

Effects of climate variability and insurance adoption on crop production in select provinces of South Africa

Zelda Anne Elum, Godwell Nhamo and Michael Akwasi Antwi

ABSTRACT

Increasing climate variability increases the risks in production and prices of agricultural products. Inarguably, Africa's susceptibility to climate change is high because it hosts the majority of the world's poor who cannot afford the costs of coping mechanisms. Agricultural insurance is being largely put forward as a coping measure of adapting to climate change to sustain farm production and farmers' livelihood. The study critically reviewed numerous publications on climate change impacts and the role of insurance in the adaptation process. It examined the effects of varying weather conditions and insurance on net crop revenue using the instrumental variable regression approach on a Ricardian model. The study further identified factors influencing the purchase of insurance among the farmers with a probit model. The study data were collected from a cross section of farmers in three selected provinces of South Africa. Results of data analysis indicated that owning insurance, number of labourers employed, size of irrigated farmland and rainfall have significant effects on net revenue. It was also revealed that experience, indicated by years of farming and revenue, influenced farmers' adoption of insurance. Consequently, the paper advocates for the provision of efficient irrigation facilities and promotion of insurance among farmers.

Key words | agriculture, climate change, economic impact, insurance, South Africa, variability

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INTRODUCTION

Agricultural commodity producers across the globe are facing increasing production and price risks attributed to climate change (Raju & Chand 2008). The adverse effects associated with climate change and weather conditions include flooding, drought, fire, hail, extreme temperatures, incidence of pest and diseases, among others, and have been shown to affect agriculture and livelihood in many ways, such as increasing input costs and reducing profits due to total failure or reduced harvest, and severe incidence of livestock deaths (CARE 2009; Müller 2009). Thus, climate change risks can adversely affect the current and future

decisions of farmers on timing of farm operations, seriously affecting farm production and income. The term 'risk' has been defined as 'that which represents the probability of occurrence of an event which may have adverse consequences at any stage in the pathway of a production chain' (Pasaribu 2010). On this note, it is imperative that farmers adopt some form of measures to mitigate their losses from climate-related disasters and one such measure is the uptake of insurance.

Global population is increasing and certainly future population increases will lead to increasing competition for available land for human food, animal feed and recreational needs. This would be made worse by the increasing challenges posed by climate change, however, the adoption of insurance coverage provides an opportunity

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to encourage farmers to continue in business and sustain food production. Agricultural insurance is a financial protection given to farm investments and is one method by which farmers can minimise financial implications of production variability and guard incomes against the catastrophic effect of losses arising from extreme weather events. Insurance spreads farm losses over space and time, and encourages farmers to sustain investments in agriculture despite the occurrence of natural hazards. Insurance can be used together with other climate risk management tools to strengthen societal resilience (Raju & Chand 2008). This refers to an increase in the ability of the general public or group of persons to cope with natural disaster and a reduction in their vulnerability to climate change impacts.

The economic impact of climate change on South African field crops has been studied (Akpalu *et al.* 2008), but to the best of our knowledge there is limited literature on the implication of climate variability for agricultural insurance. Thus, the main aim of this study is to examine whether changing weather condition and insurance significantly impact the net returns of crops across the provinces of Gauteng, Limpopo and Mpumalanga in South Africa and to also generate information on agricultural insurance with a special focus on South Africa. To this end, the work is structured into four parts as follows. The first section introduces the study and its objectives, then gives numerous literature references and discusses climate change impacts on agriculture, and the role of the insurance industry in mitigating climate risks on a global and national level. The next sections lay out the methodology, presents and discuss the analysed results, before drawing conclusions in the final section.

THEORY: ECONOMIC IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

Climate change affects human health, agriculture, water resources, machinery, roads, housing, coastal and terrestrial ecosystems and biodiversity. Its impacts have been of concern to a range of stakeholders at both national and international levels including governments, business and labour (UNFCCC 2007; Müller *et al.* 2011). Farmers deserve a special mention among these stakeholders, especially in

developing countries where the livelihoods of many people face threats from climate change. Although agriculture impacts climate change, this study focuses on the effects of climate variability on agriculture. On a brief note, for example, agriculture on the one hand negatively influences climate change through the significant usage of fossil fuels. Food systems globally consume about 30% of the world's total energy (Elum *et al.* 2016). On the other hand, agriculture provides positive effects for climate change, as all plant cover acts as a carbon sink. Nevertheless, going by reports, between 75 and 250 million people in Africa would be exposed to water stress by 2020 as a result of climate change (UNFCCC 2007). The changes in rainfall patterns could cause drought or flooding while rising temperature will cause changes in planting seasons, wildfires and increased incidence of pest and diseases (Chambwera & Stage 2010). The impact of climate factors such as higher temperatures and decreasing rainfalls on agriculture could lead to diminished production and higher prices that could result in socio-political instability (Sullivan 2014). Without doubt, climate change presents challenges to agricultural production and infrastructures and affects farmers' livelihoods in Africa. More so, the continent has been identified as highly vulnerable to changing climate due to varying prevailing factors such as poverty, illiteracy, lack of manpower, weak institutions, poorly developed infrastructure, poor health care, armed conflicts, unbridled corruption, population increase and land degradation (UNFCCC 2007).

