Gendered Impact of Weather Shocks and Norms on the Farm and Off-farm Sectors of Nigeria

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1 Introduction

Weather shocks impact both the farm and the non-farm sectors including the labour supply to both sectors. Yet many studies on weather shocks focus on the farm sector neglecting their impact on the non-farm sector. Understanding how these shocks shift labour supply across both sectors and the drivers of such shift in terms of gender and its norms are key for effective policies formulation on gender, adaptation and climatic shocks. Also understanding how these shifts in labour supply ultimately impacts the welfare of the people is key. Studies by Grabrucker and Grimm (2021) and Haggblade, Hazell and Brown (1989) showed that weather shocks on the farm sector spread to the non-farm sector through the linkages that exists in both sectors. Farming decisions when faced with these shocks could vary with gender due to the gender-unequal practices resulting from gender norms that vary across regions (Guarnieri and Tur-Prats 2016). Interesting about this study is that it is the first paper to study weather shocks and off-farm in Nigeria and the first to consider the gender dimension. It contributes to the literature by investigating how off-farm activities can offer adaptation opportunities for men and women in a context where social and gender norms vary considerably across regions. This paper provides novel empirical evidence of the impact of weather shocks on labour supply to the non-farm sector separately for women and men employing labour hours rather than using a dummy variable of if they own non-farm enterprises as their main occupation as used Grabrucker and Grimm (202). Also investigating the role of gender norms on the impact of rainfall shocks on off-farm labour supply. In this paper we focus on gender norms that supports men as against women to understand how it impacts their ability to move out or remain in the farm sector when faced with weather shocks. This is very important because gender norms vary considerable across regions in Nigeria. Data on the gender norms was gotten from Afrobarometer. Firstly we established that weather shocks negatively impacts the farm sector (farm yield) as the impact on the non-farm sector is a spillover from the farm sector. In carrying out this analysis we employed the Climate data merged with georeferenced Nigerian General Household Survey panel data.Three waves (2010/2011, 2012/2013, and 2015/16) were used and it consisted of 5,000 randomly selected households across the six zones in the country growing different crops in the regions. The major crops grown across each zones was used to determine the impact of weather shocks on the farm yield. The climate data is the CRU TS v4.05 which is the most recent dataset by the Climate Research Unit of the University of East

Anglia funded principally by the UK's Natural Environment Research Council (NERC) and the US Department of Energy. The monthly precipitation data was used to obtain a common growing time range to cover the major crops grown across the country. In other to identify major crops grown acorss regions and across gender, a descriptive statics analysis was carried out. The first empirical specification of the paper was to see the impact of rainfall shocks on agricultural production. The second empirical specification was to determine the impact of rainfall shocks on labour supply to non-farm sector, and also interacting gender norms with the shocks to determine impact on the labour supply. The results of this paper excessive rainfall shock decreases total output per hectare for 0.5 standard deviation for major crops grown in the regions across Nigeria and that excessive rainfall shocks affect positively labour supply to off-farm employment significantly for the female-headed households, however, in regions where gender norms favour the men as against the women the reverse is the case for the female headed households.

1.1 Background

In Nigeria, rural households depend largely on rainfed agriculture as their primary source of livelihood, leaving them vulnerable to weather and climate shocks (Hirvonen, 2016; Hertel and Rosch, 2010). These shocks such as droughts, floods, cyclones, heat waves, and hailstorms result in poor yields, malnutrition, food shortages, food, water and vector-borne diseases, migration, reduced investment, labour shift and reduced labour productivity, conflict, food insecurity, increased use of child labour,increased area planted and poverty[1]. Studying weather shocks and its negative effects are of particular importance in sub-Saharan Africa and Nigeria specifically as agriculture is on the decline, coupled with rising population growth and the expected to experience the soonest, weather extremes as reported by Harrington et al. (2016). Also, climatic changes that in the past occurred for hundreds of years currently occur only in decades (IPCC, 2014), and these changes are increasing due to increasing human activities. The focus of many climate studies over the years has been on the impact of climate change on health , on education, household income and consumption, on mitigation, coping/adaptation strategies and vulnerability and and on agricultural yield[2].

