria. The agricultural sector, although not one of the most significant sectors in countries rich in mineral resources, is still important to study because of the large proportion of the population living in rural areas (76% in Afghanistan, 31% in Iran, 63% in Pakistan, 44% in Syria and 28% in Turkey. In the Greater Middle East countries, agriculture suffers the consequence of the 'Dutch Disease' as resources are syphoned away to the oil or other mineral sectors as well as to more lucrative, but illegal, enterprises (poppy cultivation). Some of these countries also have been, and still are involved, in political, military and civil struggles and countries such as Iran and Syria have faced or still face strict export and import bans. These trade restrictions, in addition to the other issues mentioned, might be an important factor affecting the growth of the agricultural sector in these countries with important consequences for the well-being of the rural population and a factor affecting migration to the urban centers.

Even as the developing world was quickly adopting new technologies, some studies showed decreasing productivity in some areas of the world. If the deterioration in productivity is confirmed, it is a reason for concern since not only a large section of the population is dependent on agriculture in these countries but also their agricultural products are a main source of exports and foreign exchange.

Climate change is also a crucial environmental problem. According to the International Panel on Climate Change (IPCC), climate change will affect the Middle East and North Africa region in the coming decades. Decrease in precipitation and higher temperatures will increase the occurrence of droughts while increasing population and agricultural production will enhance the demand for water. Hence, the productivity of the agricultural sector might be affected by climate change. Changes in climate patterns might lead to damage in the agriculture sector and could be counterproductive to an economic reform process.

FAO (2001) assessed the impacts of rainfall on agricultural production and indicated that there are important interaction between production and climate variability. Many studies have shown the effect of climate changes on agricultural productivity. They found that a decrease in water availability could play an important role in reducing agricultural productivity. (Parry et al. 2004; Tao et al. 2003, 2008; Xiong et al. 2007; Schlenker and Lobell 2010). Kumar et al. (2004) and Sivakumar et al. (2005) concluded that changes in precipitation patterns will affect agricultural production.

Drine (2011) indicated that drought and lower precipitation are major factors affecting agricultural productivity in the North Africa and the Middle East (MENA) countries. Using a Ricardian approach, Mendelsohn *et al*. (1994) determined the impacts of climate on U.S. farmland prices and net revenues and found that the climate effects were significant. Several studies such as Rowhani *et al.* (2011), Müller *et al.* (2011), Schlenkler and Lobell (2010), O'Connell and Ndulu (2006), Collier and Gunning (1999), Bloom and Sachs (1998), Rosenweig and Parry (1994) have pointed out the potential impact of climatic change on the performance of agriculture in Sub Saharan Africa. Sanghi *et al*. (1998) argued that the effect of climate change on agricultural productivity is negative in Brazil. Moreover, using actual sale price of land at the farm's level, Maddison (2000) determined the marginal value of characteristics of several farmlands in England and Wales. The results showed that frost days in winter play a significant role in agriculture and climate and soil quality affect farmland prices. Kibonge (2013) shows that weather variability affect agricultural productivity in Sub Saharan Africa. The results highlight that precipitation and temperature have a positive impact on production up to a certain threshold.

With a glance at global agricultural production, Alston, Babcock and Pardey (2010) showed decrease in global yield growth rates for wheat, corn, soybeans and rice over period 1990-2007 for middle and high income countries. Fuglie (2010) found decrease in global yield growth rates while his results indicate decreasing TFP growth rates in developing economies. On average, he calculates that agricultural TFP growth rate has decreased from 2.30 percent over the 1990s to 1.90 percent over the 2000s.

The studies which have estimated agricultural TFP in the countries of interest are few. Belloumi and Matoussi, (2009) calculated TFP growth rate for 16 countries in the Middle East and North Africa (including Iran, Turkey and Syria) and found increasing agricultural productivity for the group. Fulginiti and Perrin (1997, 1998 and 1999) confirm the results obtained earlier by Kawagoe and Hayami (1985) and Lau and Yotopoulos (1989) and Kawagoe et al. (1985). They estimated agricultural productivity by using an output-based Malmquist Index over the period 1961-1985. Their results showed negative productivity growth for some of the 18 countries in their study. They also mentioned that those that tax agricultural had the most negative rates of productivity change.

More directly relevant to the countries in this study, Shahabinejad and Akbari (2010) analyzed agricultural productivity growth in the "Developing Eight" (Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey) over the period 1993 - 2007 using data envelopment analysis (DEA). Their results showed Total Factor Productivity was positive and that technical change is the main source of this growth. They estimated an average technical change 1.5% and a negative average efficiency change (-

0.4%) for this region. Results also indicated all countries have improved technology more than efficiency in this period.

Fulginiti and Perrin (1998) indicated productivity losses for Pakistan and productivity gains for Turkey during the period 1961-1985 while other literature has shown positive TFP growth rate (0.28%) for Pakistan during 1965-2005 (Ahmed,1987).

The countries of interest in this study have individually been the subject of a few studies. Considering Pakistan, Chaudhry (2005) estimated an increasing TFP, 1.75%, over period 1985-2005. Evenson and Pray (1991) calculated an increasing TFP growth rate 1.07% for 1965-1985. Other studies by Kemal et al (2002), Ali (2004) and Ahmad et al. (2008) indicate that agricultural TFP in Pakistan has grown at an annual average rate of 0.37%, 2.17% and 0.28% around the period 1965-2001, respectively. These studies recommended that some policies such as increasing the area under cultivation and fertilizer at affordable prices for the farmers can accelerate TFP growth in the agriculture sector of Pakistan (Ali et al., 2006; Riazuddin, 2006).

A study by Khani and Yazdani, (2012) on the determinants of Total Factor Productivity in Iran in the period 1959-2007 showed that 1% change in skilled human capital leads to 30% increase in Total Factor Productivity and one percent change in physical capital leads to a 55% increase in Total Factor Productivity in the agricultural sector. Mohammadrezazadeh et al. (2012) estimated a Translog production function including GDP, human capital, physical capital and employment in the agricultural sector over the period 1967-2008. The average TFP growth rate was 0.03% in this study. Using a Solow Residual model and data on employment, capital stock and value added of various economic sectors, Tahamipour et al. (2008) found agricultural TFP increasing at 2.5% in the period 1991-2008.

Regarding macro determinants of TFP growth in the Turkish economy, Acemoglu (2008) showed that growth is the result of more physical and human capital and that institutional reform to create economic freedom is very important. Rao et al. (2004) estimated a 0.1% agricultural TFP growth for Turkey using Malmquist indexes during the period 1970-2001. Belloumi and Matoussi (2009) showed that the rate of productivity decrease in Turkey was -1.1% using the same technique and almost the same period.

A few papers discuss Afghanistan's agriculture and agricultural productivity. A study by Trueblood and Coggins (2000) using the Malmquist index over the 1961-1991 period estimated a declining TFP growth rate of -1.61%. Oliphant (2007) obtained a -0.5% declining agricultural TFP growth rate for Afghanistan using an arithmetic index for the period 1961- 2006.

Considering Syria, Rao et al. (2004) estimated a TFP growth rate of 0.9% during 1970-2001using Malmquist indexes. A study by Belloumi and Matoussi, (2009) using the same method during the period 1970-2000 calculated increasing TFP growth rate of 0.2%, with technical change as the main component.

Parametric or non-parametric distance functions have been applied to estimate TFP growth rates in several studies. Estimating a stochastic parametric distance frontier, Fulginiti, Perrin and Yu (2004), Bharati and Fulginiti (2007) and Trindade and Fulginiti (2015) estimated the differences in efficiency performance of selected countries using various institutional and economic variables. They indicated that life expectancy and trade intensity play a positive role on increasing efficiency. Headey et al. (2005) estimated the impact of different environmental variables on agricultural TFP growth rates using different parametric method. They pointed out that the number of agricultural scientist per thousand workers; agricultural expenditure as percentage of GDP and the real rate of assistance to agriculture have significantly positive roles on TFP growth rates.

This study performs an analysis of agricultural productivity growth in Iran, Afghanistan, Pakistan, Turkey and Syria (referred to as the Greater Middle East) with the purpose of assessing the effects of weather variables on TFP growth in this region. We will consider economic, as well as political and social factors that might be affecting agricultural performance in these countries. We incorporate various environmental characteristics of each country to understand efficiency differences across them (Battesse and Coelli, 1995).

We construct a Standard Precipitation Index for these countries as a proxy for drought and use it, along with precipitation and other variables in a stochastic frontier production function from where we obtain estimates of the TFP growth rate and the contribution of weather variables to total output growth in the region over the period 1980-2010.

The rest of the study is organized as follows. Section 2 describes the methodology and section 3 provides an explanation of the data used in the analysis. The estimation and results are described in section 4. Finally, section 5 contains conclusion and final comments about the results.

2. The Model

This study aims at estimating TFP for these selected countries and to shed light on the potential role of institutional and weather factors in understanding agricultural growth.

We use a production function, as in Fulginiti, Perrin, and Yu (2004), Bharati and Fulginiti (2007), Trindade and Fulginiti (2014), following Solow and Griliches, and many other multi-country studies. Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) modified the production function and proposed a stochastic frontier production function with presence of technical inefficiencies obtained by a one-sided error term. Following Battese and Coelli (1995) we present the following model:

(1) $Y_{it} = f(x_{it}, t; \beta)$ $\quad\quad i = 1,\dots,I,\ t = 1,\ \dots,\ T$

Selecting a translog functional form, this production frontier is

$$\text{(2) } LnY_{it} = \alpha_0 + \sum_m \alpha_m ln x_{mit} + \alpha_t t + \sum_{m,n} \beta_{mn} ln x_{mit}\, ln x_{nit} + \frac{1}{2}\sum_m \beta_{mm}(ln x_{mit})^2 + \frac{1}{2}\beta_{tt}(t)^2 + \sum_m \beta_{tm} ln x_{mit}\, t + v_{it} - u_{it}$$

where Y_{it} is output of the *i*-th country in time period *t*, $x_{it}$is an *Nx1* vector of the logarithm of inputs for the *i*-th country in time period *t,* β is a vector of unknown parameters. The error term ($\varepsilon_{it} = v_{it} - u_{it}$) is decomposed into two random variables where v_{it} are random component assumed to be iid N (0, σ_v^2) and u_{it} is a non-negative random error distributed iid N (μ_{it}, σ_v^2) representing technical inefficiency across production units (or individual production units effects.) In our case, it accounts for heterogeneity across countries that can cause departures from maximum potential output.