Evidently, climate change has an impact on agriculture (Seo & Mendelsohn 2008). Two broad approaches often employed in the assessment of the economic impact of climate change on agriculture are the agronomic-economic and the Ricardian approaches (Kumar 2007). The agronomic-economic method uses a crop model that has been standardized from controlled experiments in which the crops are grown under a field or laboratory settings with different simulated climates and levels of carbon dioxide. However, this approach has the disadvantage of not including adaptation in its estimates since it does not allow changes in the farming methods across experimental fields (Di Falco *et al.* 2012). On the other hand, the Ricardian model, which models autonomous adaptation by farmers endogenously, assumes that land rents or farm net revenues

would reflect farmland net productivity and thus captures the adaptation and farm choices made by the farmer in response to changes in environmental and weather conditions. However, its limitations are the assumptions of constant prices and of every farmer choosing a production portfolio that maximizes profits (Maddison 2007). Unfortunately, in developing countries, many farmers are found not to be profit maximisers (Chambwera & Stage 2010). However, the Ricardian approach has been used in various studies; for example, in the study of agriculture's sensitivity to climate change across the United States of America and also in examining the economic impact of climate change on major field crops in South Africa (Mendelsohn & Dinar 2003; Gbetibouo & Hassan 2005).

Overview of South African agriculture

The agricultural sector in South Africa contributes 2.6% (DAFF 2013) to the country's GDP and employs 5.1% of the country's labour force (DAFF 2010). South Africa has a dual agricultural economy comprising of a commercial sector that is well developed and a considerably less developed subsistence sector. The major crops grown include maize, wheat, oats, sorghum, rye, barley, tobacco, cotton, deciduous fruit trees and citrus fruit. Notably, maize one of the main staple crops of South Africa is produced almost throughout the country. Maize accounts for 70% of total produced grains and occupies 60% of cropped area (Akpalu *et al.* 2008). South Africa is considered a dry country with more than two-thirds of its area experiencing less than 500 mm average annual rainfall (Durand 2006) and as such, agriculture activities have been to a large extent adapted to semi-arid conditions. Irrigated farming involves 1.3 million hectares of land and this places South Africa as the largest 'irrigation country in the Southern African region' (Durand 2006). Most of the 22 major rivers in the country provide water for numerous activities including agriculture; however, it has been projected that water requirement in South Africa will exceed available water by 2025 (UNEP 2013).

Furthermore, according to Archer *et al.* (2008), agriculture in South Africa is viewed as an area of priority for creating an enabling environment for adaptation to climate change. In a study mapping the South African farming

sector's vulnerability to climate change, it was observed that Mpumalanga province, North West, Gauteng and Northern Cape had mid-range vulnerability, Limpopo, Eastern Cape and Kwazulu Natal were most vulnerable regions while the Free State vulnerability fell into an indeterminate zone and the Western Cape had the lowest level of vulnerability (Gbetibouo & Ringler 2009). It is worth noting that most climate change impact studies of agriculture in South Africa have been on food crops, but this study extends focus to cotton which is a non-food crop and also to vegetables such as cabbage and potato. Cotton is mostly cultivated in the North West's Rustenburg district, Natal Waterberg district and Tzaneen section of Limpopo province. According to DAFF (2015), cabbage production is concentrated in Mpumalanga and the Camperdown and Greytown districts of Kwazulu-Natal while potatoes are grown in high-lying areas of Free State and Mpumalanga as well as in Limpopo, the Eastern, Western and Northern Cape and Kwazulu-Natal.

