International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 4 No. 2, 2016, pp. 125-135

EFFECT OF HUMAN CAPITAL ON MAIZE PRODUCTIVITY IN GHANA: A QUANTILE REGRESSION APPROACH

Isaac Nyamekye
Department of Resource Economics and Environmental Sociology, University of Alberta 515 General Services Building, Edmonton, Alberta, T6G 2H1, Canada, Tel: 1-780 680 3788. E-mail: inyameky@ualberta.ca.

Dela-Dem Doe Fiankor
Department of Agricultural Economics and Rural Development. Georg-August University of Göttingen, Germany.

Jonathan Okyere Ntoni
Department of Resource Economics and Environmental Sociology, University of Alberta, Canada.

Abstract

Agriculture continues to play an important role in the economy of most African countries. Thus, productivity growth in agriculture is necessary for economic growth and poverty reduction of the region. While, theoretically, investing in human capital improves productivity, the empirical evidence is somewhat mixed, especially in developing countries. In Ghana, maize is associated with household food security, and low-income households are considered food insecure if they have no maize in stock. But, due to low productivity, Ghanaian farmers are yet to produce enough to meet local demand. Using quantile and OLS regression techniques, this study contributes to the literature on human capital and productivity by assessing the effect of human capital (captured by education, farming experience and access to extension services) on maize productivity in Ghana. The results suggest that although human capital has no significant effect on maize yields, its effect on productivity varies across quantiles.

Keywords: *Productivity, human, capital, quantile, regression*
JEL Codes: C21; D13; O15; Q12

1. Introduction

Agriculture still plays an important role in the economy of most sub-Saharan African countries. Given that the sector contributes a third of total GDP and employs about two-thirds of the labour force, productivity growth in agriculture is a necessary tool for economic growth, development and poverty reduction (Båge, 2006; Pinckney, 1995; Pingali, 2007). Nevertheless, current productivity in the agricultural sector falls below Africa's potential and lags behind that of other developing regions (AGRA, 2013; Diao, Hazell, & Thurlow, 2010). While investing in the human capital base is regarded as one of the most effective ways to improve agricultural productivity (Bindlish & Evenson, 1997; Birdsall, Pinckney, & Sabot, 1999; Djomo & Sikod, 2012; Heckman, 2005; Huffman, 2001; Tripathi & Prasad, 2008), existing evidence in Africa is rather inconclusive (Appleton & Balihuta, 1996; Jamison & Lau, 1982; Pinckney, 1995).

According to Odusola (1998), "the concept of human capital formation refers to a conscious and continuous process of acquiring and increasing the number of people with requisite knowledge, education, skill and experience that are crucial for the economic and political development of a country". Theoretically, this concept is modelled around the hypothesis that human knowledge and skills directly raise productivity and increase an economy's ability to develop and adopt new technologies (de la Fuente, 2013). Several studies have shown that investing in human capital yields social rates of return much higher than on ordinary commercial ventures or physical capital (Birdsall et al., 1999; Kagochi & Jolly, 2010; Lucas, 1988; Romer, 1986, 1990; Umo, 2007). These high rates of return are partly due to the ability of human capital to raise the productivity and competitiveness of resources such as land, labour, and capital (Gallacher, 1999; Kagochi & Jolly, 2010; Kleynhans, 2006; Kwon, 2009; Schuh & Angeli-Schuh, 1989; Zubović, 2009). Becker (1964) and Drucker (1968) contend that knowledge as a form of human capital has become increasingly important in productivity and is thus regarded as the fourth economic pillar alongside land, labour, and capital. Knowledge is embedded in human beings by means of education and training, as well as through diverse forms of informal learning.

In agriculture, the workforce acquires knowledge through various educational systems. Rivera (1998) summarizes these into: formal education provided by mainstream educational institutions, non-formal agricultural and extension education systems, and mass media. Wouterse (2015) differentiates between the cognitive and non-cognitive effects of education in agriculture. The former refers to the formation of general skills of literacy, numeracy and transfer of specific knowledge. This may result in improved allocative efficiency, enabling farmers to follow written instructions for chemical inputs and calculate accurate dosages. Non-cognitive effects may result in changes in people's attitudes and preferences. Nevertheless, irrespective of its form, education improves productivity to a very significant extent (Rivera, 1998; ILO, 2008).