Only few studies such as that of Grabrucker and Grimm (2020) in Thailand and Rijkers and Söderbom, 2013 in Ethiopia have extended the impact of climatic shocks to non-farm activities. Non-farm activities range from agro-industrial activities which encompass activities beyond farm harvesting to including, marketing, storing and processing of agricultural goods; to include other activities not related to the farm such as construction, manufacturing, and mining, among others (Haggblade et al., 1989). Rijkers and Söderbom (2013) showed that positive agricultural shocks had a positive significant effect on non-farm enterprise but suggested that

[1]Di Falco, Veronesi, and Yesuf, 2011; Doward, 2013; Osuafor and Nnorom, 2014; Ebele and Emodi, 2016; Abdulkadir, Lawal, and Muhammad 2017; Akande, Costa, Mateu, and Henriques, 2017; Serdeczny et al., 2017; Wineman, Mason, Ochieng and Kirimi, 2017; Amare, Jensen, Hallegatte, Fay, and Barbier, 2018; Herrera, Ruben and Dijkstra, 2018; Shiferaw and Cisse, 2018; Urama, Eboh and Onyekuru, 2019; Aragón, Oteiza and Rud, 2021

[2]Asiimwe and Mpuga, 2007; Fisher, et al., 2012; Björkman-Nyqvist 2013; Dolores and Mauricio 2014; Oloukoi, et al. 2014; Zamand and Hyder, 2016; Shah and Steinberg 2017; Adeoti, Coaster, and Akanni, 2016; Hirvonen 2016; Otitoju and Enete, 2016; Amare et al., 2018; Calvin et al., 2020; Ume, Opata, and Onyekuru, 2021; Meierrieks, 2021

an adverse rainfall shock negatively impacts on the non-farm enterprises through its impact on the farm. This is different from the findings of Grabrucker and Grimm (2020) that excessive rainfall shocks improved the performance of the non-farm enterprises that are linked to the agricultural sector but was not significant for deficit rainfall shocks. However, non of these studies incorporated gender and gender norms, the novelty of this paper.

The interdependencies between the rural farm and non-farm sector were studied in the works of Grabrucker and Grimm, (2020), Hussain, Memon and Hanif (2020), Rijkers and Soderbom (2013), Wand, Wang and Pan (2011) and Haggblade et al. (1989). For example, studies of Hussain et al. (2020), and Rijkers and Soderbom (2013) reported a positive spill-over effect of agricultural activities on non-farm enterprises such as a 0.5-0.7% increase in the non-farm sector from a 1% increase in agricultural growth. The work of Haggblade, et al. (1989) found a strong impact of the farm sector on the non-farm sectors through several linkages such as capital flows, labour flows, production, consumption, and investment. Wang et al. (2011) reported a positive impact of non-farm enterprises on agricultural productivity.

Some other research works have analysed the shift in labour supply to non-farm enterprises due to the impact of climatic shocks. Branco and Féres (2020) showed that drought significantly reduced labour supply in agricultural activities and increased labour supply in non-agricultural activities for rural farming households in Brazil. This study adds to these works by extending it to incorporate a gender dimension. The gender dimension is important because women are dominant in the agricultural sector in rural areas. Most of the foods (60-80%) are produced by women mostly at the subsistence level (Apata, 2011; Tersoo, 2013; Osuafor and Nnorom, 2014; Otitoju and Enete 2016) and women contribute about 60 -79% of agricultural labour (FAO and Ecowas 2018). More so, women are more vulnerable to climatic shocks than men (Ume et al., 2021; Ume, 2018; Adeoti et al., 2016; Yila & Resurreccion, 2014; Goh, 2012) due to their low adaptative capacity, limited resources and information, inability to migrate, limited or no participation in climate decisions and heavy reliance on agriculture as compared to the men (Meinzen-Dick, Brown, Feldstein, & Quisumbing, 1997; BNRCC, 2011 in Haider, 2019). The indirect impact of climatic shocks on non-farm enterprises might be more on women than men, but no study has analyzed this to the best of our knowledge. This will be the first study in Nigeria to extend the impact of climatic shocks to the non-farm sector by employing a panel data set of 5,000 households from across the country merged with precipitation data. In Nigeria, the rural non-farm sector makes up a key part of the rural economy most especially as a means of increasing household income, as a coping strategy when faced with several shocks, reduction in outmigration, increase in employment, quality of life, rural economic development, economic growth and also the rural non-farm income constituted 35% - 55% of rural incomes. [3]. Furthermore, studies by and Onwuemele (2014) reported that about 44% to 83% of rural households were engaged in non-farm activities, as well as their farm work. Also, the non-farm sector serves as an outlet for the produce from the farms as production inputs, and the income from the non-farm sector can be spent on the farm sector and vice versa through expenditure linkage. This emphasizes the significance of the non-farm sector to rural households.

[3]Nnadi, Madu, Ossai, and Ihinegbu, 2021; Odoh et al., 2019; Madaki and Adefila 2014; Haggblade et al., 2010; Kuiper, Meijerink, and Eaton 2007; Reardon, Stamouli, and Pingali 2007; Lanjouw and Lanjouw, 2005

2 Literature review

2.1 Theoretical Framework

This section explains some key concepts and the theories underpinning this study. There are linkages between the farm and non-farm sectors that shows their interdependencies, such that if a sector is affected it spills over to the other sector. Amongst such linkages are forward production linkages, backward production linkages, factor linkages, and expenditure linkages. Understanding these linkages are important for this study.