Role of insurance as an adaptive strategy to climate change impact

A UNEP Finance Initiative Report indicated that climate change-related risks can be viewed in terms of the frequency and severity of extreme weather events (e.g. flood, drought and storms) and in terms of slow onset but long-term events (e.g. sea-level rise and desertification). In recent times, discussions on the suitability of insurance in managing slow onset events in vulnerable countries have emerged. There has been a consensus that a risk transfer mechanism as insurance can help to address losses associated with the impacts of climate change (Balogun 2014). Notably, the IPCC recognizes insurance as one method of developing resilience to climate change impacts. The insurance system works on one of two principles which are: spreading the cost of those suffering losses over those commonly exposed to the possibility of loss, and spreading each individual's costs from random losses across time (Raju & Chand 2008). Insurers use the revenue collected through premiums paid by farmers in the years of good harvest to pay indemnities in time of crop failure.

Insurance as an adaptive strategy can protect farmers from losses caused by flood, drought, pestilence and disease infestation, all of which can be linked to climate change.

Insurance remains one of the practical pathways to future action on climate change adaptation (McLeman & Smit 2006). Although, insurance is a vital instrument in developing countries, it is very limited and its role is constrained by many factors. Currently, insurance covers approximately 4% of losses in the world's poorest countries, mainly because the cost of insurance products is not affordable for poor people or designed to cover their needs (Schipper *et al.* 2008). It has been pointed out that inaccessibility to insurance will affect a large proportion of agricultural producers in Africa, as they are mostly reliant on increasingly erratic rain-fed agriculture (Elum & Simonyan 2016). More so, farmers who operate small pieces of land and subsistence farming characteristic of the African continent are the most vulnerable to climate change risks (Pasaribu 2010). Reportedly, the United States and Canada account for about 62% of the global agricultural insurance market premiums compared to Africa's mere 1% (Iturrioz 2009). In comparison to other continents, Africa has the lowest insurance penetration and insurance density (UNEP Finance Initiative 2011). Insurance penetration indicates the level of development of a country's insurance sector and it is measured as the ratio of total premiums to the country's gross domestic product (GDP) expressed in percentage terms (KPMG 2014). Insurance density refers to insurance premium per capita, that is, the ratio of total premiums to the total population (KPMG 2014). Although insurance is mainly created to provide relief after the occurrence of losses, it could be designed to motivate proactive actions that reduce risks (Schipper *et al.* 2008) through new products such as weather-based index insurance (WBII).

Insurance offers protection to farmers against various risks. Apparently, farmers who are insured tend to be less risk-averse than those not insured. The most developed type of agricultural insurance has been crop insurance (Iturrioz 2009). Traditional forms of claims-based crop insurance cover multiple risks, including weather-related risks such as hail and drought, as well as non-weather catastrophes such as pest and disease outbreaks. However, the price of premiums are often high and unaffordable for poor smallholder farmers and worse still, the payment of claims is seen as too slow to quickly alleviate the adverse impacts of losses on farmer's livelihoods (Daron & Stainforth 2014). Agricultural insurance product also consists of

the earlier mentioned index-based insurance made up of area-based yield index and WBII. In area-based yield insurance, indemnity to beneficiaries are based on the average yield of all producers in the region, whether or not they purchased insurance. In WBII, claims payment is based on the occurrence of a specific weather parameter over a pre-specified period of time observed at a pre-chosen weather station (Carter *et al.* 2007; Daron & Stainforth 2014).

Agriculture insurance in South Africa is reported to have started as far back as 1900s (Mahul & Stutley 2008). Presently, the insurance industry is dominated by private investors who fix their premiums based on historical data. Hazard awareness is reportedly high in South Africa (Lamond & Penning-Rowsell 2014) and as such, natural peril cover is widespread within insurance holders. However, only 30–50% of households in South Africa have property insurance for any peril (Lamond & Penning-Rowsell 2014). The only African country with a well developed insurance market covering both life and non-life markets is South Africa and this emerges from its well developed financial system considered as a driver of growth in the insurance industry (KPMG 2014). Farm buildings are insured against damage caused by fire, hurricane, flood, heavy rain, hail, snow, lightning, explosion, landslide and avalanches among other hazards. Property insurance on the farm covers events such as fire, hurricane, hail, lightning and flood. The South African insurance industry's claims-incurred ratio (that is, the ratio of all claims paid to the total premiums received in a specified period) increased from 60.8% in 2012 to 64.7% in 2013 (KPMG 2014). Most of the weather-related claims included the floods in Limpopo and Western Cape and two significant Gauteng hailstorms (KPMG 2014). According to Mahul & Stutley (2008), about 25% of farmers and 25% of the national crop area (1.3 million ha) were insured in 2007. Furthermore, a statistical report of the South African insurance industry as at 2014 showed that the country has a penetration rate of 14%. However there is no information on the share of farmers in this coverage (KPMG 2014).

