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Complements Between Risk Aversion and Sources of Technical Inefficiency in Male-Female Productivity of Small-holder Farmers in Southwestern Nigeria

Luke O. Olarinde
Department of Agricultural Economics and Extension,
Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso 210001, Oyo State, Nigeria

Abstract: This study estimates male-female differences in agricultural productivity of small-holder farmers and evaluates these on the basis of differences in inputs used and outputs generated, socio economic and farm specific factors as a result of the intrinsic male-female differences in risk attitudes. It is hypothesized that risk aversion compliments the conventional socio-economic and farm specific factors affecting small-holder farmers efficiency level. A multistage-stratified random sample of 100 (50 each) of male and female respondents was adopted and the (input-output, socioeconomic and risk) variables used in estimating a stochastic frontier production function and a safety first model of risk aversion. Results show that there are marked differences in the efficiency levels of the overall male-female farmers and also in those of the male-female farmers for the three categories of the identified low, medium and high risk averse farmers. The male respondents tend to be less efficient (more inefficient) than their female counterparts. The benchmark findings from the study show that risk aversion plays a major and effective role on the technical efficiencies of the sampled farmers. This type of research is important because individual farmers can be identified along their risk attitudes and technical efficiency levels. This will in turn enable specific agricultural and development policies to be targeted at these different groups of farmers.

Key words: Risk aversion, male-female stochastic frontier, safety first, Nigeria

INTRODUCTION

It is often argued that women's levels of human and physical capital result in lower productivity or inability to respond to economic incentives (Gladwin, 1991; World Bank, 1994). Much of the evidence cited to support this argument comes from agriculture. Yet, the measurement of differences in agricultural productivity between men and women is fraught with conceptual and methodological difficulties (Quisumbing, 1996). These arise from the difficulty of defining appropriate measures of productivity in different farming systems, omission of individual characteristics in attempts to measure productivity differences by sex and the lack of clarity regarding the measurement of sex and gender differences (Williams; 1994).

Quite a lot of empirical evidence on gender issues is available especially, those that bother on agricultural and rural development. That is why bilateral and multilateral development agencies have gender policies, priorities and strategies, gender units, gender specialists, gender reporting criteria and monitoring (Jackson, 1996). If gender and development (GAD) has moved from the fringe to the main stream of development, this should be cause for celebration rather than the feeling of unease about what has been lost in translation. According to Quisumbing (1996), male-female productivity differences should ideally be based on estimates of total factor productivity, in which an index of output is divided by an index of inputs, aggregated over all types of outputs and inputs, respectively. It is therefore, feasible to estimate technical efficiency differences between male and female farming systems where men and women manage separate plots, as in many African societies (Boserup, 1970). Despite the numerous attempts to document male-female productivity differences, relatively few control for individual intrinsic characteristics such as the male-female variations in risk (attitudes) aversion levels. This study, in addition to assessing the conventional male-female differences in agricultural productivity, proceeds to determine and quantify the risk aversion levels (risk attitudes) of the sampled male-female farmers. In other words, male-female differences in agricultural productivity is evaluated on the basis of differences in inputs use and outputs generated as determined by socio-economic and farm specific factors as a result of the intrinsic male-female differences in risk attitudes.

THEORETICAL AND ANALYTICAL FRAMEWORK

The theoretical definition of a production function has been based on expressing the maximum amount of output obtainable from given input bundles with fixed technology (Ajibefun and Daramola, 1999). This is regarded as estimating average production function. This definition assumes that technical inefficiency is absent from the production function. Following the pioneering but independent works by Aigner ***et al.*** (1977), Battese and Cora (1977), Meeusen and Van den Broeck (1977), some serious consideration has been given to the possibility of estimating the so called frontier production functions, in an effort to bridge the gap between theory and empirical research.

