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2022

Document Version:
Other version

Link to publication

Citation for published version (APA):
Sepahvand, M. H. (2022). *Agricultural Productivity in Burkina Faso: The Role of Gender and Risk Attitudes*. (pp. 1-41). (Working Papers; No. 2022:19).

Total number of authors:
1

Working Paper 2022:19

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October 2022

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Abstract

This study analyzes how risk attitudes influence the agricultural productivity of men and women in a sub-Saharan African country, Burkina Faso. By using a large representative panel survey of farmers, the results show that as female farmers increase risk taking, the productivity of female-owned plots goes down. The study controls for various socio-economic factors and explores how the diversity of the regions of the country affects gender differences. Findings show that agricultural policy interventions in Burkina Faso need to be gender sensitized when addressing issues related to credit constraints, improved inputs, and policies that support increase in productivity.

Keywords: risk attitudes, gender differences, agriculture, productivity, sub-Saharan Africa, Burkina Faso

JEL classification: D13, D81, J16, O13, Q12, Q18

1. Introduction

Growth in agricultural productivity has been identified as a key driver of poverty reduction and increased food security in sub-Saharan Africa (e.g., Irz et al., 2001; Ligon and Sadoulet, 2008). The United Nations' Agenda 2030 formalizes these targets as the Sustainable Development Goal (SDG) 1 (No Poverty) and SDG 2 (Zero Hunger). FAO (2011), estimate that if female farmers have the same access to productive resources as men, they can increase yields by 20 to 30 per cent. This can potentially increase the total agricultural output in the developing countries by 2.5 to 4

☆ I am grateful to the National Institute of Statistics and Demography (INSD, Institut National de la Statistique et de la Démographie) in Burkina Faso for collecting the data used in this study and Statistics Sweden and the World Bank for technical assistance. Financial support by the Swedish Research Council is gratefully acknowledged. All remaining errors are my own.

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per cent and lift 100 to 150 million people out of hunger. However, recent literature argues that lower female productivity, or the inability of the female farmers to respond to economic incentives, is due to their inability to take higher risk, for instance, the gender gap disappears in the higher-payoff treatments when women express a higher willingness to take risk (e.g., Averett et al., 2018).[1]

The main objective of this study is to improve our understanding of the interaction of risk taking and gender on agricultural productivity. By studying this effect, I will be able to answer if lower measured productivity of female farmers is due to their inability to take higher risk. This will provide important inputs for policy interventions that deal with the alleviation of gender difference in agricultural productivity.

This study provides new estimates of gender differences in agricultural productivity for different levels of risk taking using the nationally representative, multipurpose Household Budget Survey (HBS) data with a panel structure, collected in 2014 and 2015 from farm households at the plot level in the thirteen regions of Burkina Faso. The analytical sample consists of all adult female and male farmers who respond to a separate module that surveys the agricultural households in the HBS. They provide additional information on crop and plot levels, in addition to their risk attitudes and other socio-economic characteristics. The findings indicate lower productivity for female-owned plots as the female farmers' risk taking increases. The results show that the female farmers do not increase their plot yield by taking higher risk. These results have clear policy implications as policy interventions to reduce the credit constraints for female farmers in sub-Saharan African countries needs to be encouraged. The findings are robust to alternative specifications. However, findings vary depending on the type of crops cultivated, the share of female farmers in the region, the soil quality, type of seed used, as well as by the poorest and richest consumption quantiles of farm households. The plot-level productivity is lowest among crops that require large quantities of inputs of fertilizer and labor, possibly owing to the lack of credit access. Findings also indicate that agro-ecological zones matter, as the size of gender differences for high risk taking female farmers is lower in the driest regions compared to the rest of the country. Additional robustness checks for the endogeneity of the risk measure reinforce the pattern between gender differences and farmers risk attitudes (see Appendix A, Table A2).

[1] However, recent empirical literature has shown that the existence and magnitude of gender differences in risk taking may change due to risk domains (e.g., Weber et al., 2002; Dohmen et al., 2011) and elicitation methods (e.g., Charness et al., 2013).

This study makes several contributions. First, it adds to the literature by explicitly investigating risk taking by female famers and its impact on the agricultural productivity using a large, nationally representative sample of farmers. To best of my knowledge, this is the first study that estimates a baseline for gender differences in agricultural productivity with different levels of risk taking (see Appendix B for a literature overview). It thereby addresses the following question: is the lower productivity among female farmers due to their inability to take higher risk? This study adopts the same form of self-reported risk question used in the German Socio-Economic Panel (SOEP). This risk question have been used in numerous studies.[2] Previous research has shown that this self-reported risk measure has high validity[3] and sufficient reliability[4]. The importance of reliability and reproducibility of scientific findings has recently been highlighted (e.g., Dreber et al., 2015; Camerer et al., 2016). Second, there is a lack of a high degree of consensus in the agricultural economics literature regarding the level of farmer's risk taking (e.g., Couture et al., 2009). Therefore, a valid and reliable risk measure is an important input for designing agricultural price and income support instruments. Furthermore, I conduct a detailed examination in order to investigate if the results are robust to alternative specifications such as the type of crop cultivated, agro-ecological zone, the share of female farmers in the region, the soil quality, type of seed used, and by consumption quantiles (top and bottom 20 per cent of the farm households). Understanding how these factors influence differences in productivity is fundamental in identifying possible policy recommendations to reduce gender differences in agricultural productivity. These policies are of special significance in progressing towards supporting SDGs to achieve sustainable development with reduced poverty, greater food security and higher agricultural productivity, better livelihoods, and gender equality.

The results of this study is also relevant for dealing with the impact of the current Russia-Ukraine conflict on Africa: over the past decade, the regions demand for cereal crops has been through imports rather than local production, where both Russia and Ukraine are among the main exporters of some of these crops to Africa. The African Union's Agenda 2063 has a unified view

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[2] Such as in China (Ding et al., 2010; Jin et al., 2017), Germany (Dohmen et al., 2012), Netherlands (Wölbert and Riedl, 2013), Thailand and Vietnam (Liebenehm et al., 2015), Sweden (Beauchamp et al., 2017) and Burkina Faso (Sepahvand and Shahbazian, 2020a, 2021).

[3] The self-reported risk question used in this study has been proven to capture individuals risk preferences by comparing it to incentivized lottery experiments, in developed countries (e.g., Dohmen et al., 2011; Lönnqvist et al., 2015), emerging countries (e.g., Hardeweg et al., 2013), developing countries and comparatively for 30 countries (Vieider et al., 2015).

[4] The reliability of the self-reported risk question in this study has been analyzed by Sepahvand and Shahbazian (2020b). They show that the reliability is satisfactory and to a large extent comparable to other studies using the same self-reported risk question.

on transforming Africa's food system, mainly on resilience in the face of the growing vulnerability and shocks caused from conflicts and crisis such as the current one between Russia and Ukraine. Rapid expansion in the continent's agricultural productivity and incorporating specific food crops into countries agriculture value chain has been identified as key in preventing future disruptions in the supply chain for cereal crops. Thus, understanding what factors that influence differences in productivity is fundamental in identifying possible policy recommendations to reduce reliance on cereal imports from outside of Africa, and promote intra-African trade and sustainable agribusiness sectors.

The remainder of this paper is organized as follows: The ensuing section, describes the agricultural norms and gender differences in Burkina Faso. In Section 3, I present the method and empirical strategy for measuring the interaction of risk and gender in agricultural productivity. Section 4 outlines the data material used in this study. In Section 5, the impact of risk attitudes and gender on agricultural productivity is comprehensively analyzed. Finally, in Section 6, I discuss the results and present my conclusions with suggestions and recommendations for future research and policy in sub-Saharan African countries.

2. The agricultural norms and gender differences in Burkina Faso

The agricultural norms in Burkina Faso are usually that a household has access to more than two plots, which are managed or owned by men and women in the same household, farming the same crops (see Appendix C for an overview of the agricultural sector). Within this substantial household control, the individual farmer in sub-Saharan Africa, including Burkina Faso, has control over which crops are planted on the plot owned by the farmer, in terms of the timing of sowing, weeding and harvesting, the quantity of inputs used on the plot, and the rights to the output from that plot (e.g., Guyer 1986; Berry 1993; Saul 1993). This control by the individual farmer implies that female and male farmers within the same household plant the same crop in the same year on different plots. Udry (1996) is one of the most influential papers on gender differences in agricultural productivity. He examines men and women living in the same household and farm the same crop at the same year in western Burkina Faso (villages between Dori and Bobo-Dioulasso). He finds inefficiency in the allocation of inputs across plots controlled by female and male farmers from the same household. Female farmers had less access to inputs. Despite this inefficiency, analyzing the technical efficiency of farmers in villages from the surrounding areas of Bobo-

Dioulasso in Burkina Faso, Sepahvand and Shahbazian (2008) show that, on average, farmers use their inputs in an efficient way. However, their sample size was small and not nationally representative.

In an attempt to replicate Udry's study, Akresh (2005), through nationally representative survey data, uses a subset of villages that are geographically close to the provinces studied by Udry (1996). He finds gender differences in agricultural productivity for his sample villages, but does not find evidence for gender difference in agricultural productivity in other parts of Burkina Faso. The results of Akresh (2005) indicate that gender differences is not an exogenous outcome, but rather an endogenous decision that may be caused by the household's behavioral decisions. Akresh (2005) proposes that understanding this decision-making process merits additional investigation. This paper aims to fill this gap, using individual's risk attitudes as the main mechanism of decision-making in order to understand gender differences in agricultural productivity.

