The Economic Impacts of Climate Change on Maize Production in Zimbabwe

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Abstract
Generally investors are risk averse and due to climate changes in Zimbabwe over decades, farmers are shifting from food crops to cash crops. Shifting to cash crops however, possess food security challenges. This study uses quantitative data analysis to establish the relationship between farm revenue and climatic variables on maize production in Zimbabwe. The Ricardian model was used as the analytical tool with the aim of establishing different impacts of precipitation and temperature on output and revenue. Results of our study reveal that level of education is statistically significant with a negative relation to the adaptation of varying planting dates. Moreover, gender proved to be statistically significant with a negative relation for both strategies relative to the minimum tillage as female heads tend to adapt to conservation practices compared to male heads.

Keywords: *Climate change, maize production, precipitation, Ricardian model, risk averse.*

1. Introduction

Climate change has resulted in changes of the statistical distribution of temperature and rainfall patterns over several decades if not centuries. Changes in climate has led to effects such as floods, cyclones, hurricanes, veiled fires and droughts. Recent studies show that climate change introduces greater variability in maize yields (Masanganise *et al*., 2005 and Labell and Asner, 2003). According to Mudzonga and Chigwada (2009) Zimbabwe's agricultural sector has been facing a decrease in maize productivity and total production over the past decade.

Investors are risk averse and can only be motivated to undertake risky investments if they expect higher risk adjusted returns. The climatic changes in Zimbabwe have led to farmers shifting from food crops to cash crops with some abandoning farming, thus Zimbabwe is facing food security challenges owing to the climate change through recurrent droughts and floods. Farmers are also facing challenges especially with resistance in pests leading to changes in the use of pesticides on crops and drugs on livestock. The Tobacco Research Board in 2012 banned the use of 14 chemicals claiming the chemicals where ineffective on pests and incompatible with soil types in the country. This was due to the changes in climate and soil composition making it incapable to blend with the chemicals to fight weeds and pests as concluded by the Tobacco Research Board.

Mika (2012) pointed out that with the change in climate; water is likely to become a problem in two aspects. Firstly, few rain days leading to greater stress on air supplied as the water table get lower and secondly, in cases of precipitation, the rain come with great intensity, increasing the likelihood of floods and natural disasters occurring. This may endanger crops and many lives, with some people being left homeless affecting agriculture output at large.

These extreme weather patterns have also led to loss of biodiversity, thus changing soil structure reducing the soil inherent fertility and impair its overall ability as a growing medium for plants (Nelson, 1997). The Zimbabwe Grain and Feed quarterly update of 2012 pointed out that due to the erratic rainfall, an average 43% of the planted area was a total crop failure. These crop failures have been attributed to severe loss of biodiversity, due to the extreme weather conditions and changing soil structure. Masika (2002) asserts that in the long run climate change will affect agriculture and ecological systems; there will be a complex patch work of alternatives which will challenge people's ability to cope. Climate change may also result in cropping and livestock production changes.

Projected adverse impacts of climate change on livelihood and human security include; a general reduction in potential crop yields, passing major risk to food security. This has brought to light the need for an econometric analysis of the impacts of climate change on maize production in Zimbabwe. The main objective of the study is to analyse the economic impacts of climate change on maize production. The other objective of the study is to identify how farmers are coping, with their adoption measures.

Impacts of climate change in developing countries remain poorly understood because few studies analyse the overall impact of climate change (Zivanomoyo and Mukarati, 2013). Zimbabwe is an agro based economy hence the effects of the climatic change have greatly threatened the existence of both commercial and subsistence farmers and the economy at large. Climate change has also affected biodiversity with an increased number of natural disasters expected (IPPC, 2001b). Funding to the agricultural sector, specifically maize, has significantly dwindled as financial institutions have suffered higher credit risk from the sector. There have been massive reduction in maize output countrywide and Zimbabwe has been hit by acute maize shortage owing to the changes in the climate. It is against this background that we undertake this research to analyse the impacts of the climatic change in a bid to come up with sound macro-economic strategies that minimise the effect and therefore assist farmers cope with such effects.