The input production elasticities are:

$$(3)\ \varepsilon_m = \frac{\partial \ln Y_{it}}{\partial \ln x_m} = \alpha_m + \beta_{mm} \ln x_m + \sum_{n \neq m} \beta_{mn} ln x_n + \beta_{tm} t$$

According to Battesse and Coelli, the mean μ of *u* can be specified as a function of z_{it} where z is a vector of independent variables of the i-th country in the t-th year:

$$(4)\ \mu_{it} = \delta z_{it}$$

Note that δ is a vector of parameters to be estimated.

Technical efficiency is measured as:

$$(5)\ TE = \exp(-u_{it})$$

Technical change is:

$$(6)\ TC = \frac{\partial \ln Y_{it}}{\partial t} = \alpha_t + \beta_{tt} t + \sum_m \beta_{tm} ln x_{mit}$$

Having calculated technical change (TC) and technical efficiency (TE), change in Total Factor Productivity can be computed as:

$$(7)\ TFP = TC + EC.$$

The difference in technical efficiency from period (t) to period (t+1) is defined as efficiency change (EC). The technical efficiency measure takes values of zero to one where one indicates full technical efficiency. Technical efficiency reflects differences across countries. The frontier methodology lends itself to the inclusion of potential factors of country heterogeneity which we refer to as efficiency changing variables (z's).

Equations (2) and (5) are estimated simultaneously by maximum likelihood methods to obtain the α's, β's and δ's.

This model enables us to test if inefficiency effects are present in the error term. $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, represents the proportion of the error term due to inefficiency effects. It lies in the range of 0-1. A value of 1 indicates that inefficiency effects largely contribute to the error term and a value of zero reflects that the error is just white noise.

3. Data

In order to estimate the production function, we follow Fulginiti, Perrin, and Yu (2004), Bharati and Fulginiti (2007), Trindade and Fulginiti (2015) closely. A panel data set for the five selected countries including Iran, Afghanistan, Pakistan, Turkey and Syria is collected for the time period 1980-2010. Data on traditional agricultural inputs (labor, land, livestock and machinery) and output were obtained from the FAOSTAT website. Fertilizer input data provided by International Fertilizer Association data was used that seems to be more recent and accurate.

Agricultural *output* is gross agricultural production in thousands of international dollars. This is an index (base 2004-2006) provided by FAO that uses a set of weighted commodity prices. Agricultural *land* is total arable and permanent crops and pastures in thousands hectares. Afghanistan (-2%) shows a decrease in use of land while Iran (+40%) and Pakistan (+6%) show increases. Agricultural *labor* is measured as the number of thousand persons who are economically actively involved in agricultural production. Afghanistan (+87%), Pakistan (+48%) and Syria (+107%) had big increases in the amount of labor employed, while Turkey (-17%) shows decreases. *Livestock* is a weighted average of the number of animals in farms presented in cattle equivalents (Hayami and Ruttan, 1985). *Fertilizer* is measured in metrics tons of Nitrogen, Potassium, and Potash (N plus P_2O_5 plus K_2O). This variable is very volatile. Pakistan (+256%) and Iran (+142%) have large increases in fertilizer use, while Afghanistan (-3%) shows a decrease.

Machinery is defined as number of agricultural tractors. This variable increased for all countries during this period, Iran (+302%), Pakistan (+290%), Syria (+299%) and Turkey (+131%), while Afghanistan had a smaller increase of +16%.

Table 1 - Summary Statistic: Output and Inputs
Region: The Greater Middle East - Period: 1980-2010

Variable	Unit	Source	Mean	Max	Min	SD	Growth Rate(%)
Output	Thousands of constant 2004-2006 US dollars	FAO	15609011.9	38009593	1913681	11493638.6	2.80
Fertilizer	Metric Tons	International Fertilizer Institute	1164.63	4360.6	35.8	1019.39	2.71
Land	Thousands hectare	FAO	15798.6	28513	5421	8091.41	0.10
Labor	Thousands person	FAO	22250.8	47189	680	21700	0.94
Machinery	No. of tractors	FAO	271042	1007620	770	292944	3.46
Livestock	Thousands cattle equivalent	FAO	45219662.96	10130674	87615000	23603141.1	0.54

Figure 1 depicts the cumulative frequency distribution (CDF) of the growth rates of inputs and outputs. This graph also demonstrated that the biggest changes are in fertilizer input over the period 1980-2010. Most of the countries used very little fertilizer at the start of the period of analysis. The median growth rate is about 2% and about 75% of the growth rates for the inputs and for output are between -3% to 3%. The output CDF lies mostly to the right side of the inputs CDF. This means that output growth rates are higher than growth rates of the inputs (except machinery). Median growth rates for machinery and output are around 2%, for fertilizer around 4% and for labor around 1%.

Figure 1- Cumulative Frequency Growth Rate (%) of Output and Inputs
Region: The Greater Middle East - Period: 1980-2010

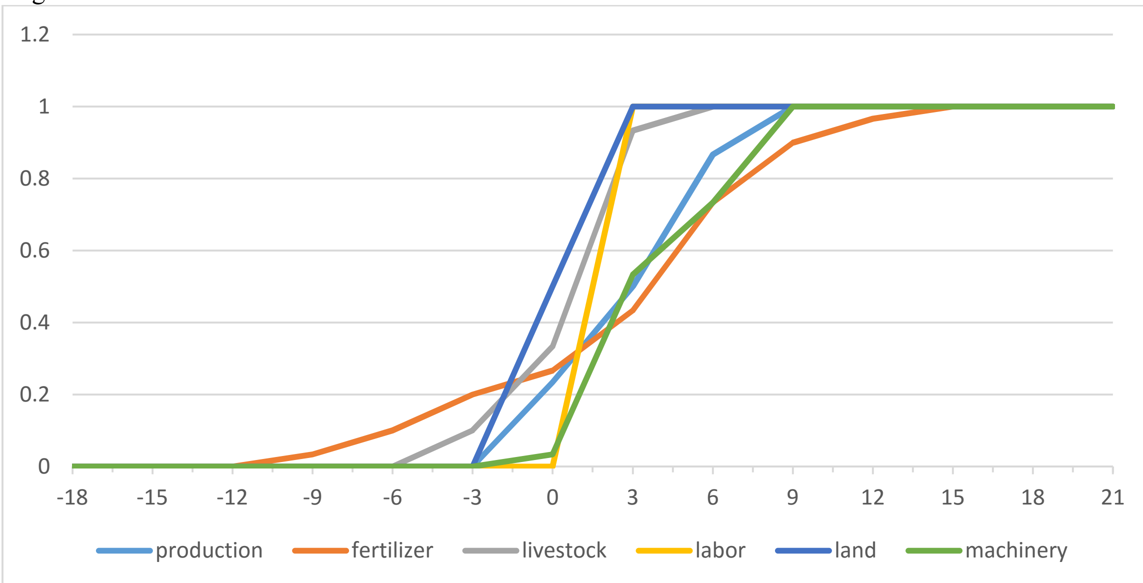
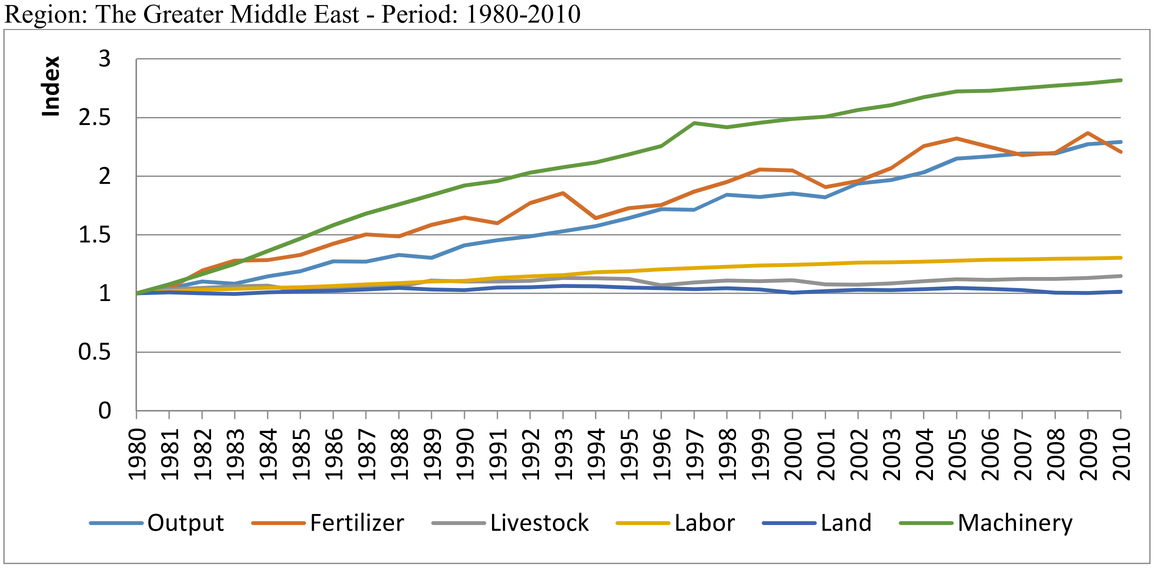


Figure 2 illustrates the evolution of the variables during 1980-2010 for the region in index form. A smooth evolution for all the variables can be observed. Machinery has increased more than other inputs. Output and fertilizer show a monotonic increase during the period. We can observe also a relative constant use of land during the period.