The above efforts, have so far led to several studies on the estimation of the inefficiency effects in stochastic frontier production functions. Some of these include Battese and Coelli (1995) who proposed a stochastic frontier production function for panel data, in which the technical inefficiency effects were specified in terms of various explanatory variables, possibly including time. Coelli (1994) had earlier expanded the Frontier programme to estimate stochastic frontier model of Battese and Coelli (1995) in addition to Battese (1992). An overview of literature indicates no considerable theoretical and conceptual link between technical inefficiency and risk aversion. There are however quite a number of separate studies on risk aversion especially as it affects sub-saharan Africa agriculture. Some of the studies which have identified risk aversion as one of the major constraints in agricultural production include: Wolgin (1975), Moscardi and DeJanvry (1977), Feinerman and Finkeshtain (1996) and Olarinde (2004). A review of these works shows that the methodology by Moscardi and DeJanvery (1977) makes it easy to introduce risk aversion into a model of a production function. This establishes the conceptual link between technical efficiency or inefficiency and the individual sampled farmers' risk attitude. A separate production function needs not to be estimated, as the quantification of risk aversion proceeds from the estimation of the stochastic frontier production function. The analytical framework guiding this study can be represented in the manner of Battese *et al*. (1996) who proposed the use of stochastic frontier specifications which incorporate models for the technical inefficiency effects and simultaneously estimate all the parameters involved. This is however with the exception that the U_{is} (which account for technical inefficiency in production) are assumed to be random variables which are independently distributed as truncations at zero of a normal distribution with mean m (Ajibefun and Daramola, 1999) and variance S^2, where M_i = f (Zi , d) and Z_i is a vector containing farmer-specific factors and a constant; d is a vector of parameters to be estimated and f(x) is a suitable functional form, usually assumed to be linear. Technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology.

$$\text{Technical Efficiency (TE)} = Y_i / Y_i = f(x_i, b)\exp(V_i - U_i) / f(x_i, b)\exp(V_i) = \exp(-U_i) \quad (1)$$

Technical efficient farms are those that operate on the production frontier and the level by which a farm lies below production frontier is regarded as the measure of technical inefficiency. The notation in (1) above can be decomposed from a suitable functional form (fx) such as the Cobb-Douglas or translog stochastic frontier production function which assumes the presence of technical inefficiency of production and this may be expressed as:

$$Yi = f(x_i; b) \exp(V_i - U_i) \quad I = 1, 2, \ldots, n \quad (2)$$

where, Y_i is the output of the i-th farm, X_i is a vector of inputs; b is a vector of parameters to be estimated, f(x) is as earlier defined; V is a symmetric random error that is assumed to account for measurement error and other factors not under the control of the farmer; U_i accounts for technical inefficiency in production; exp stands for exponential function.

The model in (2) above is such that the possible production of Y_i is bounded above by the stochastic quantity, f (x_i,b) exp (V_i), hence the term stochastic frontier. All other assumptions of the stochastic frontier remain valid (Battese *et al.* , 1996).

Risk aversion is then introduced in the model (2) above as a safety-first rule. According to this rule, an important motivating force of the decision maker in managing the productive resources that he controls and, in particular, in choosing among technological options is the security of generating returns large enough to cover subsistence needs. Assuming that the safety-first rule holds, the degree of risk aversion manifested by individual small-holder farmers can be derived from observed behaviour (Moscardi and DeJanvry, 1977). Given a production technology, the risk associated with production and market conditions, the observed level of factor use reveals the underlying degree of risk aversion.

Assume that the relationship between inputs (vector x) and yield (Y) is represented by the stochastic frontier production function in (2), a given coefficient of variation of yield ($\theta = \delta y/\mu y$), given factor prices (P_i) and a given product price (P), the preference order for a risk averse farmer can be maximized with respect to the input levels. The resulting first-order condition are

$$Pf_i = \frac{E(Y)}{X_i} = \frac{p_i}{1-\theta k(s)} \qquad (3)$$

where, f_i is the elasticity of production of the ith input, K is the marginal rate of substitution between expected net income and risk. The K stands as a function of the small-holder's household characteristic(s) and serves as the measure of risk aversion suggested by Magnusson (1969). Assuming that (3) correctly specifies the small-holder's decision-making process, the value of the risk aversion parameter K can be deduced from the observed levels of product and inputs by solving Eq. 3:

$$K_{(s)} = \frac{1}{\theta}(1 - \frac{P_i X_i}{Pf_i \mu_y}) \qquad (4)$$

Equation 4 provides a measure of risk aversion that can be derived for each small-holder from knowledge of, in this case, the stochastic frontier production function, the coefficient of variations of yield, product and factor prices and observed levels of factor use.