3. Method and empirical strategy

To measure the agricultural productivity, Y_{ij}, of a plot manager i in household j, the following conventional method is used (Quisumbing 1996; Udry 1996):

$$Y_{ij} = f(\mathrm{I}_i,\ \mathrm{X}_i,\ \mathrm{H}_j), \qquad (1)$$

where I_i is a vector of agricultural inputs used by the plot manager i (e.g., fertilizer and labor), X_i is a vector of the plot manager's characteristics, including gender and H_j is a vector of farm household characteristics, such as access to markets in terms of distance to nearest functional road and market. The female and male farmers' data is pooled to estimate the productivity outcome, the plot yield, enabling the female-male productivity differences to be estimated. This method focuses on the technical efficiency within the household. It is assumed that if the household allocates the factors of production efficiently then, within a given household that plots the same crop, it should have similar yields irrespective of whether the plot is controlled by a man or a woman. Thus, this production function approach is in fact a test for Pareto efficiency in the allocation of productive resources within the household (Udry 1996).

Following previous research, I test whether the gender of the individual who owns and manages the plot influences the plot yields[5]:

$$\ln Y_{pcij} = Z_{pcij}^{\mathrm{T}}\beta + \gamma G_{pcij} + \varepsilon_{pcij}, \tag{2}$$

where Y_{pcij} is the yield on plot *p* planted with crop *c* by the member *i* of household *j*, Z_{pcij}^{T} is a vector of individual famer's socio-economic characteristics, agricultural inputs, family structure and health, cropping strategies, access to labor, agro-ecological zones and crop choices, and G_{pcij} is the gender of the individual who owns and manages the plot[6], and ε_{pcij} is the error term.

To examine how risk attitudes influence gender differences in agricultural productivity, an interaction term is included to Equation (2) above:

$$\ln Y_{pcij} = Z_{pcij}^{\mathrm{T}}\beta + \gamma_1 G_{pcij} + \gamma_2 Risk_{pcij} + \gamma_3 (G_{pcij} * Risk_{pcij}) + \psi_{pcij}, \tag{3}$$

where Y_{pcij}, Z_{pcij}^{T} and G_{pcij} are as previously defined, $Risk_{pcij}$ is the risk attitudes of the individual who owns and manage the plot, $G_{pcij} * Risk_{pcij}$ is an indicator for different risk levels of individual *i* and their gender. ψ_{pcij} is a random, idiosyncratic error term.

Following previous literature (e.g., Quisumbing 1996; Udry 1996; Owens et al., 2003; Akresh 2005; Peterman et al., 2011), the productivity outcome is a measure of plot yield per crop (kg/ha) as for the majority of the plots included in the analytical sample, intercropping is not practiced.[7] If intercropping would be practiced, area estimates for each crop are difficult to calculate. Thus, using actual plot yields per crop would then be misleading because individual crop yields would be mechanically low. The value of crop production would then be a more appropriate measure (for a discussion, see Peterman et al., 2014). The price data linked to the HBS allows for control of general, seasonal-specific price effects by using average prices at the village or province level. This makes it possible to include the value of crop production as the productivity outcome instead of plot yield. However, it would not be possible to control for gender or other related price

[5] Typically, empirical studies estimating gender differences in agricultural productivity use a production function, estimated by taking logarithms, as in Equation (2).
[6] In this study I do not explicitly model a true production function, which has intensive data requirements focusing on modelling of all production factors, and rather are concerned with the coefficient on gender while controlling for access to all other available inputs.
[7] Intercropping is a multiple cropping practice involving growing two or more crops in proximity.

discriminations due to market access or asymmetrical information. Therefore, the plot yield is considered a better productivity outcome.

4. Data

In this section, an overview of the data used in the study is presented with a description of the control variables used in analysis. The section further presents the descriptive statistics for the differences in gender, risk and productivity.

4.1 Data description

The analyses in this study are based on the multipurpose Household Budget Survey (HBS). The HBS is a face-to-face, nationally representative panel survey covering 900 randomly selected enumeration areas (EA)[8] with twelve households per EA; this includes 10,800 households spread across the thirteen regions of Burkina Faso in both urban and rural areas (INSD, 2013).

This study focuses on different questions in a separate, extensive agricultural module of the HBS collected between December 2014 and January 2015 and administrated at the plot level. It contains questions regarding ownership and directly asks individual farmers to provide responses about their agricultural crop and input choices, land areas and soil characteristics, labor and non-labor input use, crop cultivation and production at the plot level. The HBS data allow for estimates of the agricultural production at the plot level, as it is possible to identify the specific, individual household member who owns and manages the plot. It is also possible to obtain the information about whether or not the plot is managed individually or collectivity. Therefore, the gender difference analysis includes information on the female farmers that own, use, and manage the plot, and then compares them to the omitted comparison group of male plot owners. The HBS allows for the identification of those farmers that did not own, manage, or use their plot(s); this includes, for instance, using a plot for free without any charge and permission, leasing a plot, or other forms such as sharecropping. These observations are not included in the analysis.[9] The analytical sample contains 14,590 observations on the plot level. The men own 10,840 of these plots and women

[8] The enumeration area is a statistical defined geographical unit for sampling purpose.
[9] I experimented with including these groups and controlling for same covariates as in the main model, however, doing so does not change the magnitude or relationship of the main results. So, these observations were excluded but results are available upon request.

own 3,750. Mixed ownership of the plots is not included in the analytical sample. This is because mixed ownership may reflect unobserved household-level variables that may drive why there is mixed ownership in the first place. For instance, households with intra-household conflict or bargaining difficulties may be more prone to report mixed ownership, which are mechanisms demanding more evidence based surveys to capture.[10] Since the agricultural module is within the panel structure of the HBS, it allows me to link the individual-disaggregated information on demographics, education, health, wage employment, amount of hours worked, non-farm enterprises, income from non-farm income sources, as well as data on housing, food consumption, food and non-food expenditures, as well as other topics.

4.2 Description of variables

The vector of control variables in my analysis, Z_{pcij}^{T} includes information on nine groups of indicators: 1) socio-economic indicators; 2) agricultural inputs; 3) family structure; 4) health indicators; 5) access to markets; 6) cropping strategies; 7) labor (family & hired); 8.) agro-ecological zone indictors; and 9) practicing monocropping. Socio-economic indicators include age and education indicators for the plot owner, the household size, and the (food and non-food) consumption for the previous four quarters where the plot owner lives, and whether or not the farmer (i.e., the plot owner) has a secondary employment off of the farm and access to a bank account. Agricultural inputs include measures of plot size, quantity of fertilizer (organic and chemical) and pesticides, type of seeds (traditional or improved), and soil quality (type of soil that the plot constitutes). Family structure represents the farmer's religious beliefs and marital status. Health indictors includes if the farmer has been sick in the past 15 days and whether or not the farmer smokes.

Access to market categories presents time variations in farmers distance to market and nearest functional road. Cropping strategies includes a categorical measure regarding if the farmers cultivate a cash crops or not. Labor includes number of days used by family and hired female, male, and child labor[11], and the amount of hours that the farmer has worked on the plot in the past seven days. Agro-ecological zone indictors are dummy variables of the Sahelian zone in the north,

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[10] Including mixed ownership and controlling for same covariates as in the main model, does not change the magnitude or relationship of the main results. So, these observations were excluded. Results are available upon request.

[11] Labor is also available in terms of amount of family and hired labor used (number of people). Including this type of labor, or a combination of amount and days, does not change the magnitude or relationship of the main results.

the Sudanian zone in the southwest, and the Sudano-sahelian zone in the rest of the country. The monocropping variables indicate the cultivation of a single crop. Controls are also included for type of crops cultivated on a plot (millet, sorghum, paddy rice, maize, cowpeas, peanut, sesame and cotton) and in which of the thirteen regions of Burkina Faso that the plot is located. Table A1 in the Appendix presents the descriptive statistics for all of the control variables by gender.

The analytical sample also includes a risk question that captures the farmer's willingness to take risks in general. The self-reported risk attitude question was collected in the third (July-September) and fourth (October-December) rounds of the HBS 2014. There are many different ways to elicit risk preferences (for an overview, see Charness et al., 2013). This study uses the same form of self-reported risk question as in the German Socio-Economic Panel. This type of risk question has been employed in numerous studies. Previous research shows that this self-reported risk question has a high validity and sufficient reliability. Self-reported risk questions are a simple and cost-effective way to elicit risk preferences by using large-scale surveys. These risk measurements can be easily reproduced by other researchers both over time and across countries in order to deepen our understanding of gender differences in agricultural productivity and an individual's risk preferences. The risk question that we asked the farmers of this study is as follows: "How do you see yourself: Are you a person who is fully prepared to take risks or do you try to avoid taking risks? On a scale from 1 to 10, where 1 = not at all willing to take risk and 10 = very willing to take risk. In general?" Previous research has indicated that willingness to take risk is correlated across domains, in which taking risk in general could be a proxy for other risk domains (e.g., Dohmen et al., 2011), which is also shown for Burkina Faso (Sepahvand 2020b).

4.3 Descriptive differences in gender, risk and productivity

Table 1 presents the main primary crops cultivated on 14,590 plots in the full sample and stratified by the gender of the plot owner. About 74 per cent of the plots are male owned. The most commonly grown crops across the Burkinabé plots are sorghum (24%), maize (18%), millet and peanut (15%). Paddy rice, cowpeas, sesame, and cotton account for roughly 5 to 7 per cent of the total crops. However, despite its low share, cotton is the main export crop. According to the data, female-owned plots in Burkina Faso mostly plant peanuts and sorghum, whereas the male-owned plots cultivate sorghum and maize. Sorghum is the main subsistence crop in Burkina Faso, whereas maize is both a staple and a cash crop.