2.1.1 Production Linkages

This is made up of backward and forward linkages (Grabrucker and Grimm 2020; Haggblade, et al., 1989). Forward linkage explains the farm as the owner of the production inputs required by the non-farm enterprises, which are the buyer and receivers of the inputs. Hence, the forward linkage means the selling of agricultural outputs by farms to non-farm enterprises such as food processing enterprises, and other enterprises that uses the outputs as industrial raw materials. For example, maize is useful to the food processing enterprise, animal rearers as source of feed, and as raw material to produce bioethanol. In this study it is expected that excessive and deficit rainfall, and excessive temperature shock will cause a reduction in maize yield, and invariably an increase in the market price to non-farm enterprises. Backward linkages, differ in that it refers to the non-farm enterprises supplying/selling to the farm enterprises production inputs such as fertilizers, pesticides, farm machinery, herbicides, and planting seeds. This means that the farms' demand for inputs influences non-farm enterprises that supply products and services to farms. The implication of these linkages is that the farm sector influences the non-farm sector and vice versa. If the farm is negatively impacted by climatic shocks thereby resulting in reduced output, it, therefore, means that the production output and sales of the non-farm enterprises that depend on the agricultural output for their production will be affected, but on the other hand, if there is a positive shock that encourages or leads to increased agricultural production, this will be accompanied with increased spending by the farm sector on the non-farm enterprises.

2.1.2 Theories Underpinning the Study

Theory of Production Every enterprise that is involved in production has to make decisions on what to produce, how to produce, when to produce, for whom to produce, and the quantity to produce. This is particularly true of agricultural enterprises. To make the right decisions, businesses arm themselves with the production theory to guide them. The production theory explains the principles in which businesses decide how much of each commodity to produce for sale, and how much of raw materials to employ in its production. On the one hand, production theory describes the relationship between prices of commodities and factors of production. On the other hand, it describes the relationship between the quantity of commodities and the factors of production employed in their production. Production is the process whereby inputs are combined to yield outputs in the form of goods and or services which contribute to human utility. The technical relationship between outputs and inputs is referred to as a production function.

Q = f $(x_1, x_2, x_3, ...x_n)$

- Q is the quantity or unit of output.
- X_1 to X_n are inputs such as land, labor, capital, seed, and fertilizer.

Depending on the length of run, production inputs can be fixed or variable. Variable inputs are those inputs that can be adjusted within a production cycle such as labour, fertilizer, etc. Fixed inputs are those that cannot be adjusted within a production cycle such as land. However, in the long run, all inputs are variable.

Agricultural household model The agricultural household model forms the basis of our work. The model integrates within a household utility maximization problem a family-operated firm (LaFave and Thomas, 2016). There are some assumptions underlying the model. The model assumes that markets are complete (Singh, Squire and Strauss, 1986) and as such the agricultural household in all markets act as price takers (exogenous prices) and operates as a profit-maximizing firm. Households allocate their time optimally between leisure and income-generating activities and maximize their utility (Grabrucker and Grimm, 2020). Regarding agricultural production, it is assumed that households produce farm products (Q_a), sold at price (P_a) employing inputs (labour (l_f)) at cost (v) and other production inputs (x) bought at price (P_x). Inputs which cut across from agricultural land, (Z^Q) and farm machinery (Fixed endowments), labour, pesticides and herbicides, fertilisers and seeds which are bought at a price. However, production is subject to exogenous supply shocks such as temperature (Φ) and rainfall (Ω) shocks. Also, the productivity of households is dependent on their individual characteristics, C. In terms of input demand, it varies across the entire production cycle. Farm Machinery are mostly needed for land clearing and preparation, labour is also needed for land clearing and preparation mostly in Africa where the farmers are smallholders and mainly rely on crude implements for cultivation. Labour is also required throughout the planting cycle till harvesting. This is however adjusted when faced with shocks as established in literature such as the study of Branco and Féres (2020) as drought significantly reduced labour supply in agricultural activities and increased labour supply in non-agricultural activities for rural farming households in Brazil. Seeds are for planting and are used based on standard planting distance and land size, if the land is perceived good, they use the standard required maize seeds per planting hole, but if perceived to be bad, they employ more seeds per planting hole for fear of some dying in the soil; fertilizers, herbicides, and pesticides are mainly used after planting. Fertilizer is not very affordable to farmers, so those that use fertilizer apply the quantity they can afford, which most times is short of what is required. Herbicides and pesticides are mainly used during the growing phase of the crop to curb weeds and pests, and this is also influenced by the volume of rain, if heavy rains, they employ more use of herbicides and pesticides and more labourers to achieve the task, vice versa. Irrigation which is mostly needed in the Northern regions of the country is not commonly used due to affordability. Lastly, harvesting is largely done using human labour, however, it is influenced by the expected output from the farm, which can also be influenced by climatic shocks. Furthermore, beyond agricultural production, the farmers also engage in other non-farm enterprises as source of income. The non-farm enterprises produce output (Q), and employ labour (l_n) at cost (v) assuming labour is the only input employed. Our model assumes that household maximizes their expected profits from both farm (f) and non-farm production (n) written as