In Ghana, agriculture remains an important sector of the economy, despite falling behind services and industry in contributing to national GDP[1]. The agricultural sector employs about 60% of the workforce in Ghana (ISSER, 2014) and is regarded as the backbone of the economy. Maize is an important component in the dietary requirements of most Ghanaians. It is associated with household food security; a low-income household is considered food insecure if it has no maize in stock (Akramov & Malek, 2012; Sienso, Asuming-Brempong, & Amegashie, 2013). It is a vital constituent of poultry and livestock feed, as well as a substitute for the brewing industry. Maize accounts for 55% of national grain output and is the most important cereal crop on the domestic market (Sienso, Asuming-Brempong, & Amegashie, 2013).

Although maize productivity has been increasing over the years, Ghanaian farmers are yet to produce enough to meet national demand (Sienso et al., 2013). Data from FAOSTAT (Figure 1) shows Ghana's maize import quantities exceeding exports in most years since 1961. Average maize yields reported by the Ministry of Food and Agriculture (MoFA) in 2010 was 1.9 Mt/ha against an estimated achievable yield of 2.5 to 4.0 Mt/ha (MoFA, 2010); in contrast, per capita maize consumption increased from 38.4 kg/head/year in 1980 to 43.8 kg/head/year in 2010 (MoFA, 2010). This indicates how heavily the Ghanaian populace relies on maize and how domestic farmers are not producing enough. MoFA (2011) forecasted a shortfall between domestic production and consumption of 267,000 Mt by 2015 if there were no productivity improvements, prolonging the continual reliance on imports.

[1] Agricultural contribution to GDP decreased from 43.5% in 1990 to 21.5% in 2013 (GSS, 2014).

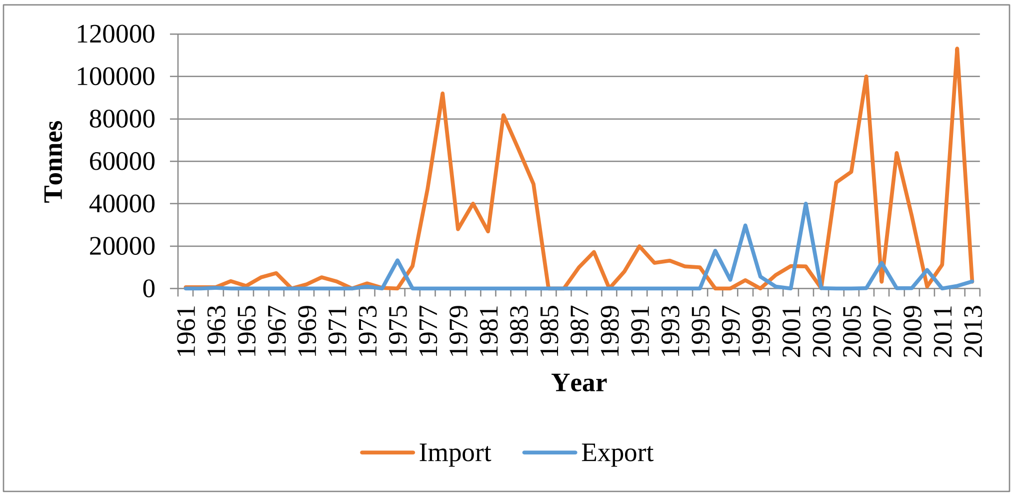

Figure 1. Ghana Maize Import and Export Trend 1961-2013

MOFA has, over the years, intensified the provision of agricultural extension services and other forms of public education targeted at improving human capital of the agricultural workforce, which they believe would lead to higher agricultural productivity (EPA-UNEP, 2010). These services are seen as efforts to promote innovation and the adoption of new technologies.