Equally important is that climate change can adversely affect insurance affordability and availability; potentially slowing the industry's growth and shifting more of the burden to governments and individuals (Mills 2005). Apparently, increasing climate-change related risks, especially in

property and agroforestry, are already seen in recent insurance claims data (UNEP Finance Initiative 2013a). To sustain financial viability in the light of climate change threats, insurers can be drivers of climate-smart agricultural practices (Brown & Funk 2008). The insurance industry has the potential to identify and develop incentives for climate risk reduction by promoting risk awareness and risk reduction solutions among the people (UNEP Finance Initiative 2013b). More so, how the insurance industry responds to climate-related events can influence the climate-change perception of the public, including policy makers (UNEP Finance Initiative 2013a). Thus, the role of insurance as an effective tool for adapting to climate change will depend on the joint efforts of the industry regulators, governments, consumers and capital market (Zhao 2011).

METHODS

The Ricardian model was the preferred method in this study as the crops were not being grown under controlled climatic conditions as required in agronomic-economic method. The

model used in this study assumes that farm net revenue per hectare is reflective of the different environmental conditions across the provinces. As such, cross-sectional observations of climate parameters with spatial variations can be used to estimate climate impacts on crops (Gbetibouo & Hassan 2005). More so, the geographical distribution of crops in an area is often reflective of the varying climate across the country. As indicated in the introduction, the aim of the study was to examine whether the changing weather conditions and having insurance coverage significantly impact crop returns in the selected provinces of South Africa. The study spelled out the following twin objectives: To quantify the impact of climate variability on net farm revenue and to examine the determinants of insurance adoption among farmers in the selected provinces (shown in Figure 1). These provinces were chosen because the literature has identified them as being vulnerable to climate change impacts.

Of the selected provinces, Gauteng is South Africa's smallest province in terms of land mass. It is regarded as the financial capital of Africa. The capital of the province is Johannesburg, the biggest city in terms of population in

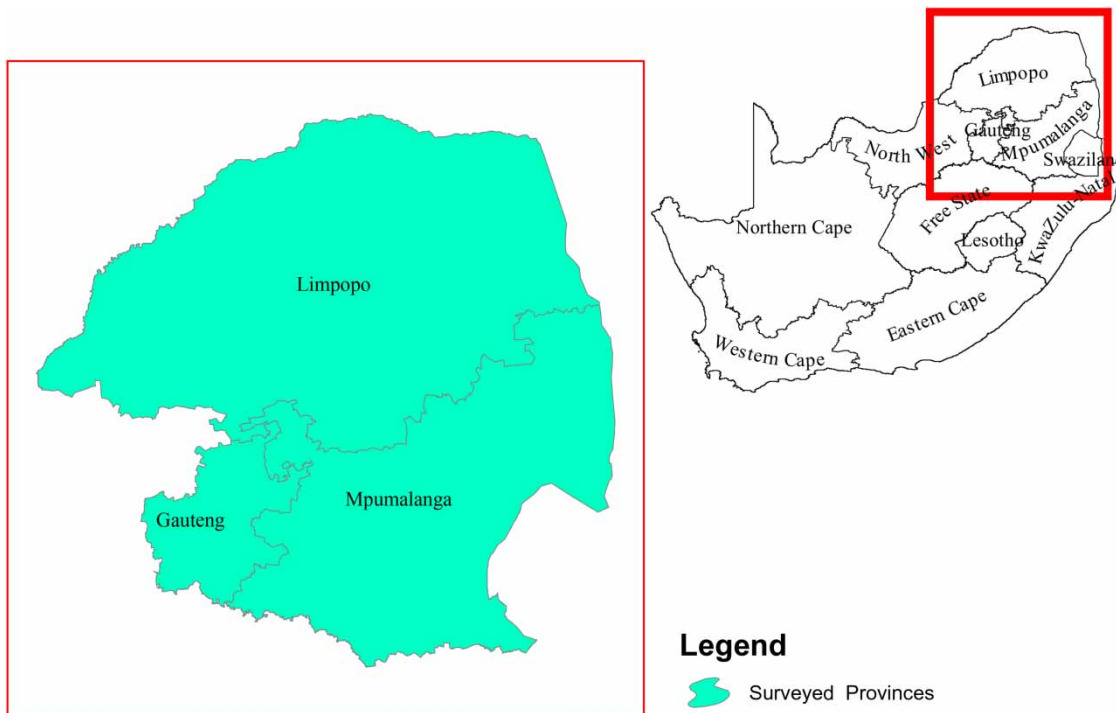


Figure 1 | Location map (South Africa).