$$MaxH_{\Pi} = (Q_f P_f - P_x X - vl_f) + (Q_n P_f - vl_n) \tag{1}$$

subject to the agricultural production technology:

$$g_f(Q_f, X, l_f; C, Z^Q, \Phi, \Omega) = 0 \tag{2}$$

From model 2 we obtain the input demand and supply functions (Grabrucker and Grimm 2020; Sadoulet and de Janvry, 1995)

Input demand:

$$X = X(P_x, P_f, V; C, Z^Q, \Phi, \Omega) = 0 \tag{3}$$

Supply function:

$$Q_f = Q_f(P_x, P_f, v; C, Z^Q, \Phi, \Omega) = 0 \tag{4}$$

Labour demand:

$$l_f = l_f(P_x, P_f, v; C, Z^Q, \Phi, \Omega) = 0 \tag{5}$$

The production technology of the non-farm good is subject to:

$$g_n(Q_n, l_n, X; C) = 0 \tag{6}$$

From model 6, factor demand and supply functions are obtained assuming labour as the only input.

Input demand:

$$l_n = l_n(P_n, V, C) = 0 \tag{7}$$

Supply function:

$$Q_n = Q_n(P_n, V, C) = 0 \tag{8}$$

Furthermore, this study assumes that households engage in non-farm production if the returns is greater than the cost. Also, it is assumed that given land, the return to farm production for the first unit of labour employed is higher than that of non-farm production, hence households will always engage in farm production and non-farm production or only farm production.

2.2 Agronomy of Crops

2.2.1 Maize

Maize is the most important cereal crop in sub-Saharan Africa and a staple food crop in Nigeria. According to Kamara et al. (2020) it is the most widely cultivated crop in the country, grown both in the Northern and Southern parts of the country. While, maize production in Africa was about 75 million tons in 2018, Nigeria accounted for about 33 million tons of maize produced in Africa, being the highest producer of Maize in Africa. Several high-yielding varieties over the years have been produced such as those tolerant to diseases, drought, striga infestation and low nitrogen (Kamara et al., 2014).Growing season for maize is between March and October to cover early and late growing season. Rainfall distribution (Kamara et al. 2014). The amount and distribution of rainfall are highly important factors in successful production. A minimal range of 480–880 mm of well distributed rainfall is adequate for maize, depending on the variety. The moisture requirements are small during the early stages of development but increase rapidly up to the flowering stage, before decreasing again as the crop matures. Maize is especially sensitive to moisture stress during flowering when a short spell of stress can reduce the crop yield by up to 30–35%. The ecological zones in Nigeria have been demarcated, based on rainfall and vegetation cover, and reflect divergence in cropping systems and production constraints. For the savannas, three ecologies have been identified for maize production: the southern and northern Guinea savannas and the Sudan savanna. Annual rainfall is about 1000 mm spread over 170 rainy days, between late May and early October in the southern Guinea savanna. Rainfall is about 800–900 mm spread over 150–160 rainy days in the northern Guinea savanna. Annual rainfall is rarely up to 700 mm in the Sudan savanna, spread over about 120 rainy days.

2.2.2 Yam

2.2.3 Sorghum/Guinea Corn Production

Sorghum, one of the most important cereal crops in Africa and in the Northern part of Nigeria, is the most important cereal food (Ajeigbe et al. 2020). In terms of production, Nigeria is the second largest producer with an estimated annual production of 6.7 million tonnes grown on about 5.9 million ha. it is mostly grown in Adamawa and Borno States, and also other states such as Zamafara, Sokoto, Taraba, Niger, Plateau, Nasarawa, Kebbi, Kogi, Kwara, Kano, Katsina, Gombe, Jigawa, Benue, and Bauchi (Ajeigbe et al. 2020). Sorgum is mainly produced for domestic consumption. It serves as food and raw materials for example for the poultry and fish feed industries. It can be used in the production of malt, sorghum meal, beverages, tuwo, Kamu amongst others. Sorghum is produced under variable average rainfall conditions between 300 mm and 1,200mm, for optimum yield. A medium- to late-maturing sorghum cultivar (i.e., maturing within 110 to 145 days) requires approximately 450-800 mm of water during a growing season. The crop is normally planted from end of May in southern Adamawa State to end of June or early July in northern Borno State, when there is adequate moisture in the soil, depending on the location and variety to be used. The harvesting time of sorghum varies with location, variety, and planting date. The early-maturing varieties are ready for harvest in October, while the medium-maturing varieties are ready in November. In Adamawa State, early and medium-maturing varieties are harvested by the end of November while late-maturing varieties are harvested in early December.