2. Literature review

The main stream of authors to initially assess the impact of climate change on agriculture in the industrial countries include Adams et al (1989, 1990, 1993 and 1999); Parry (1990); Tobey et al (1992) Kaiser et al (1993) Rosengweig and Pary (1994); Bruce et al (1996); Cline (1996); Mendelsohn (1994, 1996 and 1999) Mendelsohn and Dinar (1998).

Parry *et al.*, (1999) are of the view that climate variability directly affects agriculture production, as agriculture is inherently sensitive to climate change. Dinar et al (1996); Kurukulasuriya and Rosental. (2003), concluded that changes in temperature and rainfall result in adverse changes in land and water systems that are likely to affect agriculture production.

According to the Action Aid International (2006), climate change is likely to result in high frequency of excessive rainfall and drought that is likely to erode farmer's assets leading to food insecurity vulnerability. The ever increasing in temperature as a result of climate change reduces agricultural productivity (Rosenzweign and Parry, 1994). According to IPCC (2001), most poor countries, particularly in the tropical and sub-tropical regions would experience a significant decrease in crop yield due to decreased water availability, new and changed pest incidence.

The United Nations Joint Press Kit for Bali Climate change Conference 2007, concluded that climate change is likely to lead to an increase in hunger and malnutrition affecting the vulnerable and food insecure. The conference also noted that climate change leads to new patterns of pests and diseases. Humans, livestock and plants will be exposed to new pests and diseases that will flourish only at specific temperatures and humidity, posing new risk for food security, food safety and healthy.

Shaw *et al*, (2007) assert that climate change impacts the four dimensions of food security which are production, availability, stability access and utilization. This argument was supported by (Recacewicz, 2005). Dimension of food security availability takes into account direct impacts on the yield through crop, pests and disease, soil fertility and holding properties. Indirectly climate change affects economic growth, income distribution, agricultural demand and social access to food. On the stability point of view focus is placed on the effects of constant supply of yields and food supplies. Climate change is likely to affect supplies of yields with fluctuating supplies of yield and food supplies.

Climate change has led to environmental hazards to human health, weather patterns and biodiversity as there might be hotter days and more frequent and larger heat waves. It might result in extreme events such as decrease in availability of fresh water and food, interact with health care services and also an enhancement of disease spreads as a result of increased rainfall and temperatures (Kelly *et al*., 2005). Food borne diseases, water borne and animal diseases are likely to emerge more rapidly due to the changes in climatic conditions (Kumar and Parikhli 2001). High temperatures might lead to the enhancement of the salmonella bacteria causing gastrointestinal distress in humans. Floods may lead to the overflow from sewage treatment plants into fresh water reserves. It is believed that a greater percentage of the population is urbanised thus a majority of the nations' population is affected.

Maddison et al (2007) assert that extreme climate changes lead to floods, droughts and earthquakes thus destroying infrastructure such as hospitals, schools, roads to mention but a few, this would affect the economic performance of the country an increased mortality rate an increased expenditure on the government as buildings need to be restored. The rapid action of the climate change leave plants and animals no room to adapt even the human research and development crew can hardly adapt and find coping strategies to such changes.

An increase in temperature has been found to decrease yield and quality of many crops. A decrease in precipitation will affect the semi-arid and arid areas in a negative way as there are a decrease in soil moisture but in areas with excess water agriculture is improved (Mano and Nhemachena, 2006). Due to high temperatures the amount and quality of forage in grasslands is affected. Animals also tend to loss appetite leading to loss of weight.

In Africa the subject matter is gradually attracting much attention (Zivanomoyo and Mukarati, 2013; Hassan, 2008; Mendelsohn et al, 2008; Mano and Nhemachena, 2006; Downing, 1992;

Onyeji and Fischer,1994; El-Shaer et al,1997; Hassan et al, 1998; Hulmeand Sheared, 1999; Seleka, 1999; Maula, 2002 and Deressa et al, 2005).