South Africa as well as the commercial hub of the country. Gauteng is landlocked and bordered to the south by Free State, to the west by North West province, to the north by Limpopo and to the east by Mpumalanga. Its annual precipitation averages about 713 mm. Average maximum temperature is about 26 °C in January and 16 °C in June. Gauteng is the most urbanised and densely populated province in South Africa and has need for a robust agricultural sector to sustain the teeming population. Among the provinces, Gauteng has a higher share of agricultural area under irrigation. Mpumalanga, the second smallest province after Gauteng is bordered to the east by Mozambique and Swaziland, and to the west by Gauteng. It borders Limpopo in the north and Free State in the south. The capital is Nelspruit where the average maximum temperature is 29 °C in January and 23 °C in July with an annual precipitation of 767 mm. Agriculture occupies more than 68% of the province area. Limpopo province is the country's northernmost province and it shares international borders with three countries: Mozambique on the east, Zimbabwe on the north and northeast and Botswana on the west and northwest. It also shares borders with other provinces (Mpumalanga, Gauteng and North West). The capital of the province is Polokwane. Limpopo, despite having year-round sunshine, experiences wide climatic variations (Government of South Africa 2015).

These provinces have sub-tropical conditions (Gbetibouo & Hassan 2005) and were purposively chosen because past studies have identified them as being vulnerable to climate change impacts. In addition, insufficient resource and time constraints limited the study to the three provinces (Gauteng, Limpopo and Mpumalanga). The selected crops (cabbage, potatoes and cotton) under study also influenced the choice of province. For instance, cotton production is more popular in the Limpopo province than the other two selected provinces. These crops were however chosen because, to our knowledge, not many studies have been conducted with these crops as most climate impact models have considered food crops such as maize, wheat and sugarcane. A study of these crops is important because vegetables like cabbage and potatoes are commonly consumed in South Africa and they are very sensitive to water shortage (i.e. susceptible to drought) while a cash crop like cotton has a low sensitivity to drought.

Data

The dataset comprises of cross-sectional primary farm-level data collected with the aid of structured questionnaires from 235 farmers across the three provinces in the time period from August to October 2015. Most of the farmers were emerging farmers. These are black commercial farmers with small farm sizes; often constrained by lack of financial assistance and inability to access established markets (Barlow & Van Dijk 2013). The data for rainfall and air temperature were obtained from the South African Weather Services; average values of a 30 year period (1985–2014) were used. Increasing air temperature has been found to have significant effects on farm production in South Africa. Blignaut *et al.* (2009) opined that daily minimum temperatures are generally considered a better indicator of climate change; however, daily maximum temperatures are likely to have an impact on agriculture production in South Africa. In this study, maximum and minimum air temperatures were considered just as was used in Di Falco *et al.* (2011). The climatic data were matched with randomly sampled farms around the regions of two purposely selected weather stations in each of the provinces, thereby making a total of six weather stations from which data were collected for the three provinces. The air temperature and rainfall data were mostly uniform across farms in each province. The dataset provided information on farmers' socioeconomic characteristics (e.g. farm size, educational level, labour, size of farm irrigated, membership in organizations, insurance coverage, institutional credit access, etc.) and climatic variables (minimum air temperature, maximum air temperature and rainfall).

To achieve the objective of the study and as highlighted earlier, the Ricardian model was adopted, regressing the crop net revenue per hectare on climate and other exogenous variables. The model is expressed as:

$$Y = \left[\sum P_i Q_i(\mathbf{X}, \mathbf{F}, \mathbf{Z}, G) - \sum R\mathbf{X} \right] \quad (1)$$

where Y is the crop net revenue per hectare as used by Gbetibouo & Hassan (2005), P_i is the market price of crop i , Q_i is the output of crop i , \mathbf{X} is a vector of purchased inputs other than land, \mathbf{F} is the vector of non-climatic

variables, \mathbf{Z} is a vector of climatic variables, G is a set of socioeconomic variables and R is a set of input prices. It is supposed that the farmer will choose \mathbf{X} based on the characteristics of the farm and market prices in order to maximize net revenues. The relationship between the climatic variables and crop net revenue are assumed to be non-linear (Seo & Mendelsohn 2008). As such, the Ricardian model used in this study was that of quadratic formula and in a semi-log form:

$$\ln Y = \beta_0 + \beta_1 \mathbf{F} + \beta_2 \mathbf{Z} + \beta_3 \mathbf{Z}^2 + \beta_4 G + U \quad (2)$$