2.2.4 Pearl Millet/Maiwa

Pearl millet (Pennisetum glaucum L. R. Br.), known as maiwa in Hausa language and commonly called millet is commonly grown in the Northern part of Nigeria as an important cereal crop. it is mainly grown in Adamawa and Borno States as over 30% and 60% respectively of croplands are devoted to millet production. The crop thrives well in areas with short rainfalls and has a great adaptation to drought and high temperatures. It serves as a source of feed, food and folder, fuel. Stephen et al. (2015) reported that West Africa accounted for about 45% of the world's production. Pearl millet can be grown as a sole crop, or intercropped with sorghum, maize (Zea mays L.) or groundnut (Arachis hypogaea L.). Planting is carried out between June/july. Although the crop is grown where rainfall ranges from 200-1500 mm, it mostly occurs in areas receiving 250-700 mm. The lowest rainfall areas rely mainly on early-maturing cultivars. Despite its drought resistance, pearl millet requires evenly distributed rainfall during the growing season. Too much rain at flowering causes crop failure. Like most plants, pearl millet does best in light, well-drained loamy soils. The pearl millet growing season in West Africa ranges from 60 days in the north to 150 days in the south (Stephen et al. 2015). planting is done as soon as rains are established so the soil is moist enough to enable seed germinate. Early-planted millet in the Sudan Savannah zone is harvested in August while late-planted millet is harvested in September. In the Sahel zone of north-eastern Nigeria, millet is harvested in September(Stephen et al. 2015). Millet matures between 60-70 days and can reach 90 days depending on the variety.

2.2.5 Cocoa

Cocoa production in Nigeria is one of the major agricultural products which contribute significantly to employment generation and foreign exchange for the country. The main producing states are Ondo, Ekiti, Oyo, Osun, Ogun, Delta, Edo, Cross Rivers and Akwa Ibom. Since the introduction of cocoa to Nigeria, it has grown to become a major export crop (Oyedele, 2007). Wilcox and Abbot (2004) identified Nigeria as the third largest cocoa producing country in Africa producing about 12% of the total world production behind Ivory Coast and Ghana that produces 35% and 13% respectively. Presently, Nigeria's capacity of cocoa production has grown to about 385,000 metric tons per annum, a significant increment of 215,000 metric tons from year 2000 production level. This put Nigeria fourth among the highest cocoa producing nations in the world behind Ivory Coast, Indonesia and Ghana (Erelu, 2008). Cocoa needs a high amount of rainfall: 1,250 – 3000 mm per year. It grows best in areas where the dry season last for not more than three months. Cocoa grows best in warm temperatures: between a high of 30-32oC and a low of 18-21oC. The country has two cocoa harvest seasons, namely smaller mid-crop (April to June), and the main crop (October to December). The mid-crop accounts for about 30 percent of Nigeria's cocoa output while the main crop accounts for the remaining percentage.

2.2.6 Cassava production

Hauser et al (2014) reported Rainfall – preferably annual rainfall of 1000 mm or more; a minimum of 6 months of rain a year with at least 50 mm of rainfall per month. Cassava can be intercropped with other crops such as yam, maize and vegetables. Time of planting is done as soon as the rains become steady. This varies from March to November in the rain forest, April to August in the derived savanna, May to July in the Southern Guinea savanna and July to August in the Northern Guinea savanna. Plants can be harvested at 9 – 18 months after planting to give root yields ranging from 15 – 50 tons or more per hectare depending on the variety, environment (soil fertility status, acidity level, moisture level and sunshine hours) and agronomic practices adopted.(Nkang et al 2009)

2.2.7 Yam

Yams are starchy staples in the form of large tubers produced by annual and perennial vines grown in Africa, the Americas, the Caribbean, South Pacific and Asia. There are hundreds of wild and domesticated Dioscorea species. White Guinea yam, D. rotundata, is the most important species especially in the dominant yam production zone in West and Central Africa. It is indigenous to West Africa, as is the Yellow yam, D. cayenensis. Water yam, D. alata, the second most cultivated species, originated from Asia and is the most widely distributed species in the world. Yams are primary agricultural commodities and major staple crops in Africa. In West Africa they are major sources of income and have high cultural value. Worldwide yam production in 2007 amounted to 52 million tons, of which Africa produced 96%. Most of the world's production comes from West Africa representing 94%, with Nigeria alone producing 71%, equalling more than 37 million tons. African countries imported more than 2,000 tons in 2002, and exported 15,500, of which Nigeria exported 12%. In West and Central Africa tubers are planted between February and April, depending on whether in humid forest or on the savanna, and are harvested 180 to 270 days later.