Figure 1 displays the kernel density plots, illustrating cumulative differences in the logged value of productivity by gender in Burkina Faso. Each density line traces the probability distribution of the productivity variable across the range of logged productivity values. In Burkina Faso, the mean value of crop production is 620 kg/ha in the full sample, 533 kg/ha in the female-owned sample, and 639 kg/ha in the male-owned sample. The density plots of Figure 1 also reflect these mean differences, where the dashed line shows that the male density outcome is higher than the solid line illustrating female ownership plots.[12]

Figure 2 displays the kernel density plots, showing cumulative differences in the logged value of productivity by gender divided into those farmers that take a low, medium, or high risk on average.[13] The low, medium, and high risk is an alternative variant of the risk measurement that is ranked in three categories (i.e., low, medium, or high). Figure 2, Panel A shows that male farmers taking higher risk (medium and high) on average have a higher productivity compared to those taking a lower risk. The pattern, however, is reversed for female farmers. The density plots of Figure 2, Panel B and C reflect mean differences in productivity between male and female farmers irrespective of risk level, where the dashed line showing male density outcomes is higher than the solid line illustrating female.[14]

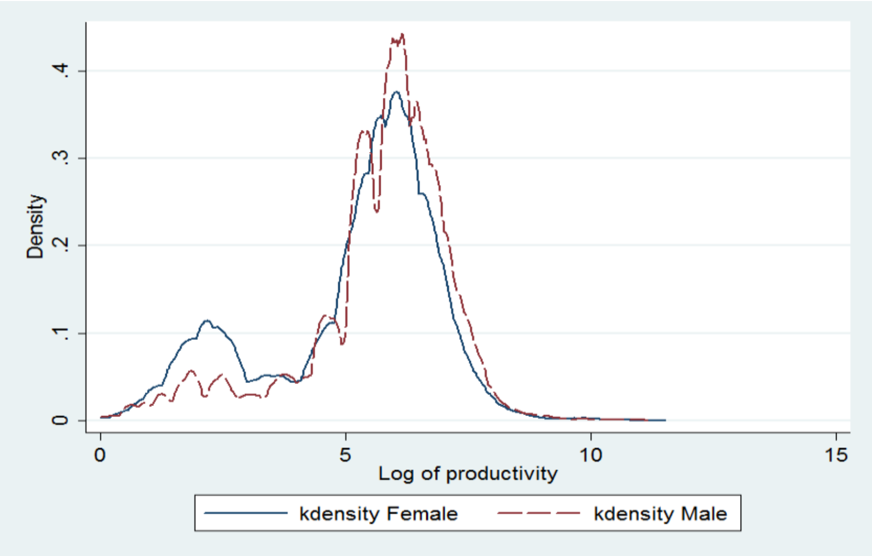
[12] As a robustness check, I derived the kernel density outcomes for the log of production by gender, and the logged value of productivity by gender separately for each of the crops represented in Table 1. The results are similar as Figure 1 and available upon request. Except for paddy rice and cotton, where male density outcomes are lower than females, which is most likely related to the smaller cell size for these plots relative to other crops in the analytical sample, hence their density outcomes could be noisy.
[13] The density plots for the cumulative differences in mean risk attitudes by gender in Burkina Faso show that male farmers on average take a higher risk than female farmers. The same pattern is detected when dividing the sample per crop for the main crops depicted in Table 1. These results are available upon request.
[14] This pattern from Figure 2 does not change by looking at the productivity of top or bottom percentile of risk takers for female and male farmers. The pattern is also no different when looking at the top and bottom percentile of productivity by gender and mean risk attitudes. The male farmers' density outcomes are higher than the females. Moreover, the pattern of Figure 2 is similar when the risk measurement is ranked into two categories (i.e., low and high risk). These results are available upon request.

Table 1. *Cultivation of crops by gender*.

	Full Sample Mean *s.d.*	Female Mean *s.d.*	Male Mean *s.d.*
Millet	0.15	0.12	0.16
	0.36	*0.32*	*0.37*
Sorghum	0.24	0.20	0.25
	0.42	*0.40*	*0.43*
Paddy rice	0.05	0.07	0.04
	0.21	*0.25*	*0.20*
Maize	0.18	0.12	0.19
	0.38	*0.33*	*0.40*
Cowpeas	0.07	0.08	0.06
	0.25	*0.27*	*0.24*
Peanut	0.15	0.26	0.12
	0.36	*0.44*	*0.32*
Sesame	0.07	0.05	0.08
	0.26	*0.21*	*0.27*
Cotton	0.05	0.02	0.06
	0.22	*0.14*	*0.24*
Observations	14,590	3,750	10,840

Note: The table presents mean, *standard deviation* (*s.d.*) and number of observations (Observations) for the main crops in Burkina Faso, for the full sample, female and male sample separately. The sample is stratified at the plot-level.

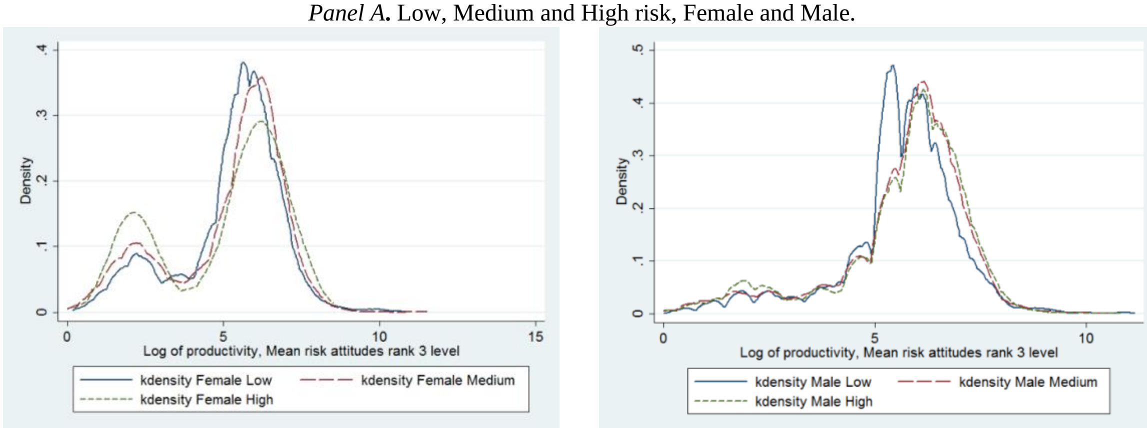
Figure 1. Kernel density of log productivity by gender in Burkina Faso.



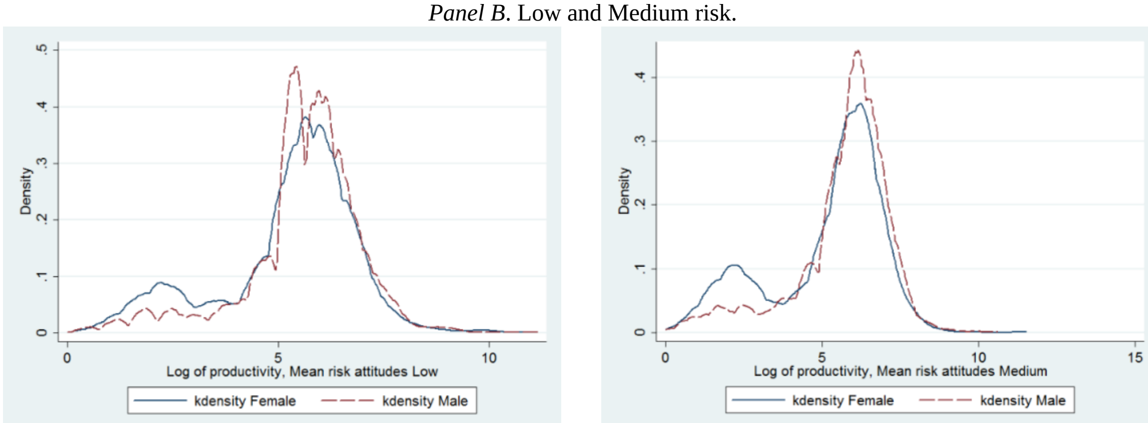
Note: On the x-axis, we have the distribution of log of productivity, which is measured as the log of plot yields per crop in kg/ha. And the y-axis is in fractions.

Figure 2. Kernel density of log productivity by mean risk attitudes with rank 3 level by gender in Burkina Faso.

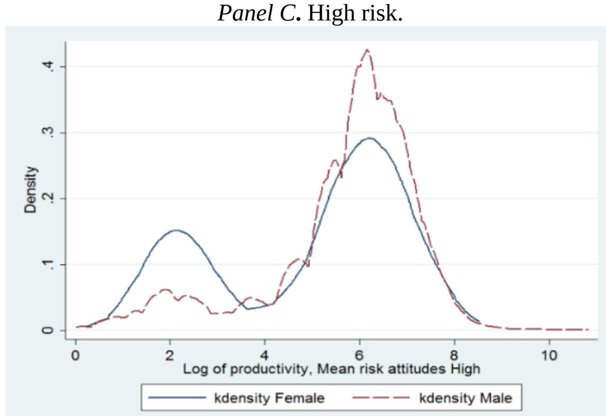
*Panel A***.** Low, Medium and High risk, Female and Male.



Panel B. Low and Medium risk.



*Panel C***.** High risk.



Note: On the x-axes, we have the distribution of log of productivity, which is measured as the log of plot yields per crop in kg/ha, separately for Female and Male low, medium, or high risk taker. The risk questions is for risk taking in general on a scale from 1 to 10, where 1=not at all willing to take risk and 10=very willing to take risk as the average of the 3rd and 4th survey round. The levels of risk depict rank on the 3 levels. And the y-axes are in fractions.

5. Results

In this section, I look at the impact of risk taking and gender on agricultural productivity. To do this, I start by exploring how the risk attitudes and gender of the individual farmer will associate with their agricultural productivity and then continue examining how regional differences affect this interaction effect.