Figure 2: Evolution of inputs and output (Index=1980)
Region: The Greater Middle East - Period: 1980-2010



In this analysis, three kinds of efficiency changing variables are considered to determine if differences in resource quality and socio-political characteristics can explain the difference in country performance. These variables are associated with the mean of the one-sided error term. Three input quality variables were selected: (i) labor quality proxied by the *secondary school enrollment ratio* taken from the World Development Indicators; (ii) health quality proxied by *life expectancy* from UNDP website; and iii) land quality proxied by the *irrigation ratio* obtained from FAOSTAT (the percentage of agricultural land that is equipped for irrigation.)

The institutional variables are as follows: (i) *Independence* is the number of years since independence, obtained from the Central Intelligence Agency World Factbook; (ii) *Armed conflict* represented by two dummy variables to indicate minor conflict or major conflict like war (contrasted with no conflict), using data from Gleditsch et al.; (iii) *Political rights and civil liberties* captured by a dummy variable categorizing countries as partially free (contrasted with not free) from the Freedom House index of political rights and civil liberties; and (iv) the *Trade openness ratio* or trade intensity ratio which is defined as the ratio of the sum of exports and imports to real GDP per capita, obtained from the World Penn Tables.

Table 2 shows the summary statistics of efficiency changing variables.

Table 2 - Summary Statistic-Efficiency Variables
Region: The Greater Middle East - Period: 1980-2010

Variable	Unit	Source	Mean	Max	Min	SD
Labor Quality	Secondary School Enrollment Ratio	World Development Indicators	60.07	97.81	20.56	19.13
Independence	Year since Independence	Central Intelligence Agency World Factbook	47.82	91	1	21.42
Health Quality	Life Expectancy	UNDP website	61.39	75.01	39.19	10.67
Openness	2005 constant price in percent	World Penn Table	64.13	132.78	11.45	22.63
Irrigation	Percent of agricultural land irrigated	FAOSTAT	20.85	76.57	3.83	22.74

In addition to the output, inputs and efficiency changing variables, we add a measure of precipitation and temperature and a measure of drought. The data set on precipitation and temperature is obtained from the National Climatic Data Center (NCDC). *Temperature* is presented as the average monthly temperature in degree Celsius. *Precipitation* is defined as the average monthly precipitation in millimeters. This variable is the average precipitation of all stations for which recent data was found. The stations and location characteristics are displayed on the map. *Drought* is a weather variable captured by the Standard Precipitation Index (SPI). We follow Kibonge (2013) and construct a Standard Precipitation Index based on monthly precipitation then count the number of months with SPI of -1 and less to proxy drought.

3.1.Standardized Precipitation Index (SPI)

SPI is the most common indicator of drought proposed by McKee *et al.* (1993, 1995) to define and monitor drought. This index indicates a drought or wet event at a certain time period for any location that has precipitation records. This index is calculated by fitting a gamma distribution for monthly precipitation at different time steps (1, 3, 6, 9 and 12 months), and then converting to the normal distribution with mean zero and a variance of one. The SPI indicates a Z-score, or the number of standard deviations that an event is from the mean. This index can be calculated for different durations, weeks or months. We choose a 1-month SPI in this study as it is more relevant for agricultural purpose and provides an indication of soil moisture and crop stress in agriculture (Kibonge, 2013). SPI takes the values between -0.99 and 0.99 for near normal situations, -1 to -1.49 for moderately dry, severely dry -1.5 to -1.99 for severely dry and values less than -2 for an extremely dry period. Any values greater or equal to 1 indicate a wet period. Drought events occur when the SPI is continually negative and has an intensity of -1.0 or less (McKee *et al*., 1993).

In this study, SPI values were calculated based on monthly precipitation data from weather stations for the following countries: Iran, Afghanistan, Pakistan, Turkey and Syria over the period 1980-2010. The data is obtained from the National Climatic Data Center (NCDC). A drought variable is then created for each country and stations indicating the number of months in a year with SPI values of -1 and less (Kibonge, 2013). In order to provide an indicator for crop stress and soil moisture in agriculture, the one-month SPI was used to construct the yearly drought variable.

Table 3 - Summary Statistic: Weather Variables
Region: The Greater Middle East - Period: 1980-2010

Variable	Unit	Source	Mean	Max	Min	SD
Precipitation	Millimeters	NCDC	221.99	630.77	43.04	161.68
Temperature	Degree Celsius	NCDC	16.01	27.26	8.33	4.77
SPI	-	NCDC	0.37	1.23	-1.90	0.34
Drought	No. of months in a year with SPI Values of -1 and Less.		0.68	4	0	1.02

Summary Statistic of Weather Variables and Station Locations on the Map
Region: The Greater Middle East- Period: 1980-2010

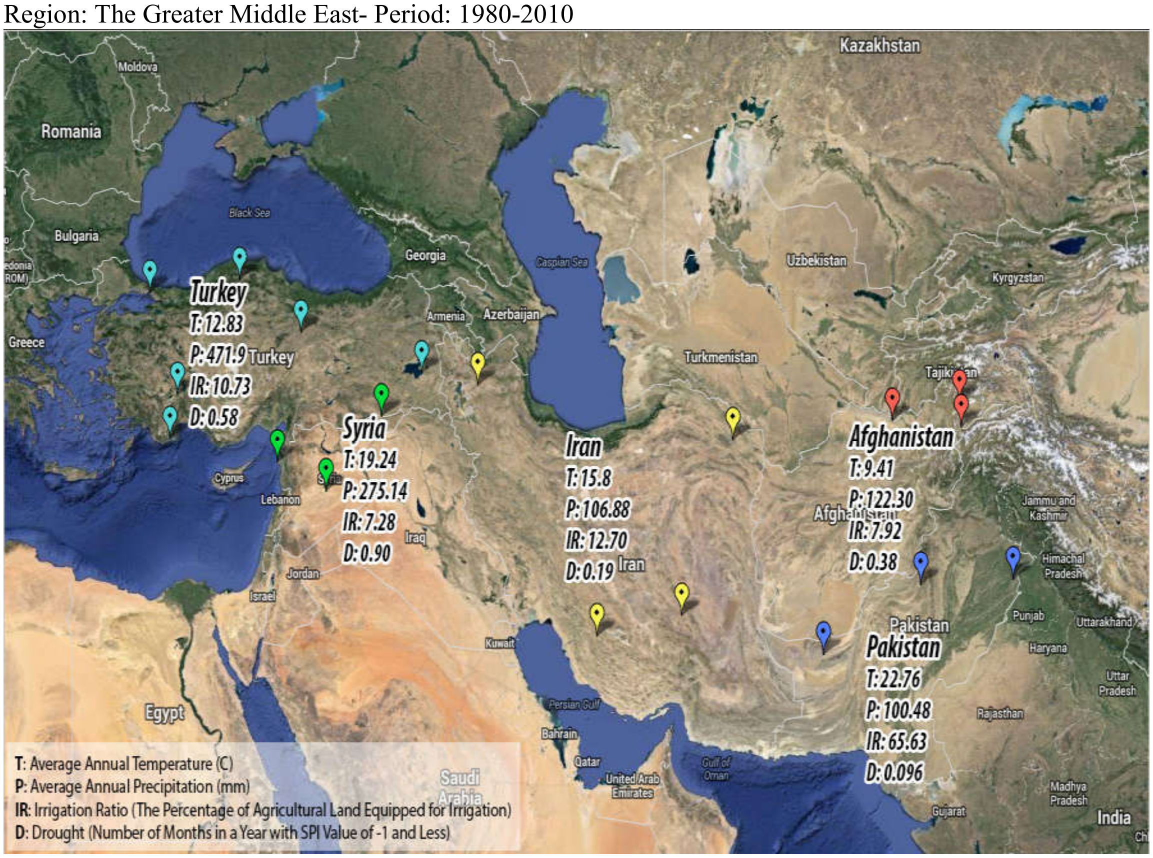


Figure 3 illustrates the average annual precipitation in available and reliable weather stations for each country over the period 1980-2010. This variable is very volatile.

Turkey (471.1 mm) has the most and Iran and Pakistan have the lowest average annual precipitation in the region considering our selected weather stations. Straight lines are due to missing data for Iran (period 1980-88) and Afghanistan (period 2001-2010). It should be mentioned that all these stations are located in agricultural areas.

