Invited presentation at the 2018 Southern Agricultural Economics Association Annual Meeting, February 2-6, 2018, Jacksonville, Florida

Crop Diversification Improves Technical Efficiency and Reduces Income Variability in Northern Ghana

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Abstract

Crop diversification is a climate smart agricultural technique which helps improve resilience for farmers in the face of volatile weather due to climate change. Previous research on its effect on technical efficiency shows contrasting results (positive and negative effects). Other literature show that crop diversification has a positive impact on income variability. Is it possible that choosing crop diversification involves a tradeoff between efficiency and resilience (income variability) for rural smallholder farmers? It is likely that merging these two separate sets of previous literature, one on the effects of crop diversification on technical efficiency, and another on its effect on income variability, can provide valuable insights on the decision making process faced by a farmer considering to adopt crop diversification. So essentially, the question we try to answer in this study is what is the effect of crop diversification on technical efficiency and income variability on the same farm household of northern Ghana? Without addressing this question, policy makers cannot tell for sure if crop diversification is a good CSA option for their farmers, and if it is, they still may not know how to promote its adoption effectively. To answer our research question, we use the Agricultural production data from northern Ghana and employ a Cobb Douglas stochastic input distance function for efficiency, and ordinary least squares for income variability. The results show evidence against 'tradeoff'. Crop diversification significantly improves efficiency and reduces income variability in northern Ghana so farmers do not have to give up efficiency for income stability or vice versa. Thus crop diversification is an ideal CSA strategy for promoting agricultural growth and resilience in northern Ghana. The data we use in this study has a maximum three crops, so our results cannot be generalized to farmers who grow more than three crops.

Key words: crop diversification, technical efficiency, income variability

1.0 Introduction

The challenge of meeting the increased demand for food while striving to eradicate hunger and poverty are more daunting in the face of climate change. The Food and Agriculture Organisation (FAO) has estimated that, to meet the demand for food in 2050, annual food production needs to increase to about 60% of what it was in 2006 (Food and Agriculture Organization 2011), and that 80% of that increase will need to come from increased yields (Alexandratos and Bruinsma 2012). This challenge is even more unerving for Sub Saharan Africa (SSA) where more that a third of the world's extreme poor live (World Bank 2017) and more than half of the population is employed in agriculture (FAO 2012). Because of its relieance on agriculture, the increase in population living in poverty due to climate change is expected to be highest in SSA (FAO 2016). However, given vast regional differences, both within and between countries in SSA, the magnitude of climate change effects will be heterogenous. In Ghana, for example, the Northern part of the country is likely to be more negatively affected than the rest of the country because it is poorer, drier and more heavily reliant on rain-fed subsistence agriculture (Antwi-Agyei, Fraser, Dougill, Stringer, & Simelton, 2012).

In coping with climate change, the government of Ghana has already pledged to take policy actions that increase agricultural resilience in its vulnerable landscapes by unconditionally increasing the adoption of climate smart agriculture (Republic of Ghana 2015). Climate smart agriculture (CSA) is an integrated approach for addressing the interlinked challenges of food security and climate change with the aim of increasing productivity, enhancing resilience and reducing emissions (World Bank, 2017). Some of the farm level CSA options include crop diversification, mixed crop-livestock farming systems, using different crop varieties, changing planting and harvesting dates, using a mixture of varieties for a crop e.g low yield- drought resistant and high yeild-water sensitive variety (Nhemachena and Hassan 2007).

In this study, we focus on Crop diversification which is one CSA technique that has been extensively promoted. Its benefits include increasing yield stability and bringing more spatial and temporal biodiversity on the farm (Holling 1973; Joshi 2005); improving soil fertility, controlling for pests and diseases and bringing about nutritional diversity (Lin 2011). We define crop diversification as the practice of cultivating more than one variety of crops belonging to the same or different species in a given area in the form of mixed cropping.

The concept of crop diversification also entails competition for resources among various crops. For example, over-diversification may place pressure on agricultural land and farm management resources and may therefore be unsustainable, short-sighted and a risky approach in the face of less reliable climate patterns. Previous research has therefore tried to understand how crop diversification affects technical, allocative and profit efficiency (Manjunatha, Anik, Speelman, & Nuppenau, 2013; Rahman, 2009). Their findings show both positive and negative effects suggesting that the effect is region-specific. Another separate set of literature has looked at the effect of crop diversification on income variability (Guvele, 2001; Van den Berg et al. 2007) and found that crop diversification reduces income variability. Combining these two separate coins of previous research to look at how crop diversification affects both technical efficiency and income variability allows us the opportunity of seeing if there is a trade-off between efficiency and reduced income variability for households that choose to crop diversify. This is critical for the effective adoption and successful implementation of crop diversification.