In theory, as discussed earlier, human capital is seen as education that augments cognitive and other skills, which in turn increases productivity (Becker, 1964; Schultz, 1961). Schultz (1961) emphasizes the role of education in improving farm efficiency and in modernizing agriculture. Empirically, however, studies that test Schultz's hypothesis show mixed results, especially from developing countries (Jamison & Lau, 1982; Lockheed, Jamison, & Lau, 1980; Yang, 1998). The main aim of this paper, therefore, is to examine the effect human capital has on maize productivity in Ghana. To achieve this objective, the study answers the following questions:

i. Does human capital affect maize productivity in Ghana?
ii. Are there differences in the effect of human capital across the various ecological zones?
iii. Are there differences in the effect of human capital across quantiles of the overall conditional distribution of maize yields?

2. Analytical Model

Following De la Fuente (2013), our analysis of the relationship between human capital and agricultural productivity is based on a Cobb Douglas production function:

$$Y_{it} = A_{it} K_{it}^{ak} H_{it}^{ah} L_{it}^{al}$$

where Y_{it} denotes the aggregate output of country i at time t, L_{it} is the level of employment, K_{it} the stock of physical capital, H_{it} the average stock of human capital per worker and A_{it} an index of total factor productivity which summarizes the current state of the technology and possibly omitted factors. The coefficients α_i (with $i = k, h, l$) measure the elasticity of output with respect to the stocks of the different factors. Under the standard assumption that the function displays constant returns to scale in physical capital and labour while holding average attainment constant, we can define a per capita production function that will relate average labour productivity to average schooling and to the stock of capital per worker.

This paper employs a Cobb Douglas production function within a quantile regression framework to investigate the productivity effects of human capital and other inputs of production over an entire distribution of maize yields across three ecological zones in Ghana. Human capital connotes the stock of knowledge, skills, and abilities embodied in individuals that determine their level of productivity (Schultz, 1961). In principle, it encompasses innate abilities and skills acquired through education, training and experience (Djomo & Sikod, 2012). In this paper, we capture human capital using education of household heads, access to extension services and experience defined by the number of years spent in farming. We estimate the economic effects of these variables at three points: the first quartile (25th percentile), the second quartile (50th percentile) and the third quartile (75th percentile) of the distribution of maize yields to analyse the category of farmers who are most efficient.

Koenker and Bassett (1998) first introduced quantile regression. It is viewed as a location model which seeks to extend the idea of linear regression to estimating "conditional quantile functions — models in which quantiles of the conditional distribution of the response variable are expressed as functions of observed covariates" (Koenker & Hallock, 2001). Quantile regressions thus permit a comparison of how the yield of the median farmer of a quantile responds to changes in its determinants relative to the response in the yield of any other farmer below or above that specific quantile.

According to Nafukho, Hairston, and Brooks (2004), one outcome of human capital investment is manifested in the form of improved individual performance and productivity. In this study, we assess the effect of human capital on productivity using maize yields as the outcome variable. Aside labour hours invested in farming, we control for other factors that impact maize productivity. The potential rise in labour productivity is linked to effective growth in knowledge (Huffman, 2001), which implies that the number of years in farming will affect productivity as farmers can benefit from accumulated experience. General literacy and numeracy skills also influence farmer efficiency, leading to productivity gains. We control for growth in knowledge using the household head's accumulated experience in maize farming, years of schooling and access to agricultural extension services. While the education level of other household members could be a relevant alternative in cases where household heads are illiterate, our data is rather limited in this regard.

Due to its ability to survive different soil and climatic conditions, maize is grown across almost all agro-ecological zones in Ghana. Nevertheless, we control for any potential differences in yields across the various zones using regional dummies. In Ghana, small-scale farmers contribute about 70% of total maize production (Angelucci, 2012). The scale of maize production affects yields as larger farms may be able to take advantage of economies of scale better than smaller farms. We consider farm size as an appropriate proxy.

As the potential to increase agricultural land area is increasingly limited, productivity-increasing external inputs have an important role to play. Agricultural management practices and input intensity adopted by farmers will determine crop yields. In Sub-Saharan Africa, most farmers have historically applied little irrigation and fertilizer to their crops (Shi & Tao, 2014) and only 6% of crop area receive irrigation supplies (Cenacchi & Koo, 2011). In Ghana, since maize production is mainly dependent on rainfall, we control for farmers' access to irrigation and fertilizer use, as these will affect their productivity. Given that pest prevalence is often higher in the tropics, we control for pesticide use. We also control for the level of technology and machinery available to farmers using the number of tractors available to them.