5.1 Impact of risk attitudes and gender on productivity

As a first step, I show results in Table 2 from estimating Equation (2). These results examine the impact on yields due to gender of the farmer who owns the plot. Each column represents a separate regression model. Column 1 presents the results for the full sample without controls (M1), the agro-ecological zones are included in model 2 (M2) and the results for the full sample with all the controls are presented in model 3 (M3). All regressions include monocropping indicators for the primary crop. The results show that the female farmers are significantly associated with lower output yields even when controlling for all the inputs (M3).[15]

Having analyzed this first step, which is typically what empirical studies estimate when investigating gender differences in agricultural productivity, I examine the possible explanations for these gender differences and find that those female farmers that take more risk are even less productive on average, as compared to the male farmers. Table 3 presents the core results, estimating Equation (3), where the impact on yields due to the interaction of risk attitudes and gender of the farmer who owns the plot is investigated. The second and third columns of Table 3 report the estimates from two different variants of the risk measurement and their interaction with the gender of the plot owner. This interaction term allows for determining if differences in agricultural productivity are correlated with the joint effect of risk attitudes and gender. The first measure of risk attitudes is a set of dummy variables that capture if the individual farmer has a low, medium, or high-risk attitude created by ranking the mean risk attitudes in the three categories. The second measure of the risk attitudes is a dummy variable taking the value one if the farmer's risk attitudes are above or below the regional average of risk attitudes.[16] In column 2

[15] These results are robust to a number of checks (available upon request), including controlling for the use of quantity produced in kg of each crop as an outcome instead of productivity and for secondary crop indicators.

[16] In an effort to capture extreme risk attitudes, I explored with another measurement, a dummy variable taking the value one if the farmer's risk attitudes is 0.5 standard deviations higher or lower than the regional average of risk attitudes (results available upon request). Including this type of risk measurement, does not change the magnitude or relationship of the main results compared to taking the value one if the farmer's risk attitudes is above or below the regional average of risk attitudes.

of Table 3, the results suggest that if the female farmers take more risk, their productivity further declines as compared to male farmers, i.e. the gender differences still exist. However, the gap, in terms of the magnitude of the gender differences increases as compared to not taking the individual farmers risk attitudes into consideration, for instance compared to column 1. This is an indication that there is an impact on the gender of the plot owner and productivity. The same pattern is also seen when using the second measure of risk attitudes, in column 3. Figure 3 shows the net impact (from Table 3) of gender on productivity for farmers taking medium or high risk compared to low risk, and for farmers taking risk above regional average compared to below regional average. Figure 3 shows that the net impact for female farmers is lower productivity when risk taking is higher, irrespective of which measurement of risk used.[17]

Table 2. *Productivity of farmers: The results for full sample*.

Dependent variable:	*Productivity*		
	M1	M2	M3
Plot ownership female (=1)	-0.47***	-0.36***	-0.27***
	(0.03)	(0.03)	(0.03)
Additional controls:			
Socio-economic indicators	No	No	Yes
Agricultural inputs	No	No	Yes
Family Structure	No	No	Yes
Health indicators	No	No	Yes
Access to markets	No	No	Yes
Cropping strategies	No	No	Yes
Labor (Family & Hired)	No	No	Yes
Agro-ecological zone indicators	No	Yes	Yes
Practices Monocropping	Yes	Yes	Yes
Constant	5.63***	5.56***	4.85***
	(0.02)	(0.03)	(0.42)
Observations	14,586	14,586	14,545
R-squared	0.016	0.064	0.217

Note: Shows coefficient estimates (OLS) for productivity for the full sample. M (1) to (3) uses the log of productivity as the dependent variable. The dependent variable is measured as the log of plot yields per crop in kg/ha. For descriptive statistics see Table A1 in the Appendix. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level, respectively.

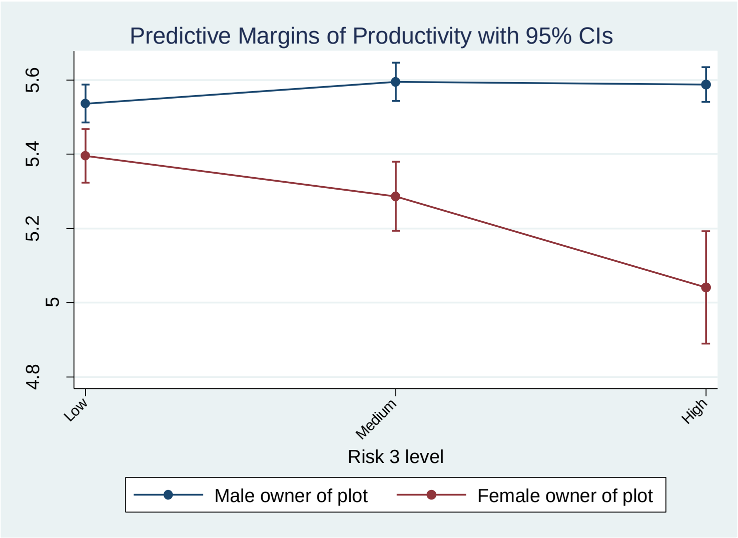
[17] Several robustness check are conducted using different variants of the risk measurement to test if the results vary with cut-off levels other than the two different variants of the risk measurement in Table 3. The results show the same trends, increased risk taking will have a net impact increase on the gender differences in agricultural productivity, i.e. the more risk female farmers take, the less productive they become compared to the male farmers. Moreover, the results of Table 3 are also robust to a number of checks, including controlling for the use of quantity produced in kg as outcome instead of productivity and for secondary crop indicators. All these results are available upon request.

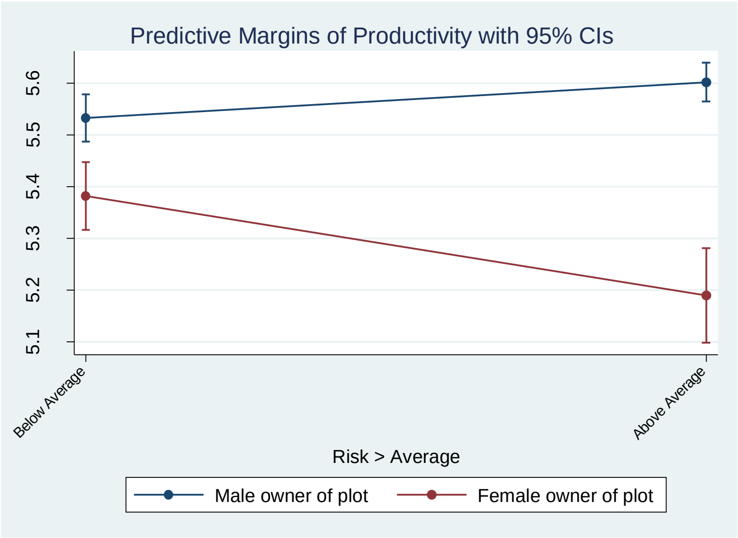
Table 3. *Productivity of farmers: The results for full sample with risk attitudes.*

Dependent variable:	*Productivity*		
	Full sample	Risk 3 level	Risk > Average
Plot ownership, female (=1)	-0.27*** (0.03)	-0.14*** (0.05)	-0.15*** (0.04)
Risk Medium		0.06 (0.04)	
Risk High		0.05 (0.04)	
Risk >Average			0.07** (0.03)
Plot ownership female (=1) * Risk Medium		-0.17** (0.07)	
Plot ownership female (=1) * Risk High		-0.40*** (0.09)	
Plot ownership female (=1) * Risk >Average			-0.26*** (0.06)
Additional controls:	Yes	Yes	Yes
Constant	4.85*** (0.42)	4.89*** (0.42)	4.86*** (0.42)
Observations	14,545	14,545	14,545
R-squared	0.217	0.219	0.218

Note: Shows coefficient estimates (OLS) for productivity for the full sample and with risk attitudes in general. All model specifications use the log of productivity as the dependent variable. The dependent variable is measured as the log of plot yields per crop in kg/ha. The interaction term is an interaction of risk attitudes in general with the gender of who owns and controls the plot. The risk variable is averaged between round 3 and 4 standardized to mean zero and standard deviation one. The Risk 3 level depicts the low (ref.), high and medium risk taking, which is on the 3 rank levels. The Risk >Average is for those taking risk above regional average, compared to below regional average (ref.). Additional controls include the same controls as in Table 2 (M3). For descriptive statistics of control variables see Table A1 in the Appendix. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% & 10% level respectively.

Figure 3. Predictive margins of the productivity of farmers: The results for full sample with risk attitudes.





Note: Shows predictive margins for the estimations in Table 3 for productivity for the full sample and with risk attitudes in general. The Risk 3 level depicts the low, high and medium risk taking, which is on the 3 rank levels. The Risk>Average is for those taking risk above regional average compared to below regional average. Standard errors are clustered at the plot level.

Gender differences in agricultural productivity may be because crop choice differ by gender, influenced by cultural norms or credit constraints. Dividing the full sample by the main crops, as in Table 4, the results show that the persistent disadvantage among female farmers taking higher risk (medium and high) still exists, but it varies by crop.[18] The gender differences in Burkina Faso seem to be driven by farmers growing sorghum, paddy rice and maize as their primary crop. Maize is a crop that requires large inputs of fertilizer, whereas sorghum and paddy rice requires large inputs of labor. Fertilizers and labor are inputs that require reliable access to credit. Further, applying more fertilizer and ploughing require additional labor, which also demands access to credit. For cotton, there might be a different pattern for female farmers.[19] Cotton is a very particular and risky crop to cultivate. Therefore, there are cotton farmer associations in Burkina Faso that aim to cover this risk. Female farmers are also members of these associations. This implies that even female farmers have access to a reliable and stable flow of credit, agricultural inputs to subsidize prices (such as fertilizers and pesticides), and stable market prices for their cotton. Therefore, female farmers who take a higher risk are on average more productive in cultivating cotton than other crops. However, looking at the net impact, even for cotton, the gender differences persist.[20]

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[18] All the results, where the full sample is divided into subcategories, have also been conducted without the interaction term between risk and gender. Moreover, the results of Table 4 hold when using the second measurement of risk (above regional average). These results are available upon request.

[19] However the estimate is not significant, and the cell size for that crop is small compared to other crops, hence the estimate might be noisy.