Figure 3- Average Annual Precipitation (mm)
Region: The Greater Middle East - Period: 1980-2010

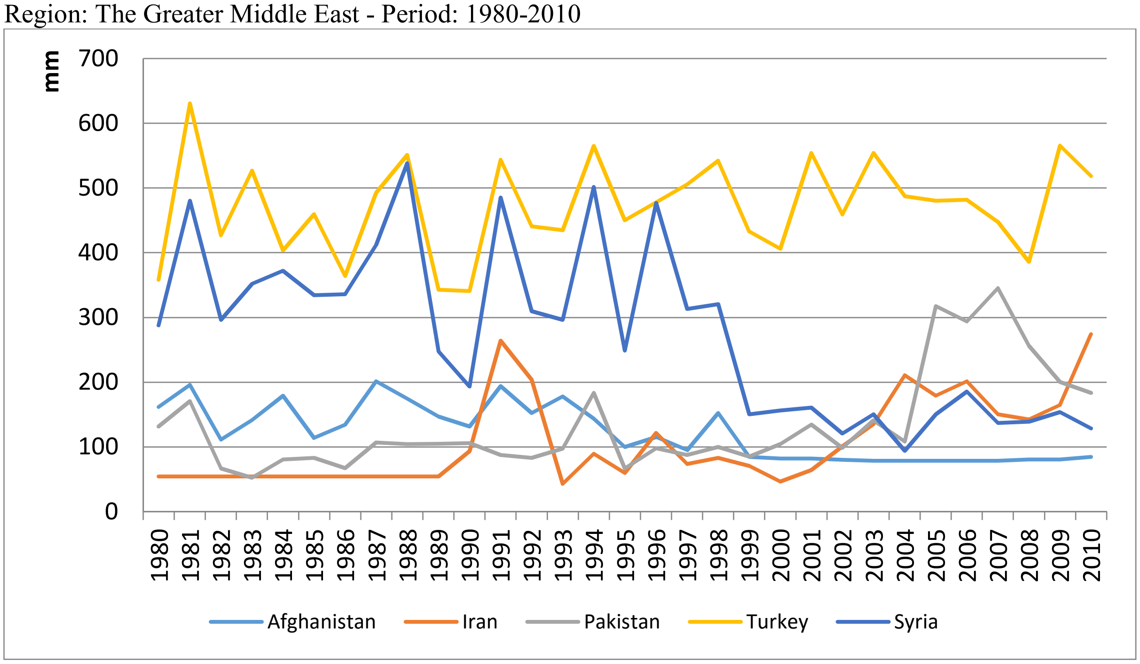
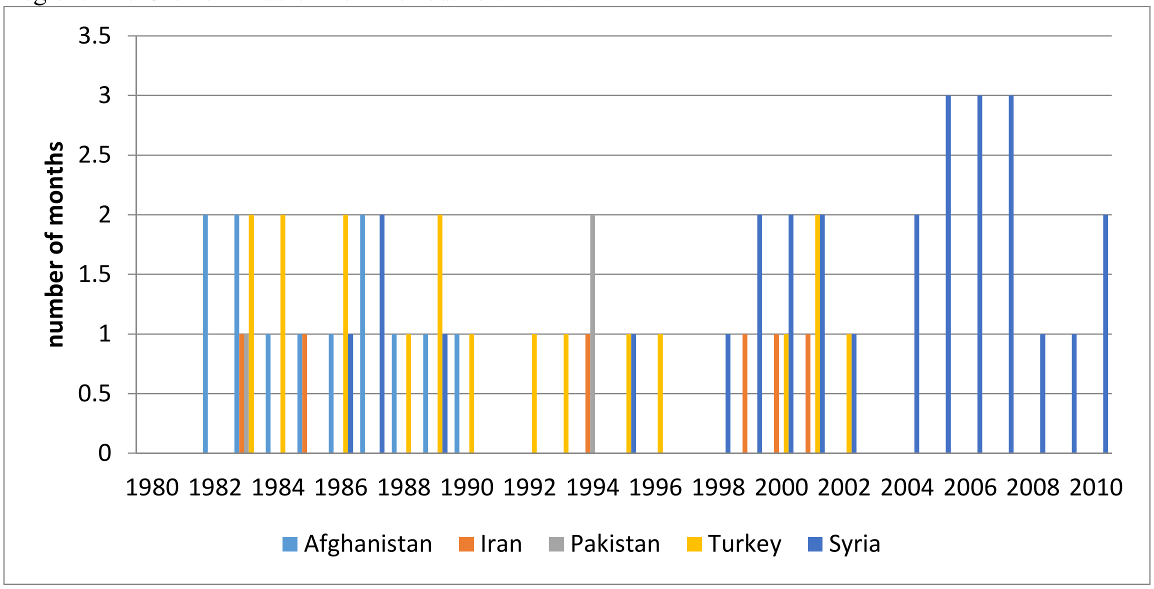


Figure 4 displays the drought episodes for each country during 1980-2010. Drought episodes calculated based on the one-month SPI developed in this study.

Figure 4- Drought Episodes, based on SPI index
Region: The Greater Middle East - Period: 1980-2010



Afghanistan and Turkey have experienced the most drought episodes in the 1980s followed by Iran and Turkey in the1990s and Syria in 2000s. The highest number of drought events occurred in Syria during 2005-2007. The estimates indicated that Syria suffered from several drought events during the entire period, particularly in the 2000s.

4. Estimation: Stochastic Production Frontier

4.1. Estimation considering Weather Variables

A translog production function is estimated using a Maximum Likelihood (ML) frontier approach. In addition to the five traditional inputs (land, labor, livestock, fertilizer and machinery), we include precipitation and temperature in the main structure of the form.

Precipitation and temperature are included in the production function following specification of yield equations in other studies that focused on climatic effects (Schlenker and Roberts, 2009; Schlenker and Lobell, 2010). This allows us to determine the direct effects of these variables on the level of production. Drought and irrigation are introduced as efficiency changing variables to capture potential differences in performance across countries.

The Maximum-Likelihood approach of FRONTIER 4.1 (Coelli, 1996) was used to estimate the 53 parameters in the model, 9 of which are the efficiency changing variables. These estimates are referred to as the full model. Following Fulginiti, Perrin and Yu (2004), we use the likelihood ratio test to compare functional forms nested within the model in equation (1) and use the principle of downward selection to eliminate non-significant terms of the full model, one by one, as suggested by Jorgenson and Gallant (1979). This model is referred to as the reduced model. There were 7 non-significant parameters in the full model including the interactions of precipitation with machinery (x1x6), with fertilizer (x4x6), with labor (x5x6), with temperature (x6x7), and with land (x2x6) as well as the interactions of machinery with land (x1x2) and with fertilizer (x1x4). We started by testing the null hypothesis, model without one non-significant variable (reduced model or shorter model), against the alternative hypothesis, model with all variables (full model). Log Likelihood Ratio test in the first row of the table 4 shows that the reduced model (model without x1x6) cannot be rejected at 5% level of significance. So, we continue to discard x4x6, x5x6, x1x2, x1x4, x2x6 and x6x7 one by one. The LRT results in the table 4 indicate that when variables x2x6 and x6x7 are eliminated the null hypothesis (reduced model) is rejected, so we do not eliminate these variables from the specification.

Table 4- Results of Performing Log Likelihood Ratio include weather variables

Null Hypothesis	**Log Likelihood Ratio Test**	
Discard X1X6	0.15	Null hypothesis could not be rejected at 5%.
Discard X1X6, X4X6	0.21	Null hypothesis could not be rejected at 5%.
Discard X1X6, X4X6, X5X6	4.11	Null hypothesis could not be rejected at 5%.
Discard X1X6, X4X6, X5X6, X1X2	5.10	Null hypothesis could not be rejected at 5%.
Discard X1X6, X4X6, X5X6, X1X2,X1X4	4.70	Null hypothesis could not be rejected at 5%.
Discard X1X6, X4X6, X5X6, X1X2,X1X4, X6X7	12.72	Null hypothesis could be rejected at 5%.
Discard X1X6, X4X6, X5X6, X1X2,X1X4, X2X6	12.83	Null hypothesis could be rejected at 5%.

The value of the inefficiency variance parameter (γ) is 0.96 and it is highly significant indicating that a significant portion of the error variance is due to inefficiency effects so an OLS estimation is not correct The average production elasticities for this estimation are: land, 0.331, labor, 0.150, fertilizers, 0.346, tractors, 0.204, livestock, 0.009, precipitation, 0.00028 and temperature, 0.0046.[1]

The results show that precipitation and temperature play a positive and significant role on agricultural production.

4.2.Estimation without Weather Variables

We use the likelihood ratio test to compare functional forms nested within the model and use the principle of downward selection to obtain a reduced model. There were 6 non-significant parameters in the full model including the interactions of

[1]Percentage of monotonicity violation are 7.42%, 35.43%, 8.5%, 41.2% and 18.11% respectively for land, labor, fertilizers, livestock and machinery.

machinery with land (x1x2), with fertilizer (x4x1), with labor (x5x1) and interaction of land with labor (x2x5), and with fertilizer (x2x4) as well as the interactions of fertilizer with labor (x4x5). Table 5 shows the results of performing Log Likelihood Ratio test. Likelihood-ratios tests for the x1x4 and x2x4 indicated variables are not necessary.

Table 5- Results of Performing Log Likelihood Ratio excludes weather variables

Null Hypothesis	Log Likelihood Ratio Test	
Discard X1X4	0.16	Null hypothesis could not be rejected at 5%.
Discard X1X4, X2X4	0.23	Null hypothesis could not be rejected at 5%.
Discard X1X4, X2X4, X1X2	7.91	Null hypothesis could be rejected at 5%.
Discard X1X4, X2X4, X1X5	7.88	Null hypothesis could be rejected at 5%.
Discard X1X4, X2X4, X2X5	8.03	Null hypothesis could be rejected at 5%.
Discard X1X4, X2X4, X4X5	7.94	Null hypothesis could be rejected at 5%.

The value of the inefficiency variance parameter (γ) is 0.78 and this value is highly significant. The average production elasticities for all inputs have been computed using equation (3). The average production elasticities for this estimation are: land, 0.288, labor, 0.092, fertilizers, 0.196, tractors, 0.194, and livestock, -0.051.[2]

4.3. Agricultural Productivity Growth

4.3.1. Agricultural Productivity Growth without Weather Variables

The main purpose of this section is a comparison between calculated TFP considering weather variables and TFP without them.

Average agricultural output growth for the region was 2.8% per year. TFP's growth rate when weather variables are not considered is 2.77% per year during this period. Table

[2] Elasticity estimates were negative for fertilizers at 4.91%, for livestock at 60.01%, for machinery at 6.71%, for labor at 35.71% and for land at 4.13% of the data points.