Farmer Based Organisations (FBOs) have proliferated in recent decades and about 10,000 farmer-based cooperatives were counted in rural Ghana in 2010 (Salifu, Francesconi &

Kolavalli, 2010). These organisations are seen as drivers of agribusiness development, especially in rural areas. One way they aim at increasing farmer welfare is through provision of credit, sharing of knowledge and increasing productivity. We therefore control for their potential effect on yields.

Adopting Buchinsky (1998)'s notation, we specify our model as:

$$Y_i = F(edu, exp, ae, lab, tr, fert, ins, cred, coop, farmsize, irr, reg) + u_i \qquad (1)$$

where u_i is the stochastic component of the farm yield for farmer *i* and F(.) is the deterministic component of maize yield; and $\boldsymbol{Y_i}$ is maize yield in kilograms. The right-hand side covariates are: ***exp,*** which is the number of years a farmer has been cultivating maize; ***ae*** is a dummy for access to Agricultural Extension services; **lab** is the hours of labour used; ***tr*** is the number of tractors available for agricultural purposes in the community; ***fert*** and ***ins*** are dummies for chemical fertilizers and insecticides use, respectively; ***edu*** is the number of years spent in school by the household head; ***cred*** is a dummy for access to credit; ***coop*** is a dummy for cooperative membership, ***farmsize*** is the land area (acres) used for maize production; ***irr*** is a dummy for access to irrigation, and ***reg*** is dummies for 2 out of the 3 ecological zones in Ghana, with the forest zone excluded to serve as a base category for comparison.

Employing a Cobb–Douglas production function, we estimate equation (1) using a quantile regression technique (Koenker & Bassett, 1998). Specifically, given a sample (y_i, x_i), i = 1,..., n, from some population, where x_i is a K * 1 vector of regressors, it is assumed that

$$y_i = x_i\beta_\theta + \mu_{\theta i} \qquad \text{(2a), then the}$$
$$Quant_\theta(y_i|x_i) = x_i\beta_\theta \qquad \text{(2b) and}$$
$$Quant_\theta(\mu_i|x_i) = 0 \qquad \text{(2c)}$$

where $Quant_\theta(y_i|x_i)$ denotes the conditional quantile of y_i, conditional on the regressor vector $\boldsymbol{x_i}$. According to Buchinsky (1998), if $F\mu_\theta(.)$ were known, then various techniques could be used to estimate β_θ. However, here the distribution of the error term, $\mu_{\theta i}$, is left unspecified. As implied by (2b), it is only assumed that $\mu_{\theta i}$ satisfies the quantile restriction $Quant_\theta(\mu_i|x_i) = 0$ (Buchinsky, 1998). The parameter vector β_θ is then obtained by minimizing the sum of the absolute deviations from an arbitrarily chosen quantile of maize yield across farmers.

In the case of equation (2), this sum is expressed as:

$$min \sum_{i=1}^{n} \left| y_{\theta i} - \sum_j \beta_{\theta j} x_{ij} \right|$$

where $y_{\theta i}$ is the maize yield for farmer *i* at quantile *θ(i=1..., n)*; x_{ij} is the covariate *j* (e.g., education) for farmer *i(j=1,k);* and *j* is the effect of covariate *j* on farm yield at quantile *θ*. The solution to equation (3) is then found by rewriting into a linear programming problem of the entire sample and applying linear programming computation algorithms (Evenson & Mwabu, 2001).

According to Koenker and Hallock (2001), asymptotic and bootstrapping methods can be used to obtain the standard errors and confidence limits for the regression estimates. Both methods provide robust results, but the bootstrap method is preferred, as it is more practical (Hao & Naiman, 2007). Therefore, the standard errors of our results as reported in this paper were obtained with the bootstrap approach. To allow for comparison, we also estimate with ordinary least square (OLS) and report the mean effects of the explanatory variables together with the quantile estimates.