Mano and Nhemachena (2006) indicated that when revenue in Zimbabwe is regressed against various climates, soil, hydrological and socio economic variables in the Ricardian model, the net effects of climate change in Zimbabwe is quite significant. A 2.5C and 5C increase in temperature resulted in decrease in farm revenue of approximately US$0.3 and US$3 billion respectively.

Several authors using climate data and crop yield per farm net revenue have predicted similar outcomes in various African countries. Mendelsohn et al (2007) established that between 42%-60% of the total GDP in West Africa will be lost by the year 2010. Kelly et al (2005) and Quiggig and Horowits (1999, 2003) are of the view that even adaption is assumed there is still every room to expect that farmers income loose when climate variables change rapidly. They believe that the rise in the mean temperature does not matter per se but the rapidity of change might lead to the variance between climate actual and farmers' best guess values.

3. Data collection and methods

The main objectives that are to be addressed as mentioned above are to analyse the economic impacts of climate change on maize production and to establish how farmers are copying, their adoption measures. The study was carried out in Mashonaland East region of Zimbabwe targeting subsistence maize farmers. To attain the objectives of this research qualitative and quantitative data was be used. Quantitative approach aims at establishing the relationship between farm revenue and climatic variables (temperature and precipitation) on maize production across sectional basis. Fixed price strategy was used to various maize output collected. Data pertaining temperature and precipitation was collected from the Meteorological Department; output data was obtained from AGRITEX and prices from the Grain Marketing Board of Zimbabwe which was averaged to come up with a constant base price. The aim was to establish different impacts of precipitation and temperature on output to revenue.

3.1 Conceptual framework

The Ricardian model was used as the analytical tool with the aim of establishing different impacts of precipitation and temperature on output and revenue. The model is based on the assumption of direct cause and effect relationship between climatic events and farm value. It evaluates contribution of environmental conditions to household income. In this case all farmers are assumed to be profit maximises within a competitive environment. The Ricardian model is based on hypothesis that climate shifts production function of agriculture and study yield of specific crop and estimates short run equilibrium relationship between climate and agricultural output.

Using this approach, the net productivity function ois specified as;

$$R = P_iQ_i(X, F, Z, G) – P_xX$$

Where R is the net revenue per hectare, P_i is the market price of crop i, Q_i is output of crop i, X is a vector of purchased inputs (other than land) F is a vector of climate variables, Z is a set of soil variables, G is a set of economic variables such as market access and P_x is a vector of input prices. The farmer is assumed to choose X to maximise net revenues given the characteristics of the farm and market prices. The Ricardian model is a reduced model that examines how a set of exogenous variables F, Z and G affect farm value (Mendelsohn *et al*.1994)

The Ricardian model is a reduced form model that examines how several exogenous variables affect revenue. The standard Ricardian model on a quadratic formulation of climate change is given as;

$R = 0 +1F +2F^2 +3Z +4G + u$

u is the error term, F and F^2 capture levels of quadratic terms of precipitation and temperature. The introduction of quadratic terms reflect the non-linear shape of the response function between revenue and climate when quadratic term is the positive net revenue is U –shaped and when negative it is hill shaped.

4. Results and Discussion

4.1. Coping strategies employed by rural farmers

Adaptation strategy	Percentage
Dry and early planting	15%
Irrigation	2%
Varying planting dates	17%
Minimum tillage	19%
Multiple cropping	15%
Drought resistant varieties	9%
Shifting to tobacco	10%
Non farming activities	8%
Do nothing	5%

Minimum tillage (19%), varying planting dates (17%), dry and early planting (15%) and multiple crop rotation (15%) are the most practised ways of combating effects of climate change by rural farmers in Mashonaland province. According to the results, 15% of the farmers adopted dry and early planting and only 2% of the farmers have engaged in irrigation. This low response might be the result of few farmers with access to the Nyatsime River and income to buy irrigation equipment. Varying planting dates occupied 17% of the farmers; this might be because they had large farm size and readily available source of income.