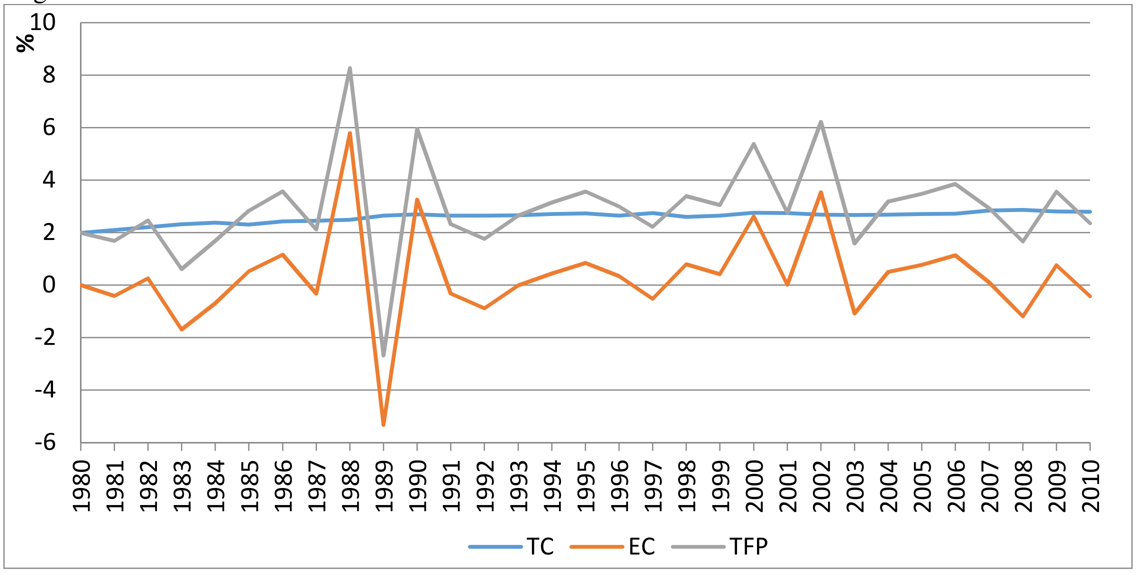
6 shows growth rates per decade. TFP growth has been positive and slightly increasing in 1990s with respect to previous decade. Average TFP growth rate in this study is consistent with results in Fuglie (2010) for West Asia (excludes Pakistan and Afghanistan) over the period 1961-2007. The TFP estimates for the region is greater than the 1.1% estimated by Shahabinejad at al. (2010) for the 'Developing Eight' (exclude Afghanistan and Syria) during 199-2007 and greater than the 1% calculated by Belloumi and Matoussi (2009) for this region excluding Afghanistan and Pakistan over 1970-2000.

Figure 5 illustrates Average Weighted TC, EC and TFP Growth Rate, for the region during the period 1980-2010 when weather variables are not considered.

Table 6- Technical Change, Efficiency Change and TFP growth rates (%)
Region: The Greater Middle East without Weather Variables - Period: 1980-2010

	TC			EC			TFP		
Country	1980-1989	1990-1999	2000-2010	1980-1989	1990-1999	2000-2010	1980-1989	1990-1999	2000-2010
Afghanistan	-0.42	-0.21	-0.22	-0.05	0.33	-0.23	-0.48	0.11	-0.45
Iran	2.76	3.27	3.50	0.03	0.11	0.12	2.80	3.39	3.63
Pakistan	2.07	2.89	3.05	-0.44	1.08	-0.11	1.62	3.97	2.94
Turkey	2.73	2.55	2.31	0.00	0.22	0.16	2.73	2.78	2.47
Syria	1.14	1.50	1.84	-0.00	-0.26	0.59	1.13	1.23	2.44
Greater Middle East	2.35	2.67	2.74	-0.02	0.29	0.30	2.33	2.96	3.04

Figure 5– Average Weighted TC, EC and TFP Growth Rate, (without Weather Variables)
Region: The Greater Middle East - Period: 1980-2010



Estimation of growth decomposition in table 7 shows that the average output growth can be decomposed into a scale increase of 2.05% and a 0.74% increase in TFP. This indicates that, on average, TFP's contribution to the output growth for Iran, Turkey, Pakistan and Syria is 28%, 30%, 26% and 22% respectively. Innovations in Iran and Turkey seem to be important contributors to output growth.

Table 7 – Growth Decomposition (%), (without Weather Variables)
Region: The Greater Middle East - Period: 1980-2010

Country	Output Growth	Input Change	EC Change	TC Change	TFP Change
Afghanistan	1.37	1.37	-0.692	0.684	0.00
Iran	4.25	3.09	0.159	1.006	1.16
Pakistan	3.44	2.52	-0.147	1.072	0.92
Turkey	1.93	1.33	-0.425	1.03	0.60
Syria	2.98	2.32	-0.238	0.90	0.66
Greater Middle East	2.80	2.06	-0.192	0.939	0.74

Figure 6- Average Efficiency Levels, (without Weather Variables)
Region: The Greater Middle East- Period: 1980-2010

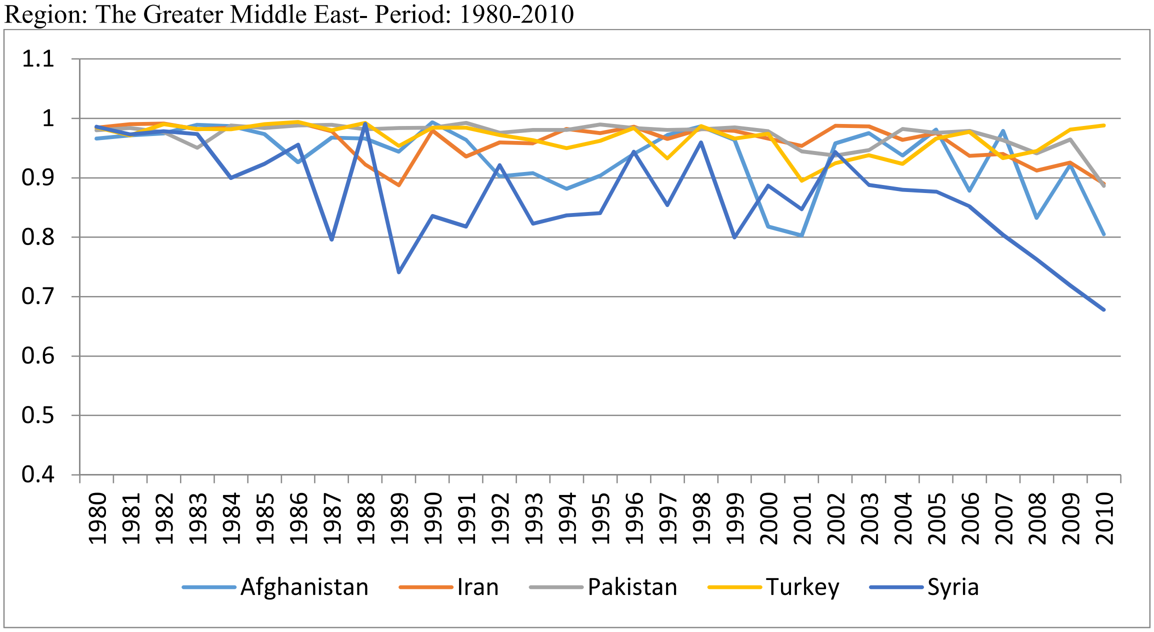
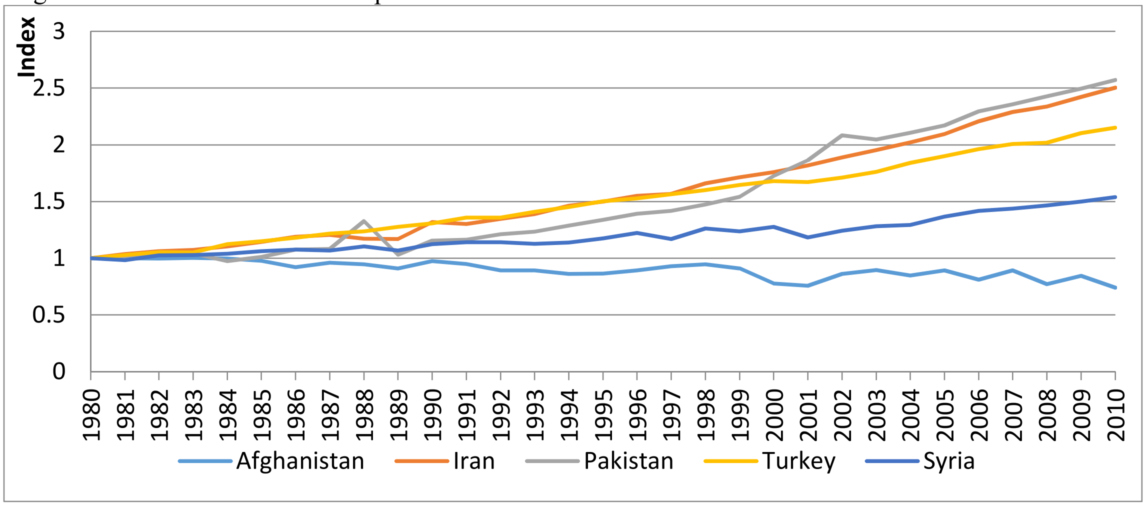


Figure 6 shows that among these five countries analyzed, Iran, Pakistan and Turkey have the most effective catching-up performance. On the other hand, Afghanistan and Syria are the most technically inefficient countries. Figure 7 shows the strong agricultural productivity performance of Iran, Pakistan and Turkey while Afghanistan seems to fall behind the other countries in the region.

Figure 7- TFP Index (without Weather Variables)
Region: The Greater Middle East- period: 1980-2010



4.3.2. Agricultural Productivity Growth with Weather Variables

Average agricultural output growth for the region was 2.80% per year. Estimated TFP's growth rates are 2.66% per year during this period. Table 10 shows that Iran and Pakistan had the larger agricultural output growth rates. As TFP's growth rates are 3.34% for Iran and 2.81% for Pakistan (table 10). Afghanistan had the smallest output growth rates and negative TFP growth rates. Turkey's and Syria's TFP growth rates are 2.55% and 1.16%, respectively (table 10). As expected the average TFP growth for the region is 2.66%, smaller when weather variables are included than the 2.77% obtained without weather variables. Our estimates indicate that a 1% increase in precipitation increases output by 0.02 percent and a 1% increase in temperatures increase output by 0.5 percent.