The aim of this study is therefore to examine the effect of crop diversification on the technical efficiency and income variability of small holder farmers in northern Ghana. We use the stochastic input distance function and Ordinary Least Squares (OLS) for our analyses . Using the Agricultural Production Survey (APS) data on northern Ghana, which has a maximum of three crops per household, our findings suggest that crop diversification significantly improves technical efficiency and reduces income variability. Results from this study will be useful in informing Ghana's policy actions on increasing the adoption of crop diversification for increasing both resilience and efficiency for its vulnerable farmers.

2.0 Methods

2.1 Data

This study uses cross sectional data from the Agricultural Production Survey (APS) conducted in in Northern Ghana in 2016. The survey was funded by USAID under its Feed the Future initiative. Its sample size was 7,600 households randomly sampled through probability possibility sampling. The data collected during the survey included household demographic, production and marketing characteristics. The survey was completed in 5 visits during which information about the farmer's on going production was accurately recorded to minimize recall bias.

The survey focus was on three main crops being supported by USAID i.e., maize rice and soybean. Our crop diversification index is therefore based on these three crops. For fertilizer and seed inputs, the survey collected value of inputs used instead of quantity. So, for these inputs, we use value of input as a proxy for quantity in measuring technical efficiency. The survey did not collect data on output nor input prices. Summary statistics on the relevant variables used in this study are presented in Table 1 below. The choice of explanatory variables was based on previous literature.

Table 1: Summary Statistics on Key Variables

Variable	Description	N	Mean	SE	Min	Max
SID	SID index of diversification	7,138	0.68	0.18	0	1
CV Income	Coefficient of income variation	5,118	135.57	44.42	5.17	173.21
Age	Age in years	6,968	43.92	14.39	14	110
Male	1 if male	7,138	0.62	0.48	0	1
Household size	Number of people living in the household	7,138	9.52	6.10	0	68
No education	1 if no education	7,138	0.69	0.46	0	1
Elementary education	1 if elementary education	7,138	0.17	0.38	0	1
Secondary education	1 if secondary or higher education	7,138	0.03	0.17	0	1
US Beneficiary	1 if USAID beneficiary	7,138	0.32	0.47	0	1
Commercial	1 if commercial intent	6,824	0.86	0.35	0	1
Mechanized	1 if used mechanization	7,138	0.52	0.50	0	1
Improved seed	1 if used improved seed	7,138	0.17	0.37	0	1
Crop credit	1 if purchased crop credit	7,138	0.26	0.44	0	1
Fertilizer	1 if used fertilizer	7,138	0.73	0.44	0	1
Technology	1 if used other improved technologies	7,138	0.48	0.50	0	1
Technical assistance	1 if accessed technical assistance	7,138	0.30	0.46	0	1
Brong Ahafo	1 if lives in Brong Ahafo	7,138	0.15	0.36	0	1
Northern Region	1 if lives in Northern Region	7,138	0	0	0	1
Upper East	1 if lives in Upper East	7,138	0.21	0.41	0	1
Upper West	1 if lives in Upper West	7,138	0.18	0.39	0	1

The key variables of interest in this study are crop diversification, income variability and technical efficiency. Crop diversification is measured using the Simpson Index of diversification (SID) calculated as, $SID = 1 - \sum_{i=1}^{k}\left(\frac{A_i}{\sum_{i=1}^{k} A_i}\right)^2$, where A_i is the land size allocated to each crop i, $0 \geq SID \geq 1$, where 1 means complete diversification and 0 means no diversification.

To calculate income variability, we use the coeficient of variation which is defined as the standard devitaion divided by the mean (Brown 1998). The coeficient of variation is scale invariant and is also insensitive to units of measurement as compared to the standard deviation or variance (Jesper

2002). The draw back with our cross sectional data is that income variability is measured at a single time period as opposed to over a period of time, as in the case of panel data were variability is more plausibly measured and robust.

The input oriented technical efficiency is defined as $\frac{x}{x^*}$ where x is the observed input quantity and x^* is the minimum input quantity at which a given quantity of output can be observed (Henningsen 2013). Technical efficiency is a relative measure of managerial ability for a given level of technology (Bravo-Ureta et al. 2007). It is our measure of interest because growing more than one crop requires managing the allocation of resources across different crops.

2.3 Empirical Model

The parametric approach of measuring technical efficiency has the advantage of accounting for noise and allowing for conventional hypothesis tests to be done compared to its counterpart, the non-parametric approach (Coelli and Perelman 1996). As with previous studies, we use the SFA to account for inherent noise in our data since, particularly because we do not account for weather differenecs in measuring technical efficiency.