[20] It could be argued that these results may reflect selection bias because of unobservables. These unobservables could be unobserved inputs such as skills and ability not captured by the survey measurements. In this study, I am able to control for a range of observed characteristics using the HBS. But, as I do not observe these farmers during several cultivation seasons, I may not be able to control for the total unobserved skill and ability of the plot owner. However, Peterman et al. (2011) show based on a plot-level farm data from Nigeria and Uganda that the gender differences remain significant when controlling for ability and skills across crops.

Table 4. *Productivity of farmers: The results for full sample with risk attitudes (3 level) and by major crops*.

Dependent variable:	*Productivity*									
	Full sample	Full sample with risk	Millet	Sorghum	Paddy rice	Maize	Cowpeas	Peanut	Sesame	Cotton
Plot ownership female (=1)	-0.27***	-0.14***	0.08	-0.21**	-0.64***	-0.28**	0.16	-0.10	-0.13	0.38
	(0.03)	(0.05)	(0.13)	(0.09)	(0.23)	(0.11)	(0.19)	(0.11)	(0.20)	(0.33)
Risk Medium		0.06	0.08	0.07	-0.46**	0.01	0.39**	0.17	-0.27*	0.31
		(0.04)	(0.08)	(0.06)	(0.20)	(0.07)	(0.17)	(0.12)	(0.15)	(0.21)
Risk High		0.05	-0.01	0.04	-0.33*	0.03	0.22	0.09	0.06	0.10
		(0.04)	(0.09)	(0.06)	(0.20)	(0.07)	(0.16)	(0.11)	(0.14)	(0.20)
Plot ownership female (=1) * Risk Medium		-0.17**	-0.41**	-0.05	0.58**	0.03	-0.76***	-0.21	-0.06	-0.16
		(0.07)	(0.19)	(0.14)	(0.29)	(0.15)	(0.29)	(0.17)	(0.30)	(0.46)
Plot ownership female (=1) * Risk High		-0.40***	-1.11***	-0.37**	0.66**	0.23	-0.52	-0.60***	-0.21	0.07
		(0.09)	(0.28)	(0.19)	(0.31)	(0.21)	(0.37)	(0.21)	(0.35)	(0.42)
Additional controls:	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	4.85***	4.89***	5.10***	4.49***	7.56***	7.61***	1.94	6.86***	5.57***	8.74***
	(0.42)	(0.42)	(1.17)	(0.73)	(1.80)	(0.84)	(1.92)	(1.33)	(1.66)	(2.43)
Observations	14,545	14,545	2,187	3,432	701	2,554	974	2,247	1,026	717
R-squared	0.217	0.219	0.189	0.199	0.228	0.224	0.199	0.212	0.173	0.293

Note: Shows coefficient estimates (OLS) for productivity for the full sample with risk attitudes in general and by the major crops. Model (1) to (10) use the log of productivity as the dependent variable. The dependent variable is measured as the log of plot yields per crop in kg/ha. The interaction term is an interaction of risk attitudes in general (ranked on 3 level) with the gender of who owns and controls the plot. Additional controls include all the controls as in Table 2 (M3), except for crops. Standard errors in parentheses are clustered at the household level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results and available upon request.

5.2 Regional differences

An interesting aspect of understanding gender differences in agriculture is in the context of the regional differences in Burkina Faso. Because, as has been previously stated, research on gender differences in agricultural productivity has mainly been based on samples with limited geographic representation. The HBS allows me to explore how the diversity of the regions of the country affects gender differences. In a first stage, I investigate the region-specific results by agro-ecological zones. Table A3 in the Appendix shows that there is a variation in productivity based on the agro-ecological zone and higher risk taking between the female and the male farmers. Female ownership is associated with significantly lower productivity in the Sudanian and the Sudano-sahelian zones. This is not the case in the northern Sahelian zone, which is the driest part of Burkina Faso. The harsh conditions in the dry Sahelian zone, with an extreme scarcity of resources and lack of rain, may have created a more efficient allocation of resources. This is because the cost of having gender differences in these harsh conditions would be higher, since discrimination based on gender would imply relatively less food for the household compared to the other zones. In the second stage, I examine if the variation in the share of female famers between regions affect gender differences in agricultural productivity. Table A4 in the Appendix shows a negative relationship between the share of female farmers that own their plot per region, ranked according to three categories (low, medium, and high share) and the gender differences in agricultural productivity. The higher the share of female farmers per region, the lower the productivity of female own plots, when compared to male owned plots. In this setting, it seems that with the increased share of female famers, there is an increase on the demand for plots with better soil quality, as well as important inputs such as type of seed and labor needed for the different parts of cultivation. This, in turn, might imply increased pressure on already credit-constrained female farmers who are taking higher compared to lower risk.

Furthermore, cultural interactions may also vary by regions, which are possibly interlinked with females' right to property with varying as qualities of land or soil. These legal and cultural norms could indeed have an effect on female farmers' agricultural productivity (Cotula 2006). First, I will present an examination of soil quality. Table A5, reported in the Appendix, show that irrespective of how the female famer has come to own her plot, either through purchase, inheritance, or as a gift, the net impact of the gender differences persists for high risk taking female farmers. However, the gender differences reduce for those female farmers who have received their plots as a wedding gift, which usually implies a plot with higher soil quality. The results suggest that soil quality impacts gender differences, where those female-owned plots that use the best soil (*Clay*[21]) have the lowest difference in agricultural productivity, compared to male-owned plots (a summary of the results are available in the Appendix Table A6). This lower gender differences suggests that ownership of plots with high quality soil may improve access to credit and acceptance within cultural and social norms. This creates conformity that allows for farmers, in particular female farmers, to become socialized into and influence the culture that they live in.

However, an important input intertwined with soil quality is the type of seed used on the plot. The estimates of Table A7 in the Appendix shows that the seed type impacts gender differences, where the gender differences in agricultural productivity are lower among those female famers who take a higher risk and use improved rather than traditional seeds. High quality seeds require additional costs and access to information before use. As previously mentioned, the level of literacy for rural women in Burkina Faso is disproportionately low, which affects their ability to access this information.

Previous research shows that richer farm households take more risky decisions and earn higher returns (e.g., Rosenzweig and Binswanger 1993). This implies that those households that are rich, compared to poor, may vary in gender differences, as the rich household may have access to a higher share of high-quality soil and improved seeds. Therefore, when the full sample is split into rich and poor households (based on top and bottom 20 per cent of total yearly consumption) and risk attitudes are interacted with the plot owner's gender, I find a differential impact of gender differences. The gender differences for female farmers who take a higher risk in rich households (the top 20 per cent) are lower compared to poor households. The summary of results for poor and rich households are reported in the Appendix Table A8.

[21] Clay soils have the highest clay content among the three soil types. This means that Clay soils have higher caution-exchange and water-holding capacity than Sandy and Laterite/Red soils. It is because the particles are so small that the water is trapped between them. After rain, the water moves into the Clay soil slowly. Therefore, crops are less likely to suffer from drought because the rainwater is held in the Clay soil.

6. Conclusions and policy implications

The alleviation of gender differences has been one of the key drivers in reducing poverty and increasing food security, while simultaneously aiming for individual's livelihoods and promoting gender equality. This prominently figures in United Nations 2030 Agenda of Sustainable Development, which leads to an increased attention to gender analysis in agricultural research in the past decade. However, it has been argued that females' lower measured productivity is due to their inability to take higher risk. Therefore, through this line of reasoning, female farmers' would experience a higher level of productivity if they take higher risk. This study, through its use of a large, nationally representative data set from the sub-Saharan country of Burkina Faso, offers multiple understandings for future research on gender differences in agricultural productivity.

First, I show that those female farmers taking more risk are even less productive on average compared to the male farmers; in other words, the gender differences do not disappear but instead increase when including risk as a possible interaction with gender. Therefore, individual famer's level of risk taking should be taken under consideration when analyzing gender differences in agricultural productivity and, where possible, robustness checks for farmers risk attitudes should be conducted to provide more credible results. This implies that attention should be paid to risk attitudes at the onset survey design, rather than ex-post analysis using proxy indicators collected in surveys, such as smoking or drinking, as these proxies for risk attitudes have not been able to capture this dimension of gender differences in agricultural productivity. The risk question used in this study to measure risk attitudes have been utilized in numerous studies and is a fairly easy and cost-effective risk measurement for researchers and practitioners to implement in other countries, repeatedly in panel surveys. This allows for comparisons over time and across countries. It also contributes to the agricultural economics literature about the level of farmer's risk taking where there is no large consensus. This is important since, recently, replicability and reproducibility of scientific findings have remerged as a salient factor (Dreber et al., 2015; Camerer et al., 2016), by being able to use and analyze the same measures as previous studies.

Second, given all of the inputs that are controlled for, female farmers taking a higher risk have the lowest productivity in Burkina Faso. This implies that particular attention should be paid to the main determinants of female farmer's risk taking when implementing programs or conducting research to understand gender differences in agricultural productivity.

Third, I find that cultural norms could play an important role for understanding the persistent disadvantage among female farmers as they influence crop choices. Gender differences in agricultural productivity vary by type of crop cultivated. This suggests that agricultural programs and research within this context should integrate the type of crop differences. For instance, female farmers have the lowest productivity for those crops that demand stable flows of credit, such as maize, that requires relatively high amount of fertilizers. However, for a risky crop, such as cotton, female famers might have high productivity, as they are no credit, input, or technological constraints because they have access to the cotton farmer associations.

Consequently, this is written not only for the research community but also with national policymakers and international donors in mind: given how gender difference differs among regions and agro-ecological zones, policy findings should not be based solely on studies using samples with limited geographical coverage. This implies that government agencies and development actors should aim to finance and support surveys with data collection efforts that have national geographical representation, which would increase the validity of national policy aiming to reduce gender differences in agricultural productivity.