2.2.8 Beans

The variety of beans that reach maturity in 40 days in Nigeria is what Nigerian beans farmers call '40 days beans'. This variety of beans enable beans farmers to harvest their beans in 40 days. It also allows them to quickly earn returns or profit from their farms.

3 Methodology

3.1 Data Description and Sources

3.2 Household Data

The analysis will rely on climate data merged with georeferenced Nigerian General Household Survey panel data collected by the National Bureau of Statistics (NBS) supported by the World Banks' Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) project. Three waves (2010/2011, 2012/2013, and 2015/16) are employed in this study. The LSMS-ISA data consists of 5,000 randomly selected households across the six zones in the country such as North-Central, North-East, North-West, South-East, South-South and South-West. The households were visited twice in a year for each wave – post-planting and post-harvest periods. The data was weighted to reflect the distribution of the full population in the country. The survey was structured into three sections: agricultural, household and community sections. These sections cover crops cultivated, farm and non-farm labour, non-farm enterprises, credit and savings, input acquisition and costs, land prices, individual characteristics, education, food and non-food expenses and food consumption, food security, plot information, time use, crops harvested, non-farm enterprises, labour information, food prices, household income, fishing, and animal holdings and costs. The first wave of the GHS panel was carried out in August – October 2010 (post-planting) and February – April 2011 (post-harvest). The second wave of the GHS panel was carried out in two visits in September – November 2012 (Post-planting) and February – April 2013 (post-harvest). The third wave was carried out in September – November 2015 (Post-planting) and February – April 2016 (Post-harvest). The Household Questionnaire provides information on demographics; education; health (including anthropometric measurement for children); labour; food and non-food expenditure; household nonfarm income-generating activities; food security and shocks; safety nets; housing conditions; assets; information and communication technology; and other sources of household income. Household location is geo-referenced to be able to later link the GHS-Panel data to other available geographic data sets (forthcoming). The Agriculture Questionnaire solicits information on land ownership and use; farm labour; inputs use; GPS land area measurement and coordinates of household plots; agricultural capital; irrigation; crop harvest and utilization; animal holdings and costs; and household fishing activities. Some information is collected at the crop level to allow for detailed analysis of individual crops. The Community Questionnaire solicits information on access to infrastructure; community organizations; resource management; changes in the community; key events; community needs, actions, and achievements; and local retail price information.

3.3 Data on Crops

The crops employed in this study were to determine the impact of weather shocks on agricultural production were Cassava, Yam, Cocoa, Beans, Sorghum, Millet and Maize. The crop yields were measured in Kg/hectare.

3.4 Data on Gender Norms

The data on gender norms were gotten from the Afrobarometer. The Afrobarometer is a pan-African, independent, non-partisan research network. It covers areas on economic, political, and social matters in Africa across more than 30 countries. Questions on gender norms covered were Women should have the same rights as men to own and inherit land? When jobs are scarce, men should have more right to a job than women? In general, it is better for a family if a woman has the main responsibility for taking care of the home and children rather than a man? These questions were asked on a 5 point rating scale such as strongly disagree, disagree, neither agree nor disagree, agree and strongly agree. Also questions asked were promoting opportunities and equality for women? Equal opportunities and treatment for women? on a 4 point rating scale of very badly, fairly badly, fairly well and very well. Other questions asked were Women and men have equal opportunities to earn an income? Women and men have equal opportunities to get a job that pays a wage or salary? and women and men have equal opportunities to own and inherit land on a 4 point rating scale of strongly disagree, disagree, neither agree nor disagree, and agree. The Principal component analysis was used to construct the gender index. We normalize the predicted score of the PCA to range between 0 and 1, with 0 denoting the highest Gender equality and 1 denoting the highest gender inequality (favour of men against women).

3.5 Data on Rainfall Shocks

The data on temperature and precipitation were obtained from the Climatic Research Unit Time Series version 4.03 (CRU TS v. 4.05) and georeferenced to the nationally representative panel data. The CRU TS v4.05 is the most recent data set by the Climate Research Unit of the University of East Anglia funded principally by the UK's Natural Environment Research Council (NERC) and the US Department of Energy. Also supported by the UK National Centre for Atmospheric Science (NCAS). It is also the most widely used climate data set on a 0.5° longitude by 0.5° latitude grid over all land domains of the world except Antarctica. The data set was released on 16 March 2021 and provides gridded time series data for several monthly weather measures for all land areas in the world excluding Antarctica for the period January 1901 to December 2020 (Harris, Osborn and Lister 2020 describes the data set). It was collected for seven variables, the minimum, maximum and mean temperatures, precipitation, wet days, vapour pressure and cloud cover. The data on rainfall were at the Local Government level. Nigeria has 775 Local Government Areas. Rainfall shocks typically refer to a deviation in the amount of rainfall in a certain period from the medium or long-term average. For instance, Ito and Kurosaki (2009) define a rainfall shock as the deviation from the level of rainfall in a particular year from the fifteen-year average. Rainfall shocks might also be defined based on the deviation from the optimal quantity of rainfall for a given crop (Grabrucker and Grimm, 2020). Some studies consider the rainfall in the rainy season only (Amare and Waibel 2014), whereas others take the whole year into account (Iyer and Topalova 2014). The paper adopts the method of Amare, et al. (2018) in measuring rainfall shocks. Firstly, this study will measure rainfall shock as a deviation of current year rainfall from the historical averages (for 50 years) for the same locality. The rainfall shock variable is measured as deviation from historical average as follows:

$$Rainfallshock(RS)_{ht} = \widehat{R_j} - R_{ht}/R^S D_h \tag{9}$$

- R_{it} means current year rainfall at the location of household h for year t.
- $\widehat{R_j}$ is the historical average rainfall (for 50years) at the location of household h.
- $R^S D_i$ is the standard deviation of rainfall at the location of household (calculated over the 50-year period).

The rainfall shock was measured as a dummy variable designed to capture extreme events as used by Amare et al. (2018):

$$[Negative/deficit/rainfallshock(NRS)_{ht} = 1\ if(\widehat{R_j} - R_{ht}/R^S D_i)] > +0.5 \tag{10}$$

$$[Positive/excess/rainfallshock(PRS)_{it} = 1\ if(\widehat{R_j} - R_{it}/R^S D_i)] < -0.5 \tag{11}$$

3.6 Data Analysis

3.7 Empirical Specification

Firstly, the study shows that rainfall shocks have an impact on agricultural production (output). This is a basic underlying assumption for this analysis. The study expects that deficit and excessive rainfall will reduce output (kg) per hectare. We carried out the estimations using log yields as dependent variable instead of continuous yields.

$$lnY_{hlt} = \beta_0 + \beta_1 R_{lt} + \varsigma_h + \theta_t + \epsilon_{hlt} \tag{12}$$

- Y_{hlt} means output in kg/ha for each crop and for each household h for year t or the total value (naira) per hectare for each crop.
- R_{lt} represents a negative or positive rainfall shock at the location of household for year t.
- ς_h is vector of household characteristics.
- θ_t is a vector of year fixed effects respectively.
- ϵ_{hlt} is cluster robust error and is assumed to be uncorrelated to all the explanatory variables. The standard errors were clustered at the local government.

The household fixed effects will control for all time-invariant unobserved household characteristics that may impact the outcome.

Impact of weather shocks on labour supply to non-farm businesses Next we determined the effect of rainfall shocks on labour supply to non-farm businesses incorporating gender norms. It is expected that the positive and deficit rainfall shocks will cause an increase in the number of hours employed in non-farm own business. In line with the finding of Branco and Féres (2020) that drought significantly increased labour supply in non-agricultural activities for rural farming households, and Grabrucker and Grimm (2020) that reported that excessive rainfall leads to a higher probability of individuals having their own business, but a deficit rainfall was not significant. The model is a linear regression model that determines if rainfall shocks increase the number of hours an individual engages in non-farm activities and the impact of weather shocks on labour supply when interacted with gender norms.

$$N_{hlt} = \beta_0 + \beta_1 R_{lt} + \beta_2 (R * G)_{lt} + \varsigma_h + \theta_t + \epsilon_{hlt} \tag{13}$$

- N_{hlt} is number of hours per week employed in non-farm employment.
- R_{lt} represents a negative or positive rainfall shock at the location of household for year t.
- G_{lt} represents gender norms, dummy variable that takes value 1 for patriarchal states (States in favour of men), and 0 for non-patriarchal states.
- h denotes household.
- l denotes LGAs (Local Government Areas).

- ς_h is vector of household characteristics.
- θ_t is a vector of year fixed effects respectively.
- ϵ_{hlt} is cluster robust error and is assumed to be uncorrelated to all the explanatory variables.

4 Results and Discussion

4.1 Descriptive statistics

4.1.1 Crops mainly grown across gender and zones

This result shows the percentage of the main crops cultivated across the six zones in Nigeria for both men and women. The common crops in terms of value (Naira) grown commonly by both men and women are Cassava, yam, sorghum, and maize. Other major crops are beans, groundnut, and millet. Across all crops, the result shows that women are more into the cultivation of these major crops as compared to the men

Table 1: The two main Crops mainly grown by women across zones

Women											
North Central		North East		North West		South East		South South		South West	
Crop	%	Crop	%	Crop	%	Crop	%	Crop	%	Crop	%
Yam	24.07	groundnut	33.33	Sorghum	83.33	yam	31.5	cassava	64.74	Cocoa	32
Cassava	22.22	Beans	15.94	Maize	16.67	Cassava	13.5	yam	18.95	Cassava	32