10% of farmers are shifting to tobacco, proving that farmers are gradually losing confidence in maize due to the price instability and also the reduction in maize yields due to climate change. 8% of the farmers shun farming and looked for other sources of income as a way of living. 5% of the population has done nothing about climate change; maybe because these farmers have large farm size thus the impact of climate change is unnoticed.

4.2 Factors affecting climate change adaptation strategies

Adaptation strategy	Coefficient.	Standard error	t-statistic	Probability
Dry planting				
Age	1.582843	1.069628	1.48	0.139
education	-4.5587**	1.70393	-2.68	0.007
Farmsize	-32.29942	.	.	.
Gender	-8.152833**	3.287249	-2.48	0.013
Household size	21.98507**	2.314464	9.50	0.000
Varying planting dates				
Age	1.833879	1.162179	1.58	0.115
Education	-5.636915**	1.781209	-3.16	0.002
Farmsize	8.134234**	3.222226	2.52	0.012
Gender	-10.30502**	3.29833	3.12	0.002
Householdsize	1.922116	1.427672	1.35	0.178

Note ***- denotes significance @ 1%, **- significant at 5% and ***- significance at 10% respectively

The table above shows the multinomial regression done to identify the factors that affect adaptation strategies by households under study. The research was done on 80 households with *Pseudo* R^2 of 68.46 meaning 68.5% of the likelihood of adaptation strategy is being explained by the independent variables

The likelihood ratio is 120.34 meaning at least one of the predictors' regression coefficients is not equal to zero with 10 degrees of freedom. The chi-square result shows that the likelihood ratio statistic is highly significant (P<0.0001) suggesting a strong explanatory power of the model.

$Prob>Chi^2$ this is the probability of obtaining chi-square statistic 120.34 if there is no effect of the adaptation strategy.

Age of the household head tend to be statistically insignificant for both strategies proving that adaptation to climate change was not influenced by age. This research concurs with the study done by Bekele and Drake (2003) where age was found to have no effect on adaptation strategies to climate change but positively correlated. Since the majority of the age was between the age of 18 and 35 there seemed to be little notified effect on change in age of household head

Education was found to be statistically significant with a negative relation to the adaptation of varying planting dates and dry and early planting strategy with a p value of 0.002 and 0.007 respectively showing that as the level of education increases the probability of farmers shunning coping strategies increases. As shown in the study by Okoye (1998) and Gaukd et al (1989) where level of education was found to be negatively correlated with adoption, the more people learn the more they become resilient to change, they look for white collar jobs to feed their families.

Farm size had no quantifiable effect on the adoption of dry and early planting adoption strategy. Farm size was statistically significant and had a positive relation to varying planting date strategy. If the farm size was to increase then the probability of adaptation to varying planting dates is likely increase while holding all other variables in the model constant. Since varying planting dates requires a larger piece of land, farmers with a greater portion of land are the ones that are more likely to adapt to this strategy as asserted by Anim (1999) in a study done in South Africa.

Gender proved to be statistically significant with a negative relation for both strategies relative to the minimum tillage with an associated p value of 0.013 and 0.002 respectively. If the gender of the household head was to change then the probability of adaptation is to decrease while holding all other variables in the model constant. Female heads tend to adapt to conservation practices compared to male heads as shown by studies done by Bayard et al 2007 and Dolisca et al 2006.

Household size proved to have different effects on the adaptation of strategies. On dry and early planting household size was found to being statistically significant with an associated p value of 0.000 meaning that as household size increases the probability of adapting to dry and early planting will also increase. But however, an increase in household size was found to be statistically insignificant for the probability of adaptation of varying planting date strategy. This could be dry and early planting demands more labour yet varying planting date is rather an income driven strategy

5. Conclusion and Recommendations

The purpose of this study was to examine the economic impacts of climate change on maize productivity in Zimbabwe's Mashonaland East region. The Ricardian Analytical tools were used. Results from the study indicate that farmers' level of education has a positive and significant impact on productivity in the face of climate change. Female headed households also tend to adopt more quickly to climate change than male headed households. Policies should therefore be put in place that support farmer education and training. Such training and education should largely target female headed households as they quickly respond to challenges brought by climate change.

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