The analysis model also included an interaction term between air temperature and rainfall variables. An instrumental variable (IV) regression approach such as the two stage least squares (2SLS) was used in the regression analysis as it was assumed that for a farmer, having an insurance coverage may influence farm revenue just as farm revenue may influence a farmer's decision to purchase insurance (Di Falco et al. 2014). In this regard, insurance is treated as an endogenous variable since the factors affecting farm net revenue could also influence a farmer's decision to purchase insurance. The 2SLS is an IV estimator that entails two consecutive ordinary least-squares (OLS) regressions. This regression was done with the help of STATA 12.0. The IV model is as shown:

$$y_i = Y_i \beta_1 + \mathbf{X}_{1i} \beta_2 + U_i \quad (3)$$

$$Y_i = \mathbf{X}_{1i} \pi_1 + \mathbf{X}_{2i} \pi_2 + V_i \quad (4)$$

where y_i is the dependent variable for the i th observation, Y_i stands for the endogenous regressors, \mathbf{X}_{1i} represents the included exogenous regressors and \mathbf{X}_{2i} are the excluded exogenous regressors. It is presumed that there is a non-zero relationship between U_i and V_i . Thus the study model is represented as:

$$\text{Net revenue/ha} = \beta_1 \text{insurance} + \beta_2 \text{irrigation area} + \beta_3 \text{labour} + \dots + \beta_n \mathbf{X}_n \quad (5)$$

$$\text{Insurance} = \beta_2 \text{irrigation area} + \beta_3 \text{labour} + \dots + \beta_n \mathbf{X}_n + \pi_1 \text{education} + \dots + \pi_n \mathbf{X}_n \quad (6)$$

Post estimation tests (test of endogeneity and Wooldridge's score test) were carried out to confirm the endogeneity of the insurance term and validity of the instruments. Further analysis involved a probit model in determining the factors influencing the demand of insurance among the sampled farmers. The probit model involves a qualitative response variable which characterizes the alternative choices of a decision maker and assumes that the insurance adoption choice by a farmer is a function of specific variables. Y is a dichotomous variable expressed as:

$$P_i = P(y_i = 1 | \mathbf{X}) = \mathbf{F}(\mathbf{X}_i, \beta) \text{ where there is insurance} \quad (7)$$

$$P_i = P(y_i = 0 | \mathbf{X}) = 1 - \mathbf{F}(\mathbf{X}_i, \beta) \text{ where there is no insurance} \quad (8)$$

$$\text{Thus } Y_i = \beta + \beta_1 \mathbf{X}_i + \dots + \beta_n \mathbf{X}_{ni} + e \quad (9)$$

where Y is the binary dependent variable for the i th observation and the \mathbf{X} s are the regressors. One of the *a priori* expectations of this analysis was that the likelihood of a farmer buying insurance would increase if farmers depended more on irrigation and if they had access to institutional credit. The variables used in the analysis are defined in Table 1. However, a possible limitation of the study data was the assumption that farmers may not want to disclose the true quantity (or revenue) of their produce while exaggerating on their expenditure.

RESULTS AND DISCUSSION

In this section, the results of the Ricardian and probit regression which were used to determine the economic impacts of climate change on crops and the determinants of insurance adoption among farmers, respectively, are presented and discussed. First, the farmers' descriptive statistics are shown in Table 2. It is inferred from the standard deviations which express the level of disparity in the variables that there was great disparity in the input expenditures and revenue obtained among the farmers. This may be attributed to the different crops planted by the farmers as the crops require different amount of inputs and also command significantly different market prices. The average age

Table 1 | Definition of variables

Variable	Definition
Net revenue	Total revenue minus total farm expenditure (in rands)
Gender	Dummy = 1 if farmer is a male, 0 otherwise
Education	Level of education attained by the farmer (dummy = 1 if farmer had formal education, 0 otherwise)
Age	Farmer's age (years)
Farming experience	Number of years spent in farming
Farm size	Cultivated size of farm (hectares)
Irrigated farm area	Share of farm land under irrigation (hectares)
Labour	Number of farm workers employed on the farm
Production expenditure	Total amount spent on farm inputs (seeds and fertilisers) for observed crop (in rands)
Quantity of output	Quantity of output (in rands)
Insurance	Dummy = 1 if farmer bought insurance, 0 otherwise
Access to formal institution credit	Dummy = 1 if farmer had access to formal institution credit, 0 otherwise
Farm organisation membership	Dummy = 1 if farmer is a member of a farm organisation, 0 otherwise
Rainfall	Average rainfall (mm) for 30 year period
Minimum air temperature	Average minimum temperature (°C) for 30 year period
Maximum air temperature	Average maximum temperature (°C) for 30 year period

Source: South Africa Weather Services (2015).