A key contribution of this study is to illustrate that the variability of results in gender differences in agricultural productivity depends on the interaction between risk attitudes and gender. However, other factors could affect the underlying risk attitudes of farmers, for instance the prevalence of polygyny, which is relatively high in many sub-Saharan African countries, including Burkina Faso. The mechanisms could be that male farmers who are more productive are richer and have more wives. For instance, this could be an underlying explanation as to why in those household considered rich, female farmers taking a higher risk are more productive compared to high risk taking female farmers in poor households. This suggests that a distinction between monogamous and polygynous households be made when attention to gender differences in intra-household bargaining is a component of research and national policy program implementation.

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Appendix A: Descriptive statistics, IV results and Regional differences

A.1 Descriptive statistics

Table A1. *Descriptive statistics for control variables*.

	Mean *s.e.* N= 14590	Mean *s.e.* N=3750	Mean *s.e.* N=10840
Outcome Variabels			
Plot ownership female (=1)	0.26	1.00	0.00
	0.00	*0.00*	*0.00*
Plot ownership male (=1)	0.74	0.00	1.00
	0.00	*0.00*	*0.00*
Control Variabels			
	Socio ec, indicators		
Age (years)			
Age (years)	45.28	40.64	46.89
	0.13	*0.23*	*0.15*
Age squared (years)	2279.11	1842.50	2430.16
	12.44	*20.41*	*14.92*
Education level (=1)			
Low education	0.88	0.93	0.87
	0.00	*0.00*	*0.00*
Primary education	0.09	0.05	0.10
	0.00	*0.00*	*0.00*
Secondary education	0.03	0.02	0.03
	0.00	*0.00*	*0.00*
University	0.00	0.00	0.00
	0.00	*0.00*	*0.00*
Secondary employment off farm			
Sec, Employed (=1)	0.05	0.04	0.05
	0.00	*0.00*	*0.00*
Household consumption 2014			
Food consumtion	778179.10	732547.80	793830.20
	4938.02	*9190.34*	*5827.31*
Non-food consumption	659464.40	608466.90	676956.00
	3774.95	*7364.17*	*4383.31*
Farmer having bank acount (=1)			
No bank account	0.91	0.97	0.89
	0.00	*0.00*	*0.00*
Bank account	0.09	0.03	0.11
	0.00	*0.00*	*0.00*
Householdsize	9.82	8.96	10.11
	0.05	*0.09*	*0.06*

Table A1. *(Continued)*.

	Agricultural inputs		
Plot size (hectares)			
Average Plot size (hectares)	1.39	1.06	1.50
	0.03	*0.07*	*0.04*
Biophysical indictors (kilograms)			
Average total fertilizers (kg)	1472.03	932.96	1658.52
	90.77	*144.14*	*111.48*
Average total pesticides (kg)	2.27	2.87	2.06
	0.36	*1.28*	*0.19*
Type of seeds (=1)			
Traditional	0.93	0.96	0.91
	0.00	*0.00*	*0.00*
Improved	0.07	0.04	0.09
	0.00	*0.00*	*0.00*
Soil quality (=1)			
Low	0.50	0.50	0.50
	0.00	*0.01*	*0.00*
Middle	0.19	0.19	0.18
	0.00	*0.01*	*0.00*
High	0.28	0.29	0.28
	0.00	*0.01*	*0.00*
	Family Structure		
Farmer's religion (=1)			
Catholic	0.22	0.23	0.22
	0.00	*0.01*	*0.00*
Muslim	0.59	0.58	0.59
	0.00	*0.01*	*0.00*
Protestant	0.04	0.06	0.04
	0.00	*0.00*	*0.00*
Anemism	0.14	0.11	0.15
	0.00	*0.01*	*0.00*
No religion	0.01	0.00	0.00
	0.00	*0.00*	*0.00*
Other religion	0.00	0.00	0.00
	0.00	*0.00*	*0.00*
Farmer's Marital status (=1)			
Single	0.03	0.03	0.03
	0.00	*0.00*	*0.00*
Married	0.92	0.80	0.96
	0.00	*0.01*	*0.00*
Divorced	0.01	0.01	0.01
	0.00	*0.00*	*0.00*
Widowed	0.05	0.16	0.01
	0.00	*0.00*	*0.00*
	Health indicators		
Farmer's health 15 past days (=1)			
Not sick	0.78	0.75	0.79
	0.00	*0.01*	*0.00*
Sick	0.22	0.25	0.21
	0.00	*0.01*	*0.00*
Farmer smoking (=1)			
Don't smoke	0.78	0.86	0.76
	0.00	*0.01*	*0.00*
Smoke	0.22	0.14	0.24
	0.00	*0.01*	*0.00*

Table A1. *(Continued)*.

	Access to markets indicators		
Farmer's distance to market (=1)			
0-14 min	0.28	0.32	0.27
	0.00	*0.01*	*0.00*
15-29 min	0.20	0.21	0.20
	0.00	*0.01*	*0.00*
30-44min	0.20	0.19	0.20
	0.00	*0.01*	*0.00*
45-59 min	0.10	0.09	0.10
	0.00	*0.00*	*0.00*
60+ min	0.21	0.15	0.23
	0.00	*0.01*	*0.00*
Farmer's distance to nearest functional road (=1)			
0-14 min	0.37	0.38	0.36
	0.00	*0.01*	*0.00*
15-29 min	0.15	0.16	0.15
	0.00	*0.01*	*0.00*
30-44min	0.14	0.14	0.14
	0.00	*0.01*	*0.00*
45-59 min	0.08	0.08	0.08
	0.00	*0.00*	*0.00*
60+ min	0.25	0.21	0.27
	0.00	*0.01*	*0.00*
	Cropping strategies		
Cash crop (=1)	0.27	0.33	0.26
	0.00	*0.01*	*0.00*
	Labor (Family & Hired)		
Average Family labor (days/hectares)			
Male labor	70.43	56.10	75.40
	1.36	*2.55*	*1.61*
Female labor	85.16	112.28	75.78
	1.71	*3.95*	*1.84*
Child labor	36.31	43.16	33.94
	0.76	*1.64*	*0.85*
Average Hired labor (days/hectares)			
Male labor	1.94	1.76	2.00
	0.13	*0.16*	*0.17*
Female labor	1.03	1.09	1.01
	0.11	*0.15*	*0.14*
Child labor	0.13	0.22	0.10
	0.01	*0.03*	*0.02*
Average Hour worked (hours)			
Hours worked	41.77	38.24	43.00
	0.13	*0.23*	*0.15*
	Agro-ecological zones		
Zone Sahelian (=1)	0.20	0.05	0.15
Zone Sudano-sahelian (=1)	0.50	0.13	0.37
Zone Sudanian (=1)	0.30	0.07	0.23

Note: The table presents mean. *standard errors* (s.e.) and number of observations (N) for the control variables.

A.2 IV results

Despite the strong correlation in Table 3 (and Figure 3) between female farmers' increased risk taking and lower productivity, the risk variables may nevertheless be endogenous. Previous literature has used cultural characteristics, such as religion, as instruments for risk attitudes (e.g., Dohmen et al., 2012). Different religious beliefs have throughout history been associated with economically relevant attitudes in shaping beliefs and attitudes that determine economic decision-making, such as Protestantism within Christianity and attitudes towards work (Weber 1930). More recently, Kijima and Gonzalez (2013) find less evidence in rural Ethiopia that religious beliefs (in terms of number of religious holidays) is related to attitudes towards work. Campante and Yanagizawa-Drott (2015) purse a somewhat similar approach but with a bigger dataset for several countries, using the World Values Survey, and finds that religious engagement and religiosity has an impact on individual beliefs and attitudes. In an investigation of the determinants that are related to attitudes in Burkina Faso, described in Sepahvand and Shahbazian (2020a), it is found that religion affects individual risk attitudes. The same pattern is also found for Germany (Dohmen et al., 2012). Thus, religion is a valid instrument.

In Table A2, I instrument for individuals' risk attitudes. The second and third columns of Table A2 Panel B report the (instrumented, second stage) estimates from the two different variants of the risk measurements and their interaction with the gender of the farmer. The same pattern is seen here as in Table 3 (and Figure 3), female farmers experience lower productivity when risk taking is higher. However, it seems that the IV estimates suffer from the problem of weak instruments as the first stage F-tests are relatively low.[22] Overall, the results reinforce the pattern of increased gender differences in agricultural productivity when including farmers risk attitudes, but given that the instrument is not particularly strong, I take the IV estimates as additional suggestive evidence.

[22] I find qualitatively similar results instrumenting using smoking and drinking alcohol that are other characteristics related to risk attitudes and risky behavior. Further, the relationship of these results does not change when using different variants of the risk measurement with cut-off levels other than the two variants of the risk measurement in Table A2 (e.g., risk measurement ranked into two categories i.e., low and high risk, or a risk measurement with a dummy variable taking the value one if the farmer's risk attitudes is 0.5 standard deviations higher or lower than the regional average of risk attitudes) or the use of quantity produced in kg as outcome instead of productivity and for secondary crop indicators. These results are available upon request.