MATERIALS AND METHODS

Area studied: The study was conducted in the Oke-Ogun belt of the South Western agroecological zone of Nigeia. However, small-holders in Ago-Area Tede, Ofiki, Sabe and Owo farming communities were surveyed for the study because they are the major settlements where food crops are grown in appreciable quantities. These farming communities are situated in the Nigerian state of Oyo, which as a whole has a comparative advantage in the production of many staple crops (RUSEP, 2002). The reason for this advantage is that the state of Oyo falls under the semi-humid zone and therefore annual crops can easily be grown. However, yam, cassava, maize and soybean are dominant both in the terms of output and cropped area. Empirical evidence (RUSEP) confirm that these crops (yam, cassava, maize and soybean) meet all the criteria for priority crop selection and the Oke-Ogun area has the highest potential for the production of these crops, because of the vast land mass.

Sampling and data collection: A multistage stratified sampling technique was adopted to select a cross-sectional sample of small-holder male-female food crop farmers for the study. Each of the 5 farming communities constitutes a stratum; 2 villages were randomly selected from each stratum, while 10 respondents comprising equal number of male and female soybean farmers were also randomly chosen from each village. The total sample size amounts to 100. Data collected include information on socioeconomic and farm specific characteristics of the male-female farmers. Also, data on farm production and input use and output levels were also collected from the sampled farmers. The main survey instrument was a detailed pre-tested and coded questionnaire.

The model: The stochastic frontier production function for the male-female small-holder farmers in the study area is assumed to be defined by:

$$\begin{aligned} \ln Y_i = \beta_0 + \beta_1 \ln(\text{seed}) + \beta_2 \ln(\text{rent}) + \\ \beta_3 \ln(\text{fertilizer}) + \beta_4 \ln(\text{Pesticide}) + \\ \beta_5 \ln(\text{tools}) + \beta_6 \ln(\text{labour}) + V_1 - U_i \end{aligned} \qquad (5)$$

where the technical inefficiency is assumed to be explained by:

$$\begin{aligned} m_i = d_o + d_1(\text{farm size}) + \\ d_2(\text{no of risks faced by the farmer}) + \\ d_3(\text{farm distance}) + d_4(\text{farmig experinces}) \end{aligned} \qquad (6)$$

where in denotes the natural logarithm (logarithm to base e) the subscript $_i$ refers to the i-th farmer, Y is the output of soybean in kg; seed is the quantity of seed planted in kg; rent is the estimated cost of cropped area; fertilizer is the quantity of chemical fertilizer applied in kg; pesticide is the total quantity of chemical (insecticide, fungicide) in kg; tools is the value of the collection of simple farm tools used in the production process and labour is the total average amount of labour employed in the cropping season in labourday.

The farm specific or inefficiency factors are farm size, number of risks faced by the farmer; farm distance and experience in food crop farming. It is assumed that quality differences in land are reflected in the rent paid by users. Unless, the land area used in agricultural production is weighted by some measures of its productivity, the result tends to be meaningless (Ajao *et al*., 2003).

The individual risk aversion parameter $K_{(s)}$ in Eq. 4 is then estimated from the parameters of the data summary statistics and those of the coefficients of the stochastic frontier production function. The parameters of the stochastic frontier model are obtained by using Frontier Version 4.1 (Coelli, 1994).

RESULTS

Technical efficiency of sampled respondents: The Maximum Likelihood Estimates (MLE) of the frontier production function are presented on Table 1. The estimate of Sigma-Square (σ^2), which is 0.814 is significantly different from zero, indicating a good fit and correctness of distributional assumption specified. The estimate of γ-parameter which measures the effects of technical inefficiency in the variations of observed output is large and has a value of 0.688. This implies that the inefficiency effects are significant in the analysis of the value of the output of the farmers. This means that 68.8 (or about 69)% of the difference between the observed and maximum production frontier outputs were due to differences in farmers level of technical efficiency and not related to random variability. These factors are under control of the farm and the influence of which can be reduced to enhance technical efficiency of the farmers. With a downward shift in constant term, the coefficients of β_1, β_2, β_3 and β_4 become significant. The farm specific technical efficiency varied between 0.1028 and 1 (Appendix I) with mean technical efficiency (TE) of 0.714. This is an indication that in the short run, it is possible to increase yield in the study area on the average by 30% by using the technology of best performers.