Table 2 | Descriptive statistics of sample farmers and variables

Variable	Mean	Standard deviation	Minimum	Maximum
Gender (dummy; 0 = Female, 1 = Male)	0.50	0.50	0	1
Education (dummy)	0.53	0.03	0	1
Age (years)	45.32	10.26	25	72
Farming experience (years)	8.64	6.39	1	40
Cultivated farm size (ha)	2.90	0.33	0.40	65
Irrigated portion of farm (ha)	2.88	2.40	0.5	15
Labour (nos of persons)	6.61	0.28	0	30
Input expenditure (rands)	9,953.39	12,526.92	0	96,200
Revenue (rands)	27,034.04	2,359.69	0	280,000
Climate change awareness (dummy)	0.93	0.017	0	1
Insurance (dummy; 0 = No, 1 = Yes)	0.23	0.03	0	1
Access to credit (dummy)	0.26	0.16	0	1
Farm organisation membership (dummy)	0.41	0.49	0	1
Rainfall (mm)	684.64	64.51	635.41	803.99
Minimum air temperature (°C)	11.89	0.14	9	15.01
Maximum air temperature (°C)	24.62	1.25	22.48	25.89

Source: South Africa Weather Services (2015).

Table 3 | 2SLS Regression estimates of sample farmers

Variables	Coefficients	$P > t $
Dependent variable = Ln (net revenue per hectare)		
Insurance (dummy; 0 = no; 1 = yes)	12.1729	0.003***
Labour (nos per hectare)	-0.2072	0.057*
Input expenditure (rands per hectare)	0.00001	0.010***
Rainfall (mm)	0.1034	0.044**
Rainfall ²	-0.0001	0.019**
Minimum air temperature (°C)	-4.0081	0.135
Minimum air temperature ²	0.1578	0.128
F test of endogeneity	7.4108 ($P = 0.0071$)	
Wooldridge's Score test of overidentification of all instruments	$P = 0.2992$	
Number of observations	235	

Notes: *significant at 10%; **significant at 5%; ***significant at 1%.

of the farmers reflected that the farmers were in their youthful and active years. Also, the average size of cultivated farms which was very small indicated that the farmers were mostly subsistence and small-scale commercial farmers.

The result of the 2SLS regression is presented in Table 3. It could be observed that the dummy for the adoption of insurance is statistically significant and positive (STATA takes zero as the base and reports for 1), implying that farmers who insured their farm business had relatively higher net revenue than those who did not. However, it is also possible that farmers with higher incomes are in a better position to afford to buy insurance. One implication of this is that insurance can be used as a means of reducing agricultural loss brought about by climate variability (Di Falco et al. 2014). The labour variable was also significant, but with a negative sign which implies that increasing number of laborers reduces the farmers net revenue. This may be so if more labour, which means higher cost of wages, is employed without increasing cultivated area as this would reduce profit. Furthermore, it emerges that the net revenue increases when more seeds and fertilisers are used as implied by increasing input expenditure. This indicates that these inputs are important in crop production. The statistical significance and positive effect of the rainfall variable shows that a unit increase in rainfall will increase net revenue by 10.3%. However, with the negative sign and significance of

the quadratic term of rainfall, the result supports Di Falco et al. (2012) that too much rainfall has adverse effects on crops, and also agrees with Gbetibouo & Hassan (2005) that there exists a non-linearity relationship between crop net revenue and climate data (rainfall). In other words, the negative squared rainfall term indicates a diminishing effect of excess rain on crop net revenue. The test of endogeneity is significant and implies that the null of exogeneity is rejected and that the insurance term can be treated as endogenous. Further, the non-significance of the Wooldridge's score test of overidentifying restrictions indicates that the instruments are valid and the null hypothesis is rejected.

The result of the probit regression is presented in Table 4. It was observed that farmers with larger farm area under irrigation were more likely to own insurance. Irrigation is one form of climate change adaptation strategy. However, in times of prolonged dry spells/drought and drying up reservoirs, farmers whose productions are largely dependent on irrigation would tend to buy insurance to minimize production loss if they had experienced water shortage in previous years. The result also revealed that farmers with longer years of farming experience were less likely to purchase insurance. Maddison (2007) noted that experienced farmers are more likely to perceive changes in the climate. Consequently, such farmers will, *ceteris paribus* recognize the need to adopt insurance. However, a situation where farmers with more farming experience are less likely to buy insurance would arise if farmers trusting in their