Given that we do not have price data in this study, we employ the input oriented distance function to measure technical efficiency and its causal relationship with crop divesification. The input oriented distance function measures by how much the input vector may be proportionally contracted when the output vector is held fixed (Coelli and Perelman 2000). Its advantage is that it does not require price data or explicit behavioural assumptions regarding cost minization or profit maximization compared to its alternative, the multiple output production function (Kumbhakar, Wang, and Horncastle 2015). For simplicity, the distance function is estimated parametrically using the Cobb Douglas production function which has the disadvantage of being less flexible compared to alternative forms such as the translog production function. The cobb douglas stochastic input distance function is specified as follows:

$$lnd_i = \sum_{i=1}^{m} \alpha_i lny_i + \delta + \sum_{j=1}^{k} \beta_j lnx_j \text{ , } for\ i = 1 \ldots N$$

Where y_i are the outputs, x_j are inputs and $\alpha, \delta\ and\ \beta$ are parameters to be estimated. After imposing the homogeneity of degree 1 restriction on inputs and normalizing using the kth input, the cobb douglas stochastic input distance function is specified as follows:

$$-lnx_k = \sum_{i=1}^{m} \alpha_i lny_i + \delta + \sum_{j=1}^{k-1} \beta_j ln(x_j/x_k) \ + \varepsilon_i$$

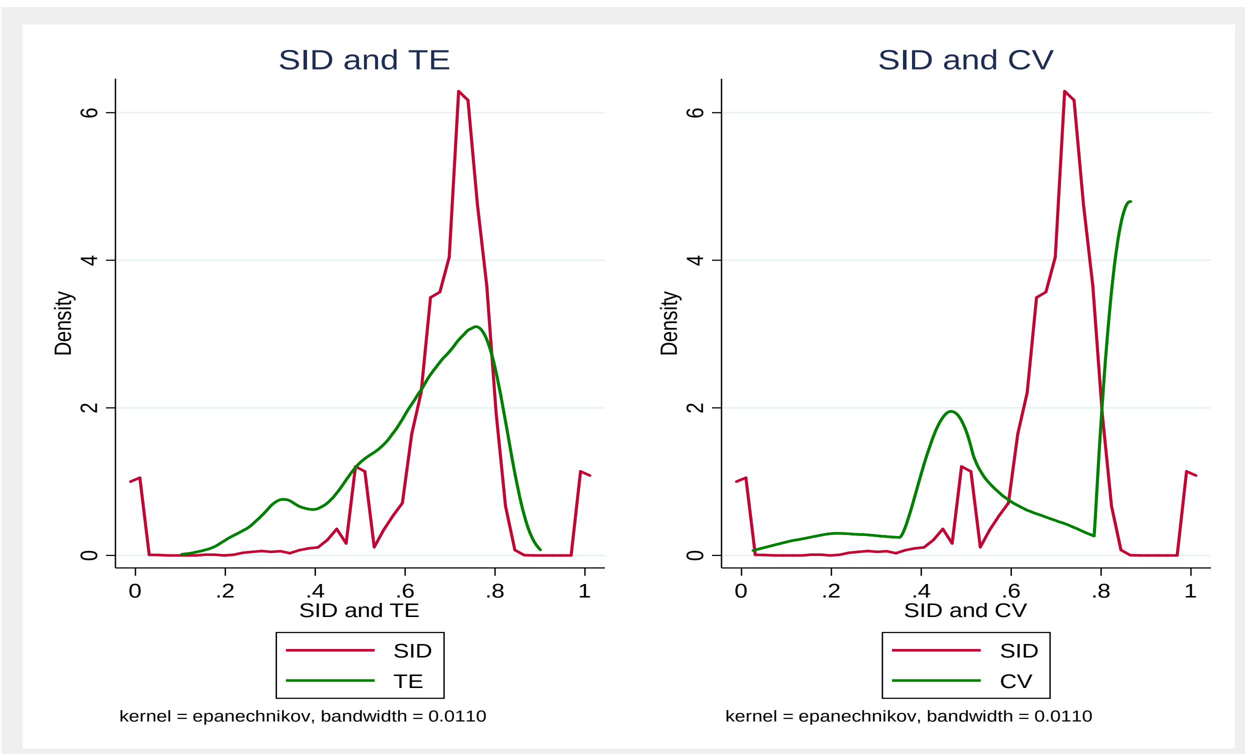
For i = Maize, rice and soybean output, j = land, labor, fertilizer and seed inputs. Where and $\varepsilon_i = v_i - u_i$ is the traditional SFA disturbance term composed of noise (v_i) and technical inefficiency (u_i). Since the inefficiency effect and the time invariant farmer-specific effects are different and should be accounted for separately in the estimation (Greene 2008), we include farmer fixed effects in our estimation so that the estimated inefficiency does not pick farmer specific heterogenity. To avoid the bias associated with a two-step approach of computing efficiency and regressing exogenous varibles on the efficiency index (Wang & Schmidt, 2002; Kumbhakar et al., 2015), we use a one step approach proposed by Kumbhakar et al., (2015).