The sources of inefficiencies can be identified by investigating the relationship between the computed TE and δ_1 to δ_4 (Table 1). The variables with positive coefficient are number of risks faced by the farmer (Z_2) and farm distance (Z_3). A negative coefficient means that the variable is improving technical efficiency; that is the farmer becomes less technically inefficient as the level of the variable increases. A positive coefficient on the other hand implies that technical inefficiency increases as the variable levels increase. Results show that farm size, numbers of risks faced by the farmer and farming experience are significant at 5, 5 and 1% probability levels, respectively. The positive coefficients of the variables on number of risks and farm distance imply that increased number of risks and longer farm distances render the farmers more technically inefficient than their counterparts who face fewer risks and whose farms are within short distances. The negative coefficients of the variables on farm size and experience implies that small-holder farmers whose farms are fairly large and who are more experienced tend to be less technically inefficient (or more technically efficient) than their counterparts without these privileges. The results obtained here indicate that more of the technical efficiency levels approaching unity would have been recorded if there were more farmers with fairly large farms and whose farming experiences had spanned previous longer years.

Table 1: Maximum likelihood estimates of the parameters of the stochastic production function (Technical Efficiency model)

Variable	Parameters	Coefficients	Standard errors
Constant	β_0	0.78621	0.30401
Seed	β_1	0.4861	0.0935
Rent	β_2	0.0021	0.0233
Fertilizer	β_3	-0.2923	0.1019
Pesticide	β_4	0.3002	0.657
Tools	β_5	-0.2905	0.0419
Labour	β^6	-0.0932	0.1148
Inefficiency factors			
Constant	δ_0	4.8353	1.5404
Farm size	δ_1	-1.4288	0.3562
No of risks faced by the farmer	δ_2	1.0727	0.1023
Farm distance	δ_3	0.3477	0.4024
Experience in food crop farming	δ_4	-2.5741	0.3677
Sigma squared	σ_2	0.8136	0.2916
Gamma	γ	0.6879	0.1375
Log likelihood function		-84.4457	

Source: Data analysis, 2005

Estimates of Cobb Douglas production function for the sampled farmers are presented in Table 2. Out of the six variables included in the model, three (seed, rent and pesticide) had expected signs. The three others have negative signs. Of the three variables with expected positive signs, β_1 (seed) variable has significant impact on the output. A unit increase in the seed quantity will improve the output by 60%. The regression coefficients of Cobb Douglas production function are the production elasticities and their sum indicates the return-to-scale. The estimates for return-to-scale for the soybean farmers are significantly less than unity. The estimate of 0.2761 is low, indicating decreasing return-to-scale in farming operation in the study area. This shows that an increase in all inputs included in the explanatory variables would result in less than proportionate increase in the output. This can mainly be explained in terms of managerial limitations and inefficient resource use. Output can still be increased with current available resources.

Male-female distribution of efficiency level of each risk averse farm firm: Data analysis revealed that 34% male and 50% female farmers are risk-preferers; 12% male and 28% female farmers are risk-neutral while 54% male and 22% female soybean farmers are risk averters (Table 3).

A check on the efficiency distribution and risk aversion levels of the respondents shows the following (Appendix 1 and Table 4): the least and most efficient male

Table 2: Elasticity estimates and returns to scale for soybean farmers

Variable	Elasticity
Seeds	0.6604
Rent	0.0433
Fertilizer	-0.0668
Pesticides	0.0185
Tools	-0.3298
Labour	-0.0495
Return-to-scale	0.2761

Source: Field survey, 2005

Table 3: Frequency distribution of male-female soybean farmers by risk aversion group

Risk aversion group	Male	Female
Risk preferers ($0<k<0.4$)	34%	50%
Risk neutral ($0.4\leq k \leq 1.2$)	12%	28%
Risk averters ($1.2<k<2$)	54%	22%
Total	50%	100%