3. Data

The study uses data from the fifth round of the Ghana Living Standard Survey (GLSS 5). The GLSS is a series of customized Living Standards Measurement Surveys conducted by the Ghana Statistical Service (GSS). Among other objectives, the GLSS 5 aimed at providing data on total earnings, hours of work and other labour market information for in-depth study of differentials among sectors of employment, branches of industry, occupations at geographic areas and between women and men (GSS, 2008). The scope of the GLSS 5 includes data on the household (i.e., housing characteristics, expenditure on food items consumed, crop production, agricultural inputs, assets, savings and loans), on the individual (i.e., demographic characteristics such as education, economic activity, health, tourism and migration) and on the community level (i.e., demographic characteristics of rural communities, education, economy and infrastructure, health and agriculture).

4. Results and Discussions

Columns (1), (2) and (3) of Table 1 present quantile regressions at the 25th, 50th and 75th percentiles, respectively, and column (4) presents results of the OLS regression. Before discussing the results, we carried out a series of diagnostic tests to ensure the robustness of our model. Since the data used is cross-sectional, there is a high potential for heteroscedasticity (Green, 2008). Therefore, we tested for heteroscedasticity in the OLS model using the Breusch-Pagan test. With a chi-square calculated at 1 df (0.60) less than the chi-square critical (3.841) and a p-value (0.4399) greater than the alpha level (0.05), we do not reject the null hypothesis of homoscedasticity. Secondly, we also ascertained whether or not our Cobb-Douglas production function has a constant return to scale by testing if the coefficients on the explanatory variables sum up to one. Since the p-value is greater than the 0.05 alpha level, we do not reject the null hypothesis of constant return to scale in our model.

The results from both the quantile regression (QR) and the OLS models (Table 1) suggest that all the human capital variables (experience, education and access to extension) do not have significant effects on maize yields. This result is consistent with Lockheed et al. (1980), who found that human capital does not significantly affect productivity in most developing countries where agriculture is traditional and no new methods and new crops are being tried. Another possible reason may be that formal education leads household members to disengage from agriculture through migration or increased participation in non-farm activities. On the other hand, land size, labour and insecticide use have a positive and significant effect on yields. Interestingly, contrary to our *a priori* expectation, being a member of a cooperative has a negative and significant effect on maize yields.

With regards to the impact of human capital across ecological zones with the forest zone as the base category for comparison, only the interaction term between savannah and access to extension is significant. The positive coefficient suggests that access to extension services by farmers in the savannah zone have a more positive effect on maize output, as compared to their counterparts in the forest zone. To further verify whether there is really a differential impact of human capital on maize yields across ecological zones using the OLS model, we did a joint significance test to see if the parameters on the human capital – ecological zone interaction terms are all equal. The test statistic of the F-test with 6 restrictions and 2,149 df is = 1.71 with p-value of 0.3209. Since the p-value is greater than the 0.05 alpha level, we do not reject the null hypothesis and thus conclude that human capital does not have significantly different effects on maize yields across ecological zones.