For the effect of crop diversification on income variability, we adopt a two-step process used by (Poon and Weersink 2011), in which we calculate the income variance for each farmer in the first step and then regress the calculated variance on explanatory variables using OLS in the second step.

3.0 Results

The results show that on average, 31% of the farmers are inefficient with an average crop diversification index of 0.68. The variability of income ranges from 135 to 173. Figure 1 below shows the distribution of crop diversification, technical efficiency and income variability (normalized by the highest coefficient of variation) for households in our sample size. The figure suggests a postive relationship between crop diversification and technical efficiency and a somewhat inverse relationship between crop diversification and income variability.

Figure 1: Crop Diversification (SID), Technical Efficiency (TE) and Income Variability (CV)



The results show that crop diversification has a positive significant effect on technical efficiency. A 1 unit increase in the crop diversification index increases technical efficiency by 0.481. This supports the relationship depicted in Figure 1 above and coincides with the findings of

Rahman (2009) and Manjunatha et al. (2013). This shows that as farmers become more diversified, they also become more efficient. However, noting that our data is limited to only three crops, these results can not be generalised to farmers with more than three crops.

Interestingly, the results also show that technical efficiency is not significantly affected by the use of improved seed whereas it is positively impacted by the use of fertiliser, mechanization, access to credit and technical assistance. In addition, older farmers are significantly more efficient than younger farmers probably because they have more experience. larger households are also significantly more efficient than smallers ones possibly due to having more available labor.

The results also show that crop diversification has a significant negative effect on income variability. A 1 unit increase in the crop diversification index decreases income variability by 51.56 units. This is consistent with the findings of Guvele (2001) and confirms that crop diversification is a useful strategy for reducing income variability associated with producing crops unpredictable weather patterns. Other factors that significantly reduce income variability include farming with a commercial intent, access to credit and use of improved farming technologies.

Table 2: Estimated Coefficients

Variables	Efficiency		Income Variability	
	Coefficient	Standard Error	Coefficient	Standard Error
Age	0.00120**	0.0006	0.117***	0.0418
Household size	0.00900***	0.001	-0.293***	0.104
Male	0.453***	0.023	1.820	1.294
Elementary	-0.0304	0.022	3.243**	1.455
Secondary_post	-0.0981**	0.046	8.915***	3.276
Commercial intent	0.316***	0.033	-14.36***	1.924
Crop Diversification (SID)	0.481***	0.057	-51.56***	3.146
Used mechanization	0.298***	0.022	1.131	1.319
Purchased Crop credit	0.196***	0.019	-6.836***	1.401
Improved seed	-0.0284	0.029	-4.342**	1.995
Used fertilizer	0.286***	0.024	-11.05***	1.6
Farming technology	0.0339	0.022	-4.032**	1.629
Technical assistance	-0.0770***	0.028	2.997	1.971
USAID beneficiary	0.0618***	0.018	-5.363***	1.349
Brong Ahafo	0.0911***	0.028	28.59***	1.493
Upper East	-0.0519*	0.028	-23.28***	1.815
Upper West	-0.0567**	0.025	-4.531**	1.77
Constant	-0.597***	0.113	195.0***	3.925

*** p<0.01, ** p<0.05, * p<0.1
Efficiency model: n=6, 686
Income variability model: n=4,716; R-Squared = 20.4%

4.0 Discussion and Conclusion

Crop diversification positively affects technical efficiency implying that, for the case of a maximum of three crops, diversified farmers gain from allocating their resources to more than one crop. It is possible, however, that results may be different in the case where farmers are growing many more crops, in which case, their resources are expected to be more difficult to allocate. Further research can include more crops to see if and how the results change. Since, the effect of crop diversification on technical efficiency is region specific, northern Ghana is a case where 'the odds are in its favor'.

Consistent with previous literature, crop diversification contributes to income stability in northern Ghana. Coupled with its positive impact on technical efficiency, crop diversification should be a preferred CSA strategy for northern Ghana. Whereas, in other regions, farmers may possibly have to sacrifice efficiency for income stability, it is not so for farmers growing a maximum of three crops in northern Ghana.

A clear implication of these results is that heavy promotion of crop diversification as a climate smart agricultural strategy for northern Ghana may provide additional benefits of enhancing efficiency rather than just improving resilience. Other strategies that improve both technical efficiency and income stability include use of fertiliser, access to crop credit, farming for commercial purposes and participating in assistance programs such as USAID’s Feed the Future initiative.

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