Table A2. *Productivity of farmers: The results for full sample with risk attitudes, IV results.*

Panel A. *First stage*
Dependent variable: *Risk attitudes*

	Risk Medium	Risk High	Risk>Average	Plot owner female* Risk Medium	Plot owner female* Risk High	Plot owner female* Risk>Aver.
Catholic	0.31***	0.10***	0.38***	0.32***	0.13***	0.37***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)
Muslim	0.38***	0.15***	0.47***	0.34***	0.14***	0.39***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Protestant	0.41***	0.04	0.43***	0.33***	0.11***	0.38***
	(0.02)	(0.02)	(0.03)	(0.01)	(0.01)	(0.02)
Anemism	0.35***	0.11***	0.41***	0.33***	0.14***	0.40***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.56***	-0.23*	0.06	0.01	-0.04	-0.19**
	(0.13)	(0.13)	(0.14)	(0.07)	(0.06)	(0.07)
Observations	14,545	14,545	14,545	14,545	14,545	14,545
R-squared	0.034	0.156	0.115	0.301	0.131	0.337

Panel B. *Second stage*
Dependent variable: *Productivity*

	Full sample	Risk 3 level	Risk > Average
Plot ownership, female (=1)	-0.27***	-0.74	-0.74
	(0.03)	(0.49)	(0.41)
Risk Medium		0.92	
		(0.47)	
Risk High		0.25	
		(0.51)	
Risk >Average			0.91*
			(0.45)
Plot ownership female (=1) * Risk Medium		-0.23	
		(0.84)	
Plot ownership female (=1) * Risk High		-2.08*	
		(1.09)	
Plot ownership female (=1) * Risk >Average			-1.31*
			(0.67)
Additional controls:	Yes	Yes	Yes
Constant	4.85***	2.97***	4.11***
	(0.42)	(0.71)	(0.50)
Observations	14,545	14,545	14,545
R-squared second stage (centered)	0.217	-0.128	-0.001
First-stage partial R-squared (Risk Medium)		0.001	
First-stage F(8, 57) (Risk Medium)		8.34	
First-stage partial R-squared (Risk High)		0.001	
First-stage F(8, 57) (Risk High)		9.21	
First-stage partial R-squared (Risk>Average)			0.001
First-stage F(8, 55) (Risk>Average)			9.46
First-stage partial R-squared (Plot * Risk Medium)		0.005	
First-stage F(8, 57) (Plot * Risk Medium)		2.40	
First-stage partial R-squared (Plot * Risk High)		0.011	
First-stage F(8, 57) (Plot * Risk High)		6.63	
First-stage partial R-squared (Plot * Risk >Aver.)			0.011
First-stage F(8, 55) (Plot * Risk >Aver.)			7.63

Note: The first stage shows the coefficient estimates for the endogenous variables on the instruments. The Second stage shows second-stage IV coefficient estimates for productivity. All model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3 except for the farmer's religious beliefs that are included as instruments for the risk variables, being catholic, muslim, protestant, animism and no religion or atheist (ref.). For descriptive statistics of control variables see Table A1 in the Appendix. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% & 10% level respectively.

A.3 Regional differences

Table A3. *Productivity of farmers by agro-ecological zones: The results for full sample with risk attitudes (3 level).*

Dependent variable:	*Productivity*			
	Full sample	Sahelian	Sudano-sahelian	Sudanian
Plot ownership female (=1)	-0.14***	0.02	-0.33***	-0.27*
	(0.05)	(0.08)	(0.05)	(0.15)
Risk Medium	0.06	-0.01	0.03	0.16
	(0.04)	(0.07)	(0.05)	(0.11)
Risk High	0.05	0.00	0.16***	0.09
	(0.04)	(0.07)	(0.05)	(0.10)
Plot ownership female (=1) * Risk Medium	-0.17**	-0.01	-0.30***	-0.38**
	(0.07)	(0.12)	(0.09)	(0.19)
Plot ownership female (=1) * Risk High	-0.40***	-0.24	-0.51***	-0.20
	(0.09)	(0.17)	(0.12)	(0.21)
Additional controls:	Yes	Yes	Yes	Yes
Constant	4.85***	4.48***	3.96***	10.57***
	(0.42)	(0.95)	(0.59)	(1.04)
Observations	14,545	2,909	7,273	4,363
R-squared	0.217	0.143	0.133	0.264

Note: Shows coefficient estimates (OLS) for productivity for the full sample and by the different agro-ecological zones. The Model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3 except for the agro-ecological zone indicators. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results and available upon request.

Table A4. *Productivity of farmers by share of female farmers per region: The results for full sample with risk attitudes (3 level)*.

Dependent variable:	*Productivity*			
	Full sample	Low	Medium	High
Plot ownership female (=1)	-0.14***	-0.04	-0.04	-0.27***
	(0.05)	(0.07)	(0.09)	(0.08)
Risk Medium	0.06	0.11**	0.02	0.04
	(0.04)	(0.05)	(0.07)	(0.07)
Risk High	0.05	0.03	0.01	0.15*
	(0.04)	(0.05)	(0.07)	(0.08)
Plot ownership female (=1) * Risk Medium	-0.17**	-0.16	-0.15	-0.07
	(0.07)	(0.11)	(0.11)	(0.13)
Plot ownership female (=1) * Risk High	-0.40***	-0.12	-0.44**	-0.72***
	(0.09)	(0.11)	(0.18)	(0.17)
Additional controls:	Yes	Yes	Yes	Yes
Constant	4.85***	6.83***	0.60	2.39***
	(0.42)	(0.58)	(0.94)	(0.84)
Observations	14,545	6,045	4,562	3,938
R-squared	0.217	0.256	0.214	0.242

Note: Shows coefficient estimates (OLS) for productivity for the full sample and by the share of female farmers in the region, which has been created by taking the share of those females that own and cultivate their plot per region in all the 13 regions according to 3 rank levels (low, medium and high share of females). The Model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results and available upon request.

Table A5. *Productivity of farmers by type of plot ownership: The results for full sample with risk attitudes (3 level).*

Dependent variable:	*Productivity*				
	Full sample	Purchase	Inherited	Wedding Gift	Gift
Plot ownership female (=1)	-0.14***	-0.25	-0.16***	0.45*	-0.32***
	(0.05)	(0.44)	(0.06)	(0.26)	(0.12)
Risk Medium	0.06	0.14	0.01	0.37	0.24***
	(0.04)	(0.36)	(0.04)	(0.29)	(0.09)
Risk High	0.05	-0.04	0.07*	0.22	0.02
	(0.04)	(0.34)	(0.04)	(0.35)	(0.09)
Plot ownership female (=1) * Risk Medium	-0.17**	-2.05***	-0.11	-0.62**	-0.14
	(0.07)	(0.78)	(0.09)	(0.31)	(0.17)
Plot ownership female (=1) * Risk High	-0.40***	-0.21	-0.33***	-0.54	-0.21
	(0.09)	(0.73)	(0.12)	(0.41)	(0.20)
Additional controls:	Yes	Yes	Yes	Yes	Yes
Constant	4.85***	5.71	5.20***	1.02	4.58***
	(0.42)	(4.01)	(0.50)	(1.92)	(1.05)
Observations	14,545	232	10,786	979	1,978
R-squared	0.217	0.616	0.213	0.291	0.316

Note: Shows coefficient estimates (OLS) for productivity for the full sample and by the different type of plot ownership. The Model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results. The type of plot ownership categorized as Other (n=570) shows similar results as Purchase, Inherited or Gift. These results are available upon request.

Table A6. *Productivity of farmers by type of soil: The results for full sample with risk attitudes (3 level).*

Dependent variable:	*Productivity*			
	Full sample	Sandy	Clay	Laterite/ Red soil
Plot ownership female (=1)	-0.14***	-0.23***	-0.01	-0.11
	(0.05)	(0.06)	(0.08)	(0.12)
Risk Medium	0.06	-0.06	0.16**	0.14
	(0.04)	(0.05)	(0.07)	(0.10)
Risk High	0.05	-0.09*	0.22***	0.08
	(0.04)	(0.05)	(0.07)	(0.10)
Plot ownership female (=1) * Risk Medium	-0.17**	-0.05	-0.11	-0.49***
	(0.07)	(0.09)	(0.13)	(0.16)
Plot ownership female (=1) * Risk High	-0.40***	-0.54***	-0.20	-0.11
	(0.09)	(0.13)	(0.17)	(0.21)
Additional controls:	Yes	Yes	Yes	Yes
Constant	4.85***	3.25***	5.25***	5.99***
	(0.42)	(0.59)	(0.79)	(1.08)
Observations	14,545	7,262	4,107	2,702
R-squared	0.217	0.207	0.243	0.318

Note: Shows coefficient estimates (OLS) for productivity for the full sample and by the different type of plot soil. The Model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3 except for the soil quality. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results. The type of plot soil categorized as Other (n=474) shows similar results as Sandy and Laterite. These results are available upon request.

Table A7. *Productivity of farmers by type of seed used: The results for full sample with risk attitudes (3 level).*

Dependent variable:	*Productivity*		
	Full sample	Traditional	Improved
Plot ownership female (=1)	-0.14***	-0.15***	0.23
	(0.05)	(0.05)	(0.21)
Risk Medium	0.06	0.05	0.12
	(0.04)	(0.04)	(0.17)
Risk High	0.05	0.04	-0.10
	(0.04)	(0.04)	(0.15)
Plot ownership female (=1) * Risk Medium	-0.17**	-0.16**	-0.36
	(0.07)	(0.07)	(0.38)
Plot ownership female (=1) * Risk High	-0.40***	-0.41***	-0.46
	(0.09)	(0.09)	(0.35)
Additional controls:	Yes	Yes	Yes
Constant	4.85***	3.85***	9.58***
	(0.42)	(0.42)	(1.85)
Observations	14,545	13,486	1,059
R-squared	0.217	0.221	0.325

Note: Shows coefficient estimates (OLS) for productivity for the full sample and by the different type of seed used for cultivation of crop. The Model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3 except for the type of seeds. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results and available upon request.

Table A8. *Productivity of farmers by consumption quantiles: The results for full sample with risk attitudes (3 level).*

Dependent variable:	*Productivity*		
	Full sample	Poorest 20%	Richest 20%
Plot ownership female (=1)	-0.14***	-0.28*	-0.05
	(0.05)	(0.15)	(0.17)
Risk Medium	0.06	-0.03	0.14
	(0.04)	(0.10)	(0.13)
Risk High	0.05	0.04	0.11
	(0.04)	(0.10)	(0.14)
Plot ownership female (=1) * Risk Medium	-0.17**	-0.12	-0.16
	(0.07)	(0.21)	(0.23)
Plot ownership female (=1) * Risk High	-0.40***	-0.32	-0.45
	(0.09)	(0.28)	(0.30)
Additional controls:	Yes	Yes	Yes
Constant	4.85***	5.58***	5.03***
	(0.42)	(0.44)	(0.50)
Observations	14,545	3,094	2,223
R-squared	0.217	0.269	0.221

Note: Shows coefficient estimates (OLS) for productivity for the full sample and by consumption quantiles (top and bottom 20 per cent of total yearly consumption for the farm households). The Model specifications use the same dependent variable, risk variables, interaction terms and additional controls as in Table 3. Standard errors in parentheses are clustered at the plot level. ***, **, * indicating significance at the 1%, 5% and 10% level respectively. The estimates with the Risk>Average measurement shows similar results and available upon request.