Table 1. Quantile and OLS Regression Estimates of the Maize Yield Function

	(1)	(2)	(3)	(4)
VARIABLES	**Q25**	**Q50**	**Q75**	**OLS**
Ln (experience)	0.0829 (0.562)	0.0918 (0.522)	0.0472 (0.302)	-0.0734 (-0.469)
Ln (education)	0.0731 (1.091)	-0.0340 (-0.520)	-0.00622 (-0.113)	0.0201 (0.443)
Ln (farmsize)	0.111** (2.084)	0.0620 (1.511)	0.0686* (1.899)	0.0841*** (2.919)
Ln (labour)	0.366*** (3.550)	0.429*** (6.498)	0.396*** (7.350)	0.395*** (8.173)
Access to credit	0.105 (1.514)	-0.0433 (-0.643)	-0.0356 (-0.559)	0.0211 (0.292)
Access to extension	0.0520 (0.224)	-0.186 (-1.189)	-0.137 (-1.233)	-0.127 (-1.071)
Coop	-0.212 (-1.503)	-0.274*** (-2.774)	-0.189** (-2.196)	-0.204*** (-2.698)
Tractors	-0.0632 (-0.312)	0.0580 (0.352)	-0.0154 (-0.0981)	-0.0449 (-0.395)
Fertilizer	0.0366 (0.237)	-0.0339 (-0.448)	0.0903 (0.918)	0.0739 (0.848)
Insecticide	0.616*** (3.836)	0.407*** (3.667)	0.390*** (4.058)	0.431*** (4.845)
Irrigation	0.667 (1.415)	0.327 (1.342)	0.0927 (0.369)	0.345 (1.428)
Coastal	-0.335 (-0.304)	-0.531 (-1.073)	-1.282* (-1.744)	-0.794 (-0.891)
Savannah	-0.462 (-0.317)	0.0949 (0.0540)	-1.244 (-0.979)	-0.685 (-0.664)
Coast_edu	-0.103 (-1.175)	0.00885 (0.126)	0.0224 (0.271)	-0.0344 (-0.531)
Coast_exp	0.0439 (0.149)	-0.00782 (-0.0556)	0.171 (0.878)	0.0817 (0.350)
Coast_ext	-0.164 (-0.642)	0.0906 (0.666)	-0.232 (-1.466)	0.0296 (0.158)
Savannah_edu	-0.100 (-0.666)	0.0938 (0.591)	0.0133 (0.0997)	-0.0487 (-0.519)
Savannah_exp	0.173 (0.468)	-0.101 (-0.228)	0.312 (1.039)	0.212 (0.787)
Savannah_ext	0.590* (1.928)	0.610*** (2.673)	0.662** (2.525)	0.494*** (2.586)
Constant	3.325*** (6.270)	4.817*** (6.989)	5.648*** (8.782)	5.089*** (8.350)
Observations	2,169			