Source: Field survey, 2005

risk preferers are respectively about 45 and 91% efficient; the least and most efficient female risk preferers are about 38 and 94% efficient; the least and most efficient risk neutral male farmers are about 51 and 88% efficient; the least and most efficient neutral risk female farmers are about 50 and 93% efficient. The least and most efficient male risk averse are about 3 and 88% efficient; the least and most efficient female risk averse are respectively about 10 and 87% efficient. The results show similar patterns in the efficiency distributions of male and female farmers in the study area. There is however an interesting marked difference in the efficiency distribution pattern for the risk averse male farmers. The least efficient risk averter male farmer is only 3% efficient while the least efficient risk averter female farmer is about 10% efficient. It can be concluded that female small-holder farmers are more efficient than their male counterparts. This is reflected in the fact that more of the female farmers are risk preferring than their male counterparts.

Differences in mean technical efficiencies for the overall respondents and the three groups of risk averse male-female farmers: Some null hypotheses concerning the differences in the technical efficiencies (by implication the technical inefficiency levels) of the overall male-female farmers; male-female high risk farmers; male-female medium (neutral) risk farmers and male-female high risk farmers were tested. The pair-wise t-(z) statistics testing procedure was used for the study and the results are presented in Table 5. All the four null hypotheses of no differences in the mean technical efficiencies are rejected. This means that there are marked differences in the inefficiency levels of the overall male-female farmers and also in those of male-female farmers for the three categories of low, medium and high risk averse farmers. In all, the male respondents tend to be more inefficient than their female counterparts.

Table 4: Frequency distribution of technical efficiency of soybean farmers

	Frequency		Percentage		Cumulative percentage	
Efficiency level	Male	Female	Male	Female	Male	Female
0.10-0.20	01	03	02	06	-	-
0.30-0.40	07	04	14	08	16	14
0.50-0.60	07	04	14	08	30	22
0.70-0.80	34	36	68	72	98	94
0.90-1.00	01	03	02	06	100	100
Total	50	50	100	100		

Source: Adapted from Appendix 1

Table 5: Test of hypothesis for the differences in mean technical efficiencies of male-female and risk averse groups of respondents

Null hypothesis	t-statistics	Critical value	Decision
1. $H_0 : \mu_{MTE} = \mu_{FTE}$	-1.472	-0.112	Reject H_0
2. $H_0 : \mu_{MLRTE} = \mu_{FLRTE}$	-0.993	-0.1951	Reject H_0
3. $H_0 : \mu_{MMRTE} = \mu_{FMRTE}$	0.574	0.1223	Reject H_0
4. $H_0 : \mu_{MHRTE} = \mu_{FHRTE}$	-0.503	-0.1818	Reject H_0

TE = Technical Efficiency; MTE = Male TE; FTE-female TE; MLRTE = Low Risk Male TE; FLRTE = Low Risk Female TE; MMRTE = Medium Risk Male TE; FMRTE = Medium Risk Female TE; MHRTE = High Risk Male TE; FHRTE = High Risk Female TE

Appendix 1: Gender distribution of risk aversion and efficiency levels of each farm firm

Firm	Tech. efficiency	Gender	Risk aversion groups	Firm	Tech. efficiency	Gender	Risk aversion groups
1	0.8	M	1	51	0.645	F	2
2	0.828	M	1	52	0.763	M	1
3	0.722	F	1	53	0.718	M	1
4	0.481	F	1	54	0.692	M	3
5	0.72	F	3	55	0.791	M	1
6	0.881	M	3	56	0.712	M	1
7	0.851	M	3	57	0.762	F	1
8	0.863	F	1	58	0.83	F	3
9	0.898	F	1	59	0.878	M	3
10	0.897	F	1	60	0.752	F	2
11	0.631	M	1	61	0.883	M	3
12	0.759	M	1	62	0.668	F	1
13	0.352	M	3	63	0.792	M	3
14	0.854	F	2	64	0.787	F	2
15	0.305	F	3	65	0.748	M	3
16	0.751	M	3	66	0.863	F	1
17	0.361	M	1	67	0.756	M	3
18	0.927	F	2	68	0.83	M	3
19	0.756	M	1	69	0.877	F	1
20	0.103	F	3	70	0.379	M	3
21	0.869	F	2	71	0.679	M	3
22	0.358	M	3	72	0.864	F	2
23	0.5	F	2	73	0.823	F	1
24	0.723	M	3	74	0.81	M	2
25	0.86	F	1	75	0.882	M	2
26	0.907	M	1	76	0.84	F	2
27	0.0263	M	3	77	0.894	F	2
28	0.716	F	1	78	0.737	F	2
29	0.937	F	1	79	0.78	M	3
30	0.759	F	1	80	0.86	F	3
31	0.379	F	1	81	0.765	M	3
32	0.596	M	1	82	0.835	F	3
33	0.777	M	1	83	0.793	M	3
34	0.838	F	2	84	0.814	F	1
35	0.873	F	3	85	0.726	F	2
36	0.523	F	1	86	0.931	F	1
37	0.678	M	3	87	0.772	F	2