Table 4 | Estimates of probit regression

Variables	Coefficient	$P > z $
Dependent variable: Insured (0 = No; 1 = Yes)		
Constant	-2.8412	0.013**
Gender	0.1541	0.451
Irrigated farm size (ha)	0.1593	0.000***
Farming experience (years)	-0.0361	0.045**
Organisation membership (dummy)	-0.2130	0.351
Rainfall	0.0029	0.081*
Hosmer-Lemesho χ^2 (8)	13.19	
Prob > χ^2	0.1054	
No of observations	214	

Notes: *significant at 10% **significant at 5%; ***significant at 1%.

acquired knowledge and judgement of uncertainties based on previous occurrence of weather patterns, choose to manage farm production risk with various adaptation strategies other than buying insurance. Hassan & Nhemachena (2008) noted that experienced farmers are expected to have more knowledge and information about climate change and agronomic practices that could be used in response to climate change. Thus, more farming experience enhances adaption. Other possible reasons for not buying insurance may be farmers' inability to afford insurance premiums and farmers with small farm sizes considering it economically unwise to buy insurance coverage. It was also found that as rainfall increases, farmers were more likely to adopt insurance. This reinforces the earlier 2 SLS result showing the negative and statistically significant quadratic term for rainfall. The result thus supports the literature (Pal & Mondal 2010; Pasaribu 2010; Di Falco *et al.* 2014) that the demand for insurance among farmers is influenced by weather and socioeconomic factors.

Furthermore, this study although focused on the effect of climate variability on agriculture, analyzed the climate parameters for a 30-year full period (1985–2014) and sub-periods (1985–1999 and 2000–2014) to examine any significant differences in the climatic parameters (Elum *et al.* 2017). Table 5 shows that Limpopo province had experienced a significant change in rainfall and minimum temperature. Similarly, change in minimum temperature was significant for Mpumalanga province. The covariances of rainfall and air temperature imply that as it gets hotter, there is less rainfall in the provinces. The persistence of such trends would indicate that these provinces are likely to face increasing challenges from climate change.

CONCLUSION

The study examined the effects of climate variability and insurance adoption on the net returns of crops across selected provinces of South Africa. It is inferred from the study that farmers with insurance coverage had higher net revenue. In addition, rainfall positively affects net revenue until it peaks (excessive rainfall) and then assumes a diminishing effect. It was further revealed that the adoption of insurance is significantly influenced by rainfall, length of

Table 5 | Analysis of climate variables

Variable	Province		
	Gauteng	Mpumalanga	Limpopo
Mean annual rainfall (mm) between 1985–2014	701.806	803.990	635.408
Change in rainfall (%)	2.594	−6.862	2.724
Mean annual min. temp. (°C) 1985–2014	9.772	10.979	13.283
Mean annual max. temp. (°C) 1985–2014	22.921	24.216	25.497
Change in min. temp. (%)	2.867	53.054	−3.878
Change in max. temp. (%)	3.284	10.719	−0.332
Change in annual rainfall between 1985–1999 and 2000–2014	−57.361	−17.014	43.744
Change in min. temp. between 1985–1999 and 2000–2014	0.021	1.107	−0.437
Change in max. temp. between 1985–1999 and 2000–2014	0.499	0.548	0.316
Variance test for rainfall ($P(F \leq f)$ one tail)	0.481	0.137	0.029*
Variance test for min. temp. ($P(F \leq f)$ one tail)	0.473	0.000**	0.000**
Variance test for max. temp. ($P(F \leq f)$ one tail)	0.437	0.348	0.285
Covariance for rainfall and max. temp. (1985–1999)	−54.484	−28.893	−32.989
Covariance of rainfall and max. temp. (2000–2014)	−72.860	−32.078	−101.122
Covariance of rainfall and min. temp. (1985–1999)	−3.498	−4.328	−13.298
Covariance of rainfall and min. temp. (2000–2014)	−0.740	−22.079	−3.501

Sources: South Africa Weather Services (2015) and Elum *et al.* (2017).

Notes: *Significant at 5% and **significant at 1% level of testing.

farming experience and the extent/level of irrigated farming. It is implied from the study that people would more likely buy insurance with increasing occurrence of flooding caused by excessive rainfall. However, farmers may choose not to participate in the insurance market due to various factors, e.g. cost constraint or trusting in their knowledge of agronomic practices for climate adaption.

The recommendations synthesized from the study are as follows. There is need for the promotion of insurance among

emerging farmers, who should also be encouraged to invest in efficient irrigation facilities as this is important for optimum crop yield. In addition, farmers should be provided with timely information on changing planting times that will not coincide with periods of heavy rains as well as adequate provision of inputs such as fertilisers and seeds. Despite the limitations of the study, the results of the analysis are consistent with those in economic literature. However, there is scope for further research for more robust results.

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