Note 1: *** p<0.01, ** p<0.05, * p<0.1

Note 2: bootstrap t-ratios in parenthesis

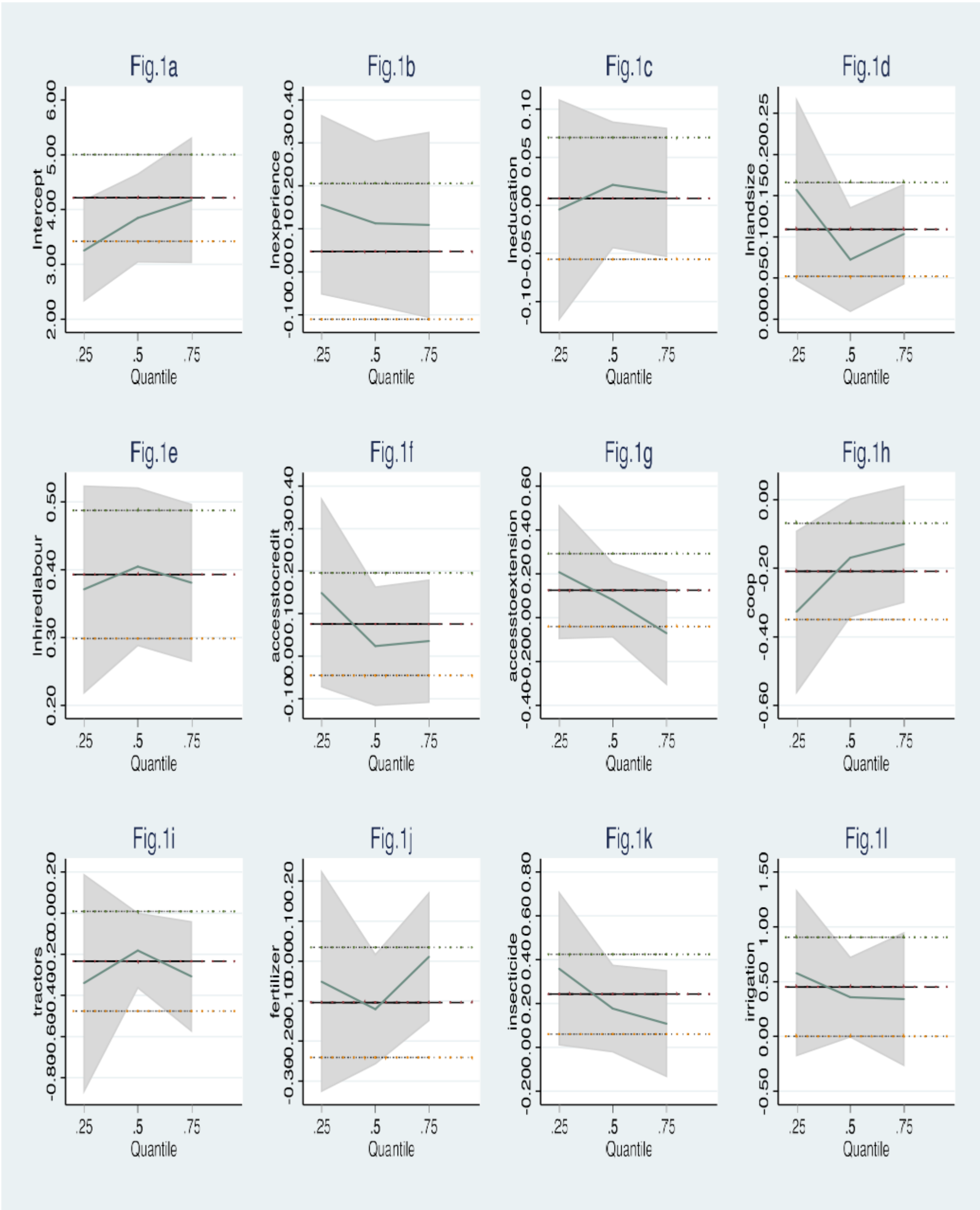

Figure 2. Quantile Regression Coefficients and Confidence Intervals for Selected Regressors as Quantiles Vary From 0 To 1

To assess the differences in the effect of human capital across different quantiles of the overall conditional distribution of maize yields, we use Figure 2 and the quantile regression coefficients in Table 1. From Table 1, although all the human capital variables are not significant, their coefficients show different relationships with maize output at different quantiles. For example, the coefficient on education is positive for the 25th quantile but negative for both the 50th and 75th quantiles. Similarly, the coefficient on access to extension is positive for the 25th quantile but negative for both the 50th and 75th quantiles. Since the coefficients are not significant, no substantive conclusion can be made here, but we argue that the effect of human capital on maize output varies across quantiles. This is also shown graphically in Figure 2, which indicates that from the 25th quantile, the effect of experience on output is negative until the 50th quantile, where it levels out to the 75th. The effect of education, on the other hand, indicates a positive effect as one moves from the 25th quantile towards the 50th; at the 50th quantile, it begins to show a negative effect.

5. Conclusion

In this paper, we investigate the effects of human capital on maize production in Ghana and examine whether it differs across ecological zones and quantiles of the conditional distribution of maize output. Adopting a Cobb-Douglas production function in a quantile regression framework, we find evidence to show that human capital does not significantly affect maize productivity in Ghana. The results also show that while the effect of human capital on maize output is not statistically different across ecological zones, farmers in the savannah zone benefit more from extension as compared to their counterparts in the forest zone. With respect to the impact across quantiles, it was found that human capital has different effects on farmers in the different quantiles.

The insignificant effect of human capital on maize productivity may primarily be due to the fact that the youth and people with higher education are mostly disengaged from agriculture, leaving it to the elderly and the uneducated. Agriculture in Ghana currently faces numerous challenges, such as poor feeder roads, inaccessible markets and storage infrastructure, which lead to high post-harvest losses and impede potential commercialisation of agriculture, thereby making it non-profitable and unattractive. For the agricultural sector to benefit from human capital development, the government and other stakeholders should make agriculture more appealing to the youth and those with higher education by tackling rural underdevelopment, inadequate infrastructure and access to markets.

References

AGRA. (2013). *Africa Agriculture Status Report: Focus on Staple Crops*. (J. von Braun, M. Bwalya, R. Cadwell, T. Elhaut, N. Ngongi, R. Osei, & G. Toenniessen, Eds.). Alliance for a Green Revolution in Africa, Nairobi, Kenya.

Akramov, K., & Malek, M. (2012). *Analyzing Profitability of Maize, Rice, and Soybean Production in Ghana: Results of PAM and DEA analysis*. Ghana Strategy Support Program (GSSP) Working Paper 28.

Angelucci, F. (2012). *Analysis of incentives and disincentives for maize in Ghana*. *Technical notes series, MAFAP*.