Appendix 1: Continued

Firm	Tech. efficiency	Gender	Risk aversion groups	Firm	Tech. efficiency	Gender	Risk aversion groups
38	0.4	F	3	88	0.866	F	3
39	0.258	F	3	89	0.596	F	1
40	0.334	M	3	90	0.849	M	2
41	0.793	M	3	91	0.793	F	3
42	0.723	M	3	92	0.724	M	3
43	0.836	M	2	93	0.836	F	1
44	0.35	M	1	94	0.35	M	3
45	0.773	M	3	95	0.774	F	1
46	0.791	M	1	96	0.791	M	2
47	0.513	M	2	97	0.513	M	1
48	0.78	M	1	98	0.78	F	1
49	0.863	F	1	99	0.863	M	3
50	0.81	F	1	100	0.714	F	1
					Mean TE	0.714	

DISCUSSION

Given the production resources at the disposal of the surveyed male-female small-holder farmers, the farmers are fairly efficient in the use of these resources. However, in this study, a line of distinction is drawn between the male-female abilities to efficiently use resources on one hand and among the three groups of low, medium and high risk averse male-female farmers. Findings show that in the former situation, number of risks faced by the farmers and farm distances are responsible for the technical inefficiency levels of sampled respondents. The implication of this is that to a large extent, agricultural risks, for example natural, economic, social and technical sources of risks as were identified to be affecting farmers in the study area, have a devastating effect on the productivity levels of farmers. Among the risks which were cited as being the constituents of these risk sources were: natural (e.g., drought, flood, wind/storms, disease and pests, etc), economic (e.g., producer price fluctuation, insufficient and untimely supply of fertilizer, insufficient or scarce seeds, etc), social (e.g. theft of produce, bush fire, invasion of farms by cows, etc), technical (e.g. poor soil, scarce labour, lack of processing facilities, etc). Some or a combination of these risks contribute to the inefficient use of the available inputs secured by the farmers. Distance between the farmers homestead and the farm was also identified to have impacted negatively on the abilities of the farmers to efficiently make use of the available resources. This is not unexpected since most of the respondents are located in the rural farming communities and in most cases, have to take to trekking to reach most of their scattered farms. This is mostly energy sapping and the strength and the zeal to carry out farming operation would have been reduced by the time they get to their farms.

In the latter situation, risk aversion was found to complement the role of the number of risks faced by the farmers and farm distance in affecting their technical efficiencies. This is also expected since the incentives to reduce the identified risks are lacking. This will therefore, call for a certain drift from good and efficient use of the available resources. A typical finding in this study however is that the negative effect of these two compliments (the conventional inefficiency factors and risk aversion) tend more to the male than the female farmers. It can be inferred that, because female farmers in this study like to take risks, they prove to be more technically efficient than the male farmers.

The result of this study shows that risk aversion plays a major and effective role on the technical inefficiencies of the sampled farmers. They also show that the tendency to be risk averse is more to the male farmers and that explains why the female farmers are more technically efficient. Based on the above and other salient nature of the findings, the provision of incentives to reduce the negative effects of the identified risk sources is highly essential. The provision of these incentives will gear up male farmers to be more efficient and they will equally render the female farmers to be further efficient.

CONCLUSION

In conclusion, this type of research has a major stake in advancing the courses of the three categories of the male-female farmers identified in this study. Individual farmers can be identified along their risk attitudes and levels of technical efficiencies. Specific agricultural and rural development policies can be targeted at these different groups for improved agricultural productivity and economic development.

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