The average output growth can be decomposed into a scale increase of 1.90% (1.901% of traditional inputs and 0.001% of weather inputs) and a 0.89% increase in TFP, table 8. This shows that, on average for the region, productivity increases are responsible for 31% of the output growth. Change in productivity accounts for 24% of output growth in Iran, 25% in Pakistan, 27% in Turkey, 20% in Syria and 1% in Afghanistan.

Table 8 – Growth Decomposition considering weather variables (%)
Region: The Greater Middle East- Period: 1980-2010

Country	Output Growth	Traditional Input Change	Weather Input Change	EC Change	TC Change	TFP Change
Afghanistan	1.37	1.36	0.000	-0.529	0.542	0.01
Iran	4.25	3.23	0.012	0.167	0.837	1.00
Pakistan	3.44	2.57	0.002	-0.028	0.889	0.86
Turkey	1.93	1.42	0.000	-0.417	0.927	0.51
Syria	2.98	2.36	0.001	-0.142	0.760	0.61
Greater Middle East	2.80	1.90	0.001	0.113	0.788	0.89

Figure 8 illustrates the evolution of the weighted average TC, EC and TFP growth rates, using output as weights, for the region. Based on Figure 9, Iran and Pakistan have the most and Afghanistan the least effective catching-up performance.

Figure 8 - Average TC, EC and TFP Growth Rates (with Weather Variables)
Region: The Greater Middle East - Period: 1980-2010

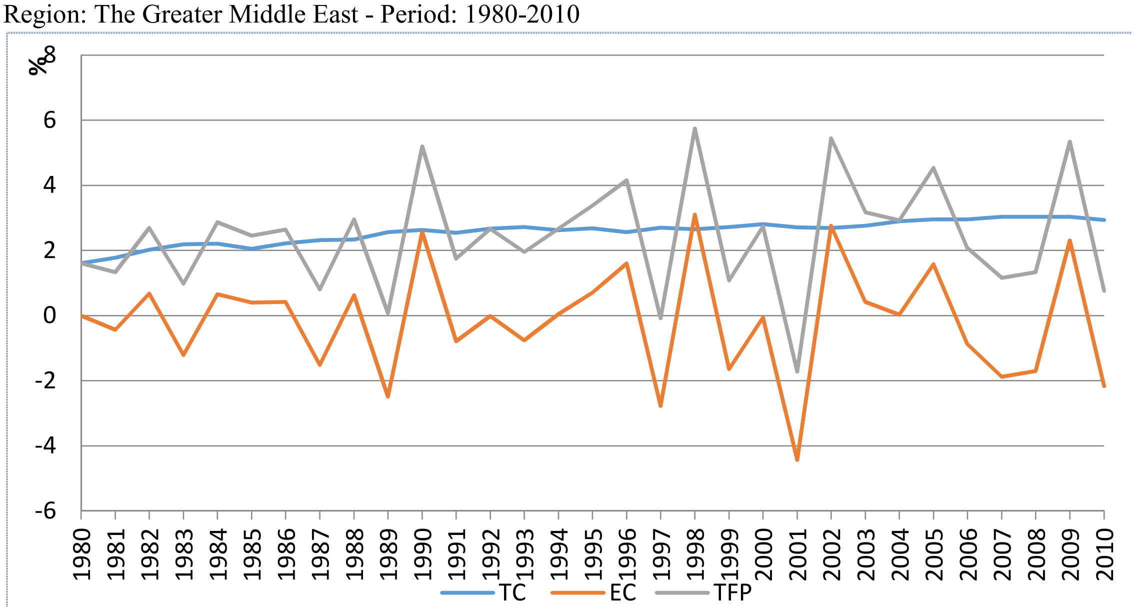


Figure 9- Average Efficiency Level (with Weather Variables)
Region: The Greater Middle East - Period: 1980-2010

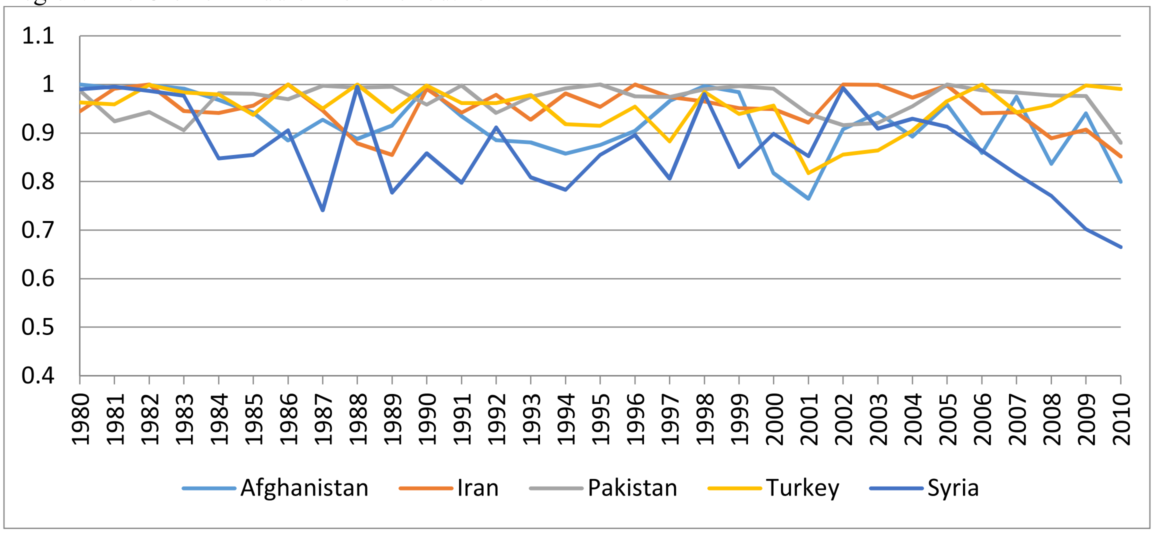


Figure 10 shows TFP indexes estimated for each country considering weather variables. Iran and Pakistan show the best performance followed by Turkey while Afghanistan shows the weakest performance.

Figure 10- TFP Index (1980=1) for Iran, Turkey, Afghanistan, Pakistan and Syria (with Weather Variables)
Region: The Greater Middle East- Period: 1980-2010

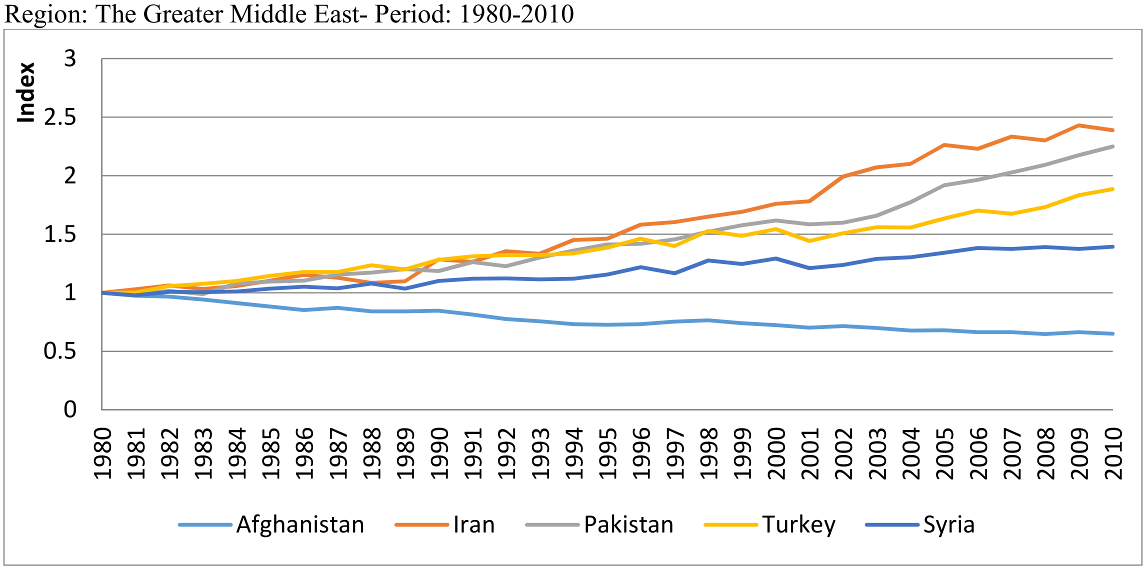


Table 9 shows TFP growth rate estimates incorporating weather variables by decades.

Table 9- Technical Change, Efficiency Change and TFP growth rates (%), (with Weather Variables) Region: The Greater Middle East- Period: 1980-2010

	TC			EC			TFP		
Country	1980-1989	1990-1999	2000-2010	1980-1989	1990-1999	2000-2010	1980-1989	1990-1999	2000-2010
Afghanistan	0.05	-0.17	-0.62	-0.07	0.98	-0.51	-0.02	0.81	-1.13
Iran	2.85	3.34	4.04	0.05	0.43	-0.81	2.90	3.77	3.23
Pakistan	1.54	2.80	3.55	0.06	0.05	-0.66	1.60	2.85	2.90
Turkey	2.61	2.23	1.75	-0.03	-0.45	1.14	2.58	1.78	2.89
Syria	1.01	1.96	2.17	-0.24	0.89	0.39	0.77	2.85	2.56
Greater Middle East	2.17	2.66	2.89	0.2	-0.01	-0.22	2.37	2.64	2.67

TFP growth rates increased from 2.37 to 2.67 over the period 1980-2010. Technical change has been enhancing for most of the countries since 1980s and the major component to TFP growth rates.