Appleton, S., & Balihuta, A. (1996). Education and agricultural productivity: Evidence from Uganda. *Journal of International Development*, *8*(3), 415–444.

Båge, L. (2006). *Seeds of Hope*. (G. Lean, Ed.). Agriculture and Economic Development: UNEP and the World Bank.

Becker, G. S. (1964). *Human Capital: A Theoretical and Empirical Analysis*. Princeton, NJ: Princeton University Press.

Bindlish, V., & Evenson, R. E. (1997). The impact of T&V extension in Africa: The experience of Kenya and Burkina Faso. *The World Bank Research Observer*, *12*(2), 183–201.

Birdsall, N., Pinckney, T. C., & Sabot, R. H. (1999). *Equity, Savings, and Growth*. Williamstown, MA: Williams College.

Buchinsky, M. (1998). Recent advances in quantile regression models : a practical guideline for empirical research. *The Journal of Human Resources*, *33*(1), 88–126.

Cenacchi, N., & Koo, J. (2011). Effects of drought tolerance on maize yield in Sub-Saharan Africa. In *Increasing Agricultural Productivity & Enhancing Food Security in Africa: New Challenges and Opportunities* (pp. 1–19).

de la Fuente, A. (2013). *Human capital and productivity*. Barcelona Economics Working Paper Series 530.

Diao, X., Hazell, P., & Thurlow, J. (2010). The role of agriculture in African development. *World Development*, *38*(10), 1375–1383.

Djomo, J. M. N., & Sikod, F. (2012). The effects of human capital on agricultural productivity and farmer's income in Cameroon. *International Business Research*, *5*(4), 149–159.

Drucker, P. (1968). *The Age of Discontinuity*. New York: Harper & Row.

EPA-UNEP. (2010). *National Programme on Sustainable Consumption and Production (SCP) For Ghana (2011-2016).*

Evenson, R. E., & Mwabu, G. (2001). The effect of agricultural extension on farm yields in Kenya. *African Development Review*, *13*(1), 1–23.

Gallacher, M. (1999). *Human Capital and Production Efficiency, Argentine Agriculture*. CEMA.

Green, W. H. (2008). *Econometric Analysis*. Canada: Pearson Prentice Hall.

GSS. (2008). *Ghana Living Standards Survey Report of the Fifth Round, (GLSS 5)*. Accra: Ghana Statistical Services.

GSS. (2014). *Ghana Living Standards Survey Report of the Sixth Round, GLSS 6*. Accra: Ghana Statistical Services.

Hao, L., & Naiman, D. Q. (2007). *Quantile Regression*. Sage Publications, Thousand Oaks.

Heckman, J. J. (2005). China's human capital investment. *China Economic Review*, *16*(1), 50–70.

Huffman, W. E. (2001). Human Capital: Education and Agriculture. In B. Gardner & G. Rausser (Eds.), *Handbook of Agricultural Economics* (Vol. 1, pp. 333–381). Elsevier B.V.

ILO. (2008). *Skills for Improved Productivity, Employment Growth and Development*. International Labour Conference, 97th Session, Geneva.

ISSER. (2014). *The state of the Ghanaian economy in 2013*. Legon, Accra: Institute of Statistical, Social and Economic Research.

Jamison, D. T., & Lau, L. J. (1982). *Farmer Education and Farm Efficiency*. Baltimore: Johns Hopkins Univ. Press.

Kagochi, J. M., & Jolly, C. M. (2010). R&D investments, human capital, and the competitiveness of selected U.S. agricultural export commodities. *International Journal of Applied Economics*, *7*(1), 58–77.

Kleynhans, E. P. J. (2006). The role of human capital in the competitive platform of South African industries. *SA Journal of Human Resource Management*, *4(3)*, 55–62.

Koenker, R., & Bassett, G. (1998). Regression quantiles. *Econometrica*, *46*(1), 33–50.

Koenker, R., & Hallock, K. F. (2001). Quantile regression. *Journal of Economic Perspectives*, *15*(4), 143–156.

Kwon, D.-B. (2009). *Human Capital and its Measurement*. The 3rd OECD World Forum on "Statistics, Knowledge and Policy" Charting Progress, Building Visions, Improving Life.

Lockheed, M. E