Appendix B: Gender, risk attitudes and agricultural productivity in sub-Saharan Africa

Gender differences in agricultural productivity have been researched extensively, but the majority of the studies are based on small samples. Moock (1976) finds that there are differences in the agricultural production due to structural barriers for male and female small-scale maize farmers in western Kenya. Moock's results show that the women have less access to agricultural extension services and credit when compared to men. Udry (1995) finds that female agricultural production in Burkina Faso is inefficient. Conducting a within-household analysis, Udry shows that plots controlled by women are less productive in terms of lower yields when compared to those controlled by men. He proposes, as an intervention to reduce gender differences in agricultural productivity, that the time spent by women in collecting water should be saved through the construction of new wells, thereby allowing women to increase their available labor endowment for agriculture. Doss and Morris (2001) show that agricultural extension services do not reach female-headed households as compared to the male ones. This, along with the lack of access to land for females, explains the gender differences in the agricultural production in Ghana. Recent studies with more reliable data (for example, with larger sample size, geographic variation, and/or panel structure) find similar patterns of gender differences in agricultural productivity. Using data from national representative surveys in Nigeria and Uganda, Peterman et al.'s (2011) estimate that productivity for agricultural plots is lower for plots owned by women. Similar results are found by Kilic et al. (2015) for a large national representative survey in Malawi; this study shows that agricultural plots managed by women are on average one-fourth less productive than those managed by men. The productivity estimates of most of these studies cluster around 20 to 30 per cent. In other words, it shows that that female-managed plots are on average 20 to 30 per cent less productive than male-managed plots.

In sub-Saharan Africa, the amount of significant inputs, such as fertilizer, seeds, and labor, may lead to gender differences in agricultural productivity even if female and male farmers have the same underlying production function in agriculture while also using same technique for similar crops (Peterman et al., 2014). Furthermore, the quality of the critical inputs used in the agricultural production may also differ between the female and the male farmers. For instance, as shown in the case of Uganda and Ethiopia, soil quality and access to roads and water sources for irrigation may differ between men and women (Nkedi-Kizza et al., 2002; Tiruneh et al., 2001). This could be due to legal norms that impose restrictions on females' property rights to have access to high quality land or soil (Cotula, 2006).

However, the assumption that female and male farmers have the same underlying production function in agriculture does not always hold. This is most likely because crop choices differ by gender. Cultural norms play an important role in explaining gender differences in agricultural productivity as they influence crop choices. For instance, Doss (2002) shows that a gender pattern exists in Ghana regarding the choice of crop used for cultivation, which could explain why female and male farmers have different agricultural production functions. Credit constraint is another important explanation for differences in crop choices by gender. In a study by the World Bank, FAO and IFAD (WB et al., 2009) both female and male farmers in Ghana view maize production as a profitable activity. However, the female famers do not grow maize because of the lack of capital and credit to purchase the required inputs or hire labor to plough the fields. This credit constraint may cause the female farmers' production frontier to persist under that of males, implying lower female productivity.

In construction, agriculture is a risky activity. Previous literature on the risk preferences of farmers is mainly from developing countries. Farmers in developing countries operate under risky and uncertain situations (Binswanger, 1980; Ellis, 1998; Di Falco and Chavas, 2009). Farmers' risk attitudes are an important factor that effects their farm production, investment and management decisions. Farmers that are less willing to take risk would avoid higher-payoff activities and investments (Alderman 2008) or adopt new technology (Liu 2013). Farm households are vulnerable to market fluctuations and climate variability. These shocks could put farmers in a state of having nothing or losing what they have (Kanbur and Squire, 2001). Therefore, risk taking in agriculture is affected by, for instance, the geographical separation of production regions and limited access to credit or insurance (Arce, 2010). Wealth is also associated with higher willingness to take risk in agriculture, as those farm households that are wealthier invest in more risky decisions and, as a result, earn higher returns (Rosenzweig and Binswanger, 1993). However, there is insufficient knowledge about farmers' risk attitudes due to lack of reliable data with sufficient sample sizes and geographical variation (e.g., Flaten et al., 2005; Mac Nicol et al., 2007; Lucas and Pabuayon, 2011; Ullah et al., 2015). One notable exception, however, is Tanaka et al. (2010). No study thus far has focused on the interaction between gender differences and risk attitudes in agricultural productivity.

Risk attitudes are considered to be a core determinant of economic behavior in developing countries (e.g., Harrison et al., 2005; Yesuf and Bluffstone 2009) as well as developed countries (e.g., Brunello 2002; Guiso and Paiella 2004; Dohmen et al., 2011). There is evidence on the relationship between the sex of individuals and their risk preferences. The majority of previous research has shown that women are more risk averse than men (e.g., Donkers et al., 2001; Croson and Gneezy 2009; Cárdenas et al., 2012; Andersson et al., 2016).[23] There is a line of literature that investigates managerial risk and gender (e.g., Faccio et al., 2016), in which the underlying theoretical perspective is that there exists a threshold; if women continue to take higher risk, their productivity will increase.[24]

Appendix C: The agricultural sector in Burkina Faso

Burkina Faso is a land-locked country. It is also one of the poorest in the world, with around 70 per cent of its population living in rural areas. The level of education and employment, particularly among women, is low in rural areas. Female literacy is below 10 per cent in the rural areas, while literacy for men is twice as high. The urban areas move toward service and low-level manufacturing, while rural areas continue to be dominated by small-scale subsistence farming. The agricultural sector constitutes about one third of the country's GDP and provides employment to about 80 per cent of the working-age population.[25] The main source of farming is small-scale, manual farming with limited access to important inputs, such as fertilizers and modern pesticides. The limited access to formal financial services makes it difficult for farm households to access inputs through credit.[26] It is usually the household head, made up of mostly men, that has access to credit. The main principal subsistence crops cultivated are sorghum, millet, and maize, which are critical to food security. Maize is also used as cash crop, but requires large amounts of fertilizer. Cotton is the main cash crop followed by peanut, sesame, cowpeas, and paddy rice (which is cultivated in limited areas of the country and demands large inputs of labor). Cotton is also the main export crop of the country. However, not every farmer cultivates cotton due to the special

[23] However, some literature does not find any difference between men and women (e.g., Harrison et al., 2007; Fraser-Mackenzie et al., 2014) or criticizes the line of research that claims to have found gender differences in risk attitudes (Nelson 2016).

[24] The scope of this study is not to find this threshold but, rather, to indicate the overall pattern between higher risk taking on gender differences in agricultural productivity.

[25] Ministry of Agriculture Burkina Faso, http://agriculture-bf.info/ (2021-04-22).

[26] Sepahvand and Shahbazian (2020b) show that 11 per cent of the individuals in a representative nationally survey have access to a bank account.

conditions of cultivation and its impact on the soil quality. It is a very risky crop to produce and almost all the cotton farmers in Burkina Faso, irrespective of their gender, are members of cotton farmer associations. These associations offer credit and technical advice, as well as distribute subsidized inputs to cotton farmers (Sepahvand and Shahbazian, 2008). Historically, in order to stimulate and promote the production of cotton, these associations have established funds that aim to offer the farmers stable prices for their cotton (Hårsmar 2004).

Figure C1. Map of the climate zones in Burkina Faso.

Source: MEDD/R-PP (2012)

There are three broad climate zones across Burkina Faso that are rainy between the end of May until September and dry the rest of the year, as shown in Figure C1: (i) the Sahelian zone in the northern part, with little rain (less than 250 mm/year); (ii) the Sudanian zone in southwestern part, with heavy rain fall (more than 1000 mm/year); and (iii) the Sudano-sahelian zone that makes up the rest of the country, with rain fall between 600-1000 mm/year. This diversification of agro-ecological zones makes Burkina Faso representative for many countries in sub-Saharan Africa, in which farmers are faced with a range of diverse ecological characteristics.

The lack of irrigation systems in the country makes the agricultural sector highly weather dependent. The vulnerability of the farmers in Burkina Faso and its neighboring countries has further increased with major changes in the climate, in terms of very warm periods and droughts. It is estimated that, between 1970s and 2010, there were over 100,000 drought-related deaths in the rural areas of West Africa due to lower rainfall and higher incidence of drought (AEO 2002; USAID 2012). Climate change will have a very large economic impact, such as reduced access to food and water (e.g., Ward et al., 2014). This will also lead to health issues through a lack of nutrition and sanitation, which gives rise to infectious diseases. Estimates from INSD (2015) show that around 43 per cent of the individuals in Burkina Faso suffered from food insecurity in 2014.[27] In particular, farming households are mainly affected. There is a seasonal variation in access to food and water, where the access is highest right after harvest and steadily declines over time. Mothers and children are considered to be those with less resilience towards shocks; if the mother is obliged to provide for her child through, for example getting access to water, it would imply less time put into labor. The availability of subsistence crops has, so far, reduced the prevalence of undernutrition in Burkina Faso. However, the demand for these crops will increase in the country in the coming decades due to rapid population growth. If it is not dealt with, it would have a devastating impact. Therefore, it is of utmost importance that the agricultural sector is productive. Otherwise, these effects could, in the future, increase global migrant flows because of climate changes that disrupt the livelihoods of populations not just in Burkina Faso but also rest of West and sub-Saharan Africa.

[27] These estimates are based on the number of calories individuals in a households get from the consumption of food products. 2,283 kcal per adult equivalent and per day is the standard level.