As table 10 illustrates, technical change plays the main role in TFP growth (2.66% average per year versus 0.005% efficiency change). Iran has the highest average TFP growth rate, followed by Pakistan, Turkey and Syria.

Both estimations show that the region experienced an increase in TFP. With improvements in the 2000s with respect to previous decades.

Table 10 - Average TFP Growth Rate Estimates (%)
Region: The Greater Middle East - Period: 1980-2010

	Stochastic Frontier Approach without weather variables			Stochastic Frontier Approach with weather variables			
Country	**TC**	**EC**	**TFP**	**TC**	**EC**	**TFP**	**Output**
Afghanistan	-0.27	-0.05	-0.32	-0.13	0.08	-0.05	1.37
Iran	3.25	0.11	3.36	3.54	-0.18	3.34	4.25
Pakistan	2.89	0.40	3.29	2.83	0.00	2.81	3.44
Turkey	2.55	0.07	2.62	2.20	0.35	2.55	1.93
Syria	1.50	0.25	1.75	1.96	-0.80	1.16	2.98
Greater Middle East	2.58	0.19	2.77	2.66	0.00	2.66	2.80

TFP growth rates across the two estimations are lower for Iran, Pakistan, Turkey and Syria when including the weather variables and slightly higher for Afghanistan. As expected, when including weather variables the residual is smaller and the TFP growth rate captured by a trend and the residual is also smaller. This does not mean that productivity was lower rather than we have an explanation (due to weather) for some of the residual output changes.

4.4. Agricultural Productivity Growth and Inefficiency Variables

Our objectives have been to estimate agricultural productivity considering weather variables in these set of countries and also to explore the potential role of extreme weather events and institutional variables in explaining the discrepancy across countries. The results of the inefficiency effects model are shown in table B-appendix and table 11. The results show that secondary school enrollment, political and civil rights, trade openness, irrigation and drought are significantly associated with differential performance across countries. Life expectancy, minor and major conflicts and years since independence, although significant, do not have the expected impact on inefficiency.

Table 11- Inefficiency Effects Model (considering weather variables)
Region: The Greater Middle East - Period: 1980-2010

Variable	Coefficient	Standard Error	t value
Intercept	-0.6885	0.1011	-6.8110
Education	-0.0000	0.0000	-5.5317
PR&CR	-0.1542	0.0237	-6.4945
Independence	0.0023	0.0006	3.9719
Openness	-0.0016	0.0005	-3.2406
Life Expectancy	0.0069	0.0013	5.2322
Minor Conflict	0.0830	0.0213	3.8966
Major Conflict	0.1448	0.0257	5.6269
Drought	0.0066	0.0008	7.9901
Irrigation	-0.0002	0.0000	-5.1461

According to these results, there is a chance for all these countries to improve agricultural productivity by respecting political and civil rights and by opening up the economy to increasing trade. The negatively significant coefficient estimated for secondary school is important as it implies that policies which improve human capital affect agricultural productivity in this region.

The significant coefficient estimated for drought is also important since it indicates that in countries with extreme drought episodes agricultural performance suffers. We also hint towards the importance of water availability in the region as we find that the higher is the percentage of land irrigated the best the region performs.

5. Conclusion

The main objective of this study is to determine the potential impact of climate change and water scarcity on agricultural production for 5 countries in the Greater Middle East over the period 1980-2010. This is a region where food security and political stability have very much been affected by water availability and where droughts have the potential of inciting revolutions. The translog production frontier function was used to estimate TFP over the period 1980-2010. Precipitation, temperature, drought and irrigation were considered in the productivity estimates. The results report increasing agricultural productivity during the period with an annual average of 2.66%. Productivity growth or innovations contributed approximately 30% of agricultural output growth, leaving the majority of this growth to be explained by growth in traditional inputs. This is important because sustained long run growth is a function of innovations and increases in efficiency rather than increases in use of traditional inputs.

We found that temperatures and precipitation play a positive significant role in agricultural production although their average contribution to output growth is small. We acknowledge that average annual temperature is a rather crude measure for this variable and temperatures during the critical periods in the growing season might be a better proxy variable. Frequent extreme drought episodes and irrigation availability though have importantly affected differential agricultural performance in the region. In particular we note the impact of drought in Syria's performance, a country severely affected by drought during the whole period and particularly in the 2000's. Considering TFP growth rates, Iran (3.34%) followed by Pakistan (2.81%) and Turkey (2.55%) have the best performance while Afghanistan (-0.05%) has the worst.

The results also highlight that improvement in human capital; more respect for political rights and civil liberties and an open economy are associated with differential agricultural performance across countries in the sample.

References

Ahmad, K., Chaudhary, M.A., and Ilyas, M., (2008), "Trends in Total Factor Productivity in Pakistan Agriculture Sector", *Pakistan Economic and Social Review*, 48 (2): 117-132.

Ahmed, S., (1987), "Pakistan, in: Productivity Measurement and Analysis: Asian Agriculture", Asian Productivity Organization, Tokyo, 381-408.

Alauddin, M., Headey, D., Rao, D. S. P., (2005), "Explaining Agricultural Productivity Levels and Growth: An International Perspective", Centre for Efficiency and Productivity Analysis, Working paper series no. 02.

Aldy, E.J., Krupnick, A.J., Newel, R.G., Parry, I.W., and Pizer, W.A., (2010), "Designing Climate Mitigation Policy", RFF DP 08-16-REV, Washington, DC: Resources for the Future.

Ali, A., Khalid, M., and Muhammad, A.,. (2008) , "Total Factor Productivity (TFP) Growth in Agriculture in Pakistan: Trends in Different Time Horizons", *Pakistan Journal of Agricultural Science*, 45(4): 508-513.

Ali, S., (2004), "Total factor productivity growth in Pakistan's agriculture: 1960-1996", *The Pakistan Development Review*, 43(4): 493-513.

Arnade, C., (1997),"Using a Programming Approach to Measure International Agricultural Efficiency and Productivity", *Journal of Agricultural Economic*s, 49:67-84.

Bharati, P., Fulginiti, L., (2007), "Institutions and Agricultural Productivity in Mercosur", In: E.C. Teixeira and M.J. Braga, editors, Institutions and Economic Development, Viçosa, Brazil.

Battese, G.E., Rao, D.S.P., and O'Donnell, C., (2004). 'A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies'. *Journal of Productivity Analysis*, 21(1): 91–103.

Battese, G.E., Coelli, T.J., (1995), "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data", *Empirical Economics*, 20, 325-332.

Belloumi, M., and Matoussi, M.S., (2009), "Measuring agricultural productivity growth in MENA countries" Journal of Development and Agricultural Economics,1(4):103-113.

CIA World Factbook. https://www.cia.gov/library/publications/the-world-factbook/

Chaudhry, A.A., (2009), "Total Factor Productivity Growth in Pakistan: An Analysis of the Agricultural and Manufacturing Sectors", *The Lahore Journal of Economics* 14:1-16.

Coelli, T.J., Rao, D.S., and Battese, G., (2005), "An Introduction to Efficiency and Productivity Analysis", Second Edition.

Coelli, T. J., Rao, D.S., Prasada, D., (2003), "Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000", CEPA Working Papers, School of Economics, University of Queensland, Brisbane, Australia.

Drine, I., (2011), Climate Variability and Agricultural Productivity in MENA region, world institute for development Economics Research, Working Papers No. 2011/96

Evenson, R. E. and Pray, C. E., (1991), "*Research and Productivity in Asian Agriculture*", Ithaca, NY: Cornell University Press.

Food and Agriculture Organization of the United Nations, (2014), FAOSTAT database. http://www.fao.org/.

FAO (2001). *Climate Change: Implications for Food Safety*. FAO.

Freedom House. "Freedom in the World Country Rating", http://www.freedomhouse.org/ratings/index.htm.

Fuglie, K. O., (2010), "Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data", Chapter 4: The Shifting Patterns of Agricultural Production and Productivity Worldwide, The Midwest Agribusiness Trade Research and Information Center Iowa State University, Ames, Iowa.

Fulginiti, L.E., Perrin, R. K., and Yu, B., (2004). "Institutions and agricultural productivity in Sub-Saharan Africa," Agricultural Economics, Blackwell, 31:169-180.

Fulginiti, L.E., and Perrin, R.K., (1999), "Have Price Policies Damaged LDC Agricultural Productivity?", Journal of Economic Policy, 17:469-475.

Fulginiti, L.E., and Perrin, R.K., (1998), "Agricultural productivity in developing countries", Journal of Agricultural Economics, 19: 45-51.

Fulginiti, L.E, and Perrin, R.K., (1997), " LDC agriculture: Nonparametric Malmquist productivity indexes", Journal of Agricultural Economics, 53: 373-390.

Fulginiti, L.E, and Perrin, R.K, (1993), "Prices and Productivity in Agriculture", Review Economic Statistics, 75: 471-482.

Gallant, A. R., and Jorgenson, D. W., (1979), "Statistical inference for a system of simultaneous, non-linear, implicit equations in the context of instrumental variables estimation", *Journal of Econometrics*, I I: 75-302.

International Panel on Climate Change (IPCC), The Regional Impact of Climate Change, http://www.ipcc.ch/ipccreports/sres/regional/index.php?idp=154

Kawagoe, T., and Hayami, Y., (1985), "An Intercountry Comparison of Agricultural Production Efficiency", Journal of Agricultural Economics, 67: 87-92.

Kawagoe, T., Hayami, Y., and Ruttan, V., (1985), "The Intercountry Agricultural Production Function and Productivity Differences among Countries", Journal of Development Economics, 19: 113-132.

Kibonge, A., (2013), "Essays on agricultural productivity in Sub-Saharan Africa", *ETD collection for University of Nebraska - Lincoln.*

Khani, H., Yazdani, Q. A., (2012), "Investigating the Total Factor Productivity in Agricultural Sector Using Growth Accounting in Iran", European Journal of Experimental Biology, 2 (1):17-23.

Lau, L., and Yotopolous, P., (1989), "The Meta-Production Function Approach to Technological
Change in World Agriculture", *Journal of Development Economics*, 31:241-269.

Mohammadrezazadeh, N., Karbasi, A., and Purmoghaddam, A., (2012), "The Analysis of productivity growth of all production Elements in Iran,s Agriculture", 8th conference of Agricultural Economics of Iran, Shiraz, Iran.

National Climate Data Center (2014), NCDC data source. http://www.noaa.gov/

Nin, A., Arndt, C., and Preckel, P.V., (2003), "Is agricultural productivity in developing countries really shrinking? New evidence using a modified non-parametric approach", Journal of Development Economics. 71:395-415.

Oliphant , W., (2007)," Understanding Afghanistan's Recent Economic Development: A Comparative Analysis with Pakistan", University of California-Irvine.

Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M., and Fischer, G., (2004), "Effects of climate change on global food production under SRES emissions and socioeconomic scenarios", *Global Environmental Change*, 14, 53–67.

Pfeiffer, L.M., (2003), "Agricultural Productivity Growth in the ANDEAN Community", Proceedings issue of the American Journal of Agriculture Economics, 85 (5): 1335-1343.

Rao, D.S., Prasada, C.T., and Alauddin, M., (2004), "Agricultural productivity growth, employment and poverty in developing countries, 1970-2000", Centre for Efficiency and Productivity Analysis (CEPA), Employment Strategy Paper no. 9/2004, School of Economics, University of Queensland, Brisbane, Australia.

Rezaei, J., Tavakoli Baghdadabad, M.R., and Faghihabadi, M., (2009), "An Evaluation of Changes in Total Productivity of Factors of Production in Iran's Agricultural Sector Using Non Parametric Methods", Iranian Journal of Rural and Development, 11(3): 97-122.

Schlenker, W., and Lobell, D.B., (2010), "Robust negative impacts of climate change on African agriculture", *Environmental Research Letters*, 5(1).

Schlenker, W. and Roberts, MJ., (2009), "Nonlinear temperature effects indicate severe damages to U.S crop yields under climate change", PNAS,106 (37): 15594-15598.

Shahabinejad, V., and Akbari, A., (2010), "Measuring agricultural productivity growth in Developing Eight", Iranian Journal of Development and Agricultural Economics, 2(9): 326-332.

Sivakumar, M.V.K., Das, H.P., and Brunini, O., (2005), "Impacts of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics", *Climatic Change*, 70: 31–72.

Tahamipour, M., and Shahmoradi, M., (2008), "Measuring Total Factor Productivity Growth in Agricultural Sector and Serving It's Proportion of Added Value Growth", 6th conference of Agricultural Economics, Mashahd, Iran.

Tahamipor, M., Kazemnejad, M., and Moazeni, S., (2008), "Comprising TFP growth between economic sectors of Iran", Sixth conference of Agricultural Economics, Mashhad, Iran.

Tao, F., Yokozawa, M., Hayashi, Y., and Lin, E., (2003), "Future climate change, the agricultural water cycle, and agricultural production in China", *Agriculture, Ecosystems & Environment*, 95: 203–15.

Trindade, F., Fulginiti, L.E., (2015), "Is there a Slowdown in Agricultural Productivity Growth in South America", *Agricultural Economics*, 46: 69-81.

Tayebi, Z., (2014), "Agricultural Productivity in the Greater Middle East", Dissertations and Theses in Agricultural Economics, University of Nebraska-Lincoln, Paper 18.

Trueblood, M.A., (1996), "An intercountry comparison of agricultural efficiency and productivity", PhD dissertation, University of Minnesota.

Trueblood, M.A., Coggins, J.,(1996), "Intercountry Agricultural Efficiency and Productivity: A Malmquist Index Approach, USDA/ERS/MTED/EAME.

World Bank, (2012), World development indicators, CD ROM, Washington, DC.

World Bank, (2013), http://data.worldbank.org/indicator/AG.LND.PRCP.MM

World Bank, (2013), Adaptation to Climate Change in the Middle East and North Africa Region,http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/0,,contentMDK%3A21596766~pagePK%3A146736~piPK%3A146830~theSitePK%3A256299,00.html

World Bank, (2013), Water Is Focus of Climate Change in Middle East and North Africa, http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/0,,contentMDK:21596757~pagePK:146736~piPK:146830~theSitePK:256299,00.html

Xiong, W., Matthews, R., Holman, I., Lin, E., and Xu, Y., (2007). "Modelling China's potential maize production at regional scale under climate change", *Climatic Change*, 85: 433–51.

Appendix: Tables

TABLE A: Parameter Estimate- Stochastic Frontier Approach

Coefficients	Estimate	std. Error	t value
(Intercept)	137.7246	1.1276	122.1352
X1	2.3041	1.9748	1.1667
X2	-18.5639	3.4806	-5.3335
X3	-10.9820	1.2814	-8.5701
X4	-2.4097	1.8446	-1.3063
X5	11.5510	1.7515	6.5948
X1sq	-0.0532	0.0500	-1.0656
X2sq	0.7836	0.9367	0.8366
X3sq	0.5410	0.1459	3.7071
X4sq	-0.0512	0.0481	-1.0635
X5sq	0.5644	0.1200	4.7018
X1X2	0.3762	0.2231	1.6861
X1X3	-0.3027	0.0852	-3.5532
X1X5	0.0124	0.0523	0.2368
X2X3	0.8806	0.2975	2.9604
X2X5	-0.8826	0.2442	-3.6144
X3X3	0.1642	0.1300	1.2631
X3X5	-0.4832	0.0898	-5.3807
X4X5	0.0065	0.0604	0.1072
T	-0.0892	0.0946	-0.9432
Tsq	0.0000	0.0001	0.0213
TX1	0.0119	0.0031	3.8560
TX2	-0.0360	0.0108	-3.3166
TX3	0.0200	0.0033	6.0244
TX4	-0.0052	0.0054	-0.9542
TX5	0.0001	0.0037	0.0343
Z-Intercept	-0.9323	0.2473	-3.7703
Z1-Education	0.0000	0.0000	-2.1790
Z2-PR&CR	-0.1526	0.0617	-2.4739
Z3-Independence	-0.0035	0.0014	-2.4707
Z4-Openness	-0.0022	0.0007	-3.2842
Z5-Life Expectancy	0.0094	0.0026	3.5880
Z6-Minor Conflict	0.0503	0.0249	2.0157
Z7-Major Conflict	0.1122	0.0316	3.5536
Z8-Irrigation	-0.0005	0.0005	-1.1332
Sigmasq	0.0082	0.0016	4.9939
Gamma	0.9436	0.0310	30.4497

X1: log of machinery, x2: log of land, x3: log of livestock, x4: log of fertilizer, x5:log of labor, T: time trend

TABLE B: Parameter Estimate- Stochastic Frontier Approach (Considering weather variables)

Coefficients	Estimate	std. Error	t value
Intercept	139.5726	0.9950	140.2766
X1	8.3809	0.5659	14.8111
X2	-17.0284	0.9040	-18.8366
X3	-14.2974	0.6805	-21.0086
X4	11.1577	0.9504	11.7403
X5	15.0625	0.9380	16.0589
X6	1.5827	0.3791	4.1752
X7	3.7938	0.9952	3.8123
X1sq	0.0526	0.0154	3.4190
x2sq	0.0531	0.6222	0.0853
x3sq	0.6560	0.1308	5.0148
x4sq	-0.4147	0.0583	-7.1184
x5sq	0.8270	0.0850	9.7312
x6sq	-0.0087	0.0053	-1.6422
x7sq	-0.6897	0.2623	-2.6292
x1x3	-0.5420	0.0411	-13.1881
x1x5	0.2195	0.0253	8.6782
x1x7	-0.5209	0.0875	-5.9552
x2x3	1.2472	0.2712	4.5986
x2x4	0.6252	0.1492	4.1902
x2x5	-1.0826	0.1721	-6.2908
x2x6	0.0533	0.0270	1.9712
x2x7	0.4043	0.2466	1.6394
x3x4	0.4319	0.0751	5.7531
x3x5	-0.6909	0.0520	-13.2828
x3x6	-0.1162	0.0335	-3.4738
x3x7	0.3751	0.0912	4.1125
x4x5	-0.1914	0.0353	-5.4260
x4x7	0.8174	0.1390	5.8794
x5x7	-0.4981	0.1256	-3.9662
x6x7	0.0012	0.0349	0.0332
T	-0.2993	0.0680	-4.4003
Tsq	0.0000	0.0001	0.4908
TX1	0.0070	0.0026	2.6383
TX2	-0.0256	0.0103	-2.4725
TX3	0.0279	0.0022	12.5124
TX4	0.0077	0.0035	2.2126
TX5	-0.0049	0.0040	-1.2071
TX6	0.0005	0.0010	0.5264
TX7	0.0314	0.0064	4.9348
Z-Intercept	-0.6885	0.1011	-6.8110
Z1-Education	-0.0000	0.0000	-5.5317
Z2-PR&CR	-0.1542	0.0237	-6.4945
Z3-Independence	0.0023	0.0006	3.9719
Z4-Openness	-0.0016	0.0005	-3.2406
Z5-Life Expectancy	0.0069	0.0013	5.2322
Z6-Minor Conflict	0.0830	0.0213	3.8966
Z7-Major Conflict	0.1448	0.0257	5.6269
Z8-Drought	0.0066	0.0008	7.9901
Z9-Irrigation	-0.0002	0.0000	-5.1461
sigma sq	0.0086	0.0007	12.2982
Gamma	0.9699	0.0000	5397295.1

X1: log of machinery, x2: log of land, x3: log of livestock, x4: log of fertilizer, x5: log of labor, x6: log of precipitation, x7: log of temperature,T: time trend