Table 2: The two main Crops mainly grown by Men across zones

Men											
North Central		North East		North West		South East		South South		South West	
Crop	%	Crop	%	Crop	%	Crop	%	Crop	%	Crop	%
Yam	33.42	Millet	22.95	Millet	30.99	Yam	34.47	Cassava	43.18	Cocoa	28.32
Maize	15.73	Maize	19.67	Sorghum	26.59	yam	23.49	Yam	31.82	Yam	21.97

4.2 Impact of rainfall shocks on commonly grown crops across the six zones in Nigeria

The result in Table 3 show that excessive rainfall shocks negatively affects the yield of the major crops grown across the regions in Nigeria. Major crops are crops that yield the highest value in Naira to the farmers. Excessive rainfall shock significantly reduce the yield of maize, Sorghum, millet and beans. However, the deficit rainfall shock had no significant impact on these crops. Hence the main driver of reduced crop yield across regions is the excessive rainfall shocks. These result confirms that rainfall shocks have a negative effect on agricultural output. Furthermore, we estimated as shown in Table 4 the impact of rainfall shocks on quantities of all the crops and their total value in Naira, the result further confirms the impact of rainfall shocks on major crops grown across regions. The result explains that both deficit rainfall shocks and the excess rainfall shocks significantly reduced yield of all crops in Kg and in Naira.

Table 3: Impact of rainfall shocks on crop yields

Variable	Output (kg) per Hectare					
Rainfall shocks	(Linear model) fixed effects					
	Maize	Sorghum	Millet	Cassava	Beans	Yam
Deficit rainfall shocks	-0.041	-0.092	0.231	-0.404**	0.209	-0.189
	(0.139)	(0.193)	(0.164)	(0.203)	(0.194)	(0.159)
Positive rainfall shocks	-0.294*	-0.308**	-0.258*	0.090	-0.454**	0.067
	(0.158)	(0.137)	(0.137)	(0.354)	(0.176)	(0.269)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household level FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2433	2680	1626	1311	1842	1595
N_g	1119	1117	687	782	794	654

Note:Robust standard errors are clustered at the local government level in parentheses. *** significant at 1% level, ** significant at 5% level.

Table 4: Impact of rainfall shocks on all crop yields and Value of yield

	Quantity (Kg/ha)	Value (Naira/ha)
negrain_s	-0.333***	-0.282***
	(0.086)	(0.085)
posrain_s	-0.250***	-0.172*
	(0.088)	(0.094)
N	10049	10425
df_a_initial	9	9
Cropcode FE	Yes	Yes
Time FE	Yes	Yes

Note:Robust standard errors are clustered at the local government level in parentheses. *** significant at 1% level, ** significant at 5% level.

4.3 Impact of rainfall shocks and gender norms on off-farm labour supply

The result in Table 5 shows that excess rainfall shocks significantly increased participation in off-farm activities by an increase in off-farm hours. However the major drivers of such significant impact are the female-headed households as rainfall shocks on off-farm labour supply was not significant for the male-headed households. When interacted with gender norms, the result shows that households significantly remain in agriculture due to low labour supply to off-farm activities, and the main drivers were the female-headed households, this could imply that for regions that favour the men as against the women the women remain trapped in agriculture when faced with excessive rainfall shocks.

Table 5: Impact of rainfall shocks and gender norms on off-farm labour supply

Variable	(Linear model) fixed effects		
	Household	Male	Female
1.l1_posrain_s	6.510***	0.536	5.973***
	(1.886)	(1.185)	(1.506)
1.l1_posrain_s#1.patri	-4.316*	0.618	-4.934***
	(2.376)	(1.654)	(1.871)
Year FE	Yes	Yes	Yes
HH FE	Yes	Yes	Yes
N	7899	7899	7899
N_g	2840	2840	2840

Note:Robust standard errors are clustered at the local government level in parentheses. *** significant at 1% level, ** significant at 5% level.

5 Conclusion

The result on the impact of rainfall shocks on total farm output which was measured using total output (kg/ha) from the farm shows that excessive rainfall shock decreases total output per hectare for 0.5 standard deviation for major crops grown in the regions across Nigeria. On the aspect of rainfall shock on the supply of off-farm labour, excessive rainfall shocks significantly increased the supply of labour to off-farm employment and was mainly driven by the female-headed households as excessive rainfall shock had no significant effect on the off-farm labour employment by male-headed households. On interacting the excessive rainfall shock with gender index, the participation of the households in non-farm employment decreased and this was driven by female headed households in regions that had norms that were not in favour of women. It was positive for the male-headed households but not significant. The study therefore concludes that excessive rainfall shocks affect positively labour supply to non-farm employment significantly for the female-headed households, however, in regions where gender norms favour the men as against the women the reverse is the case for the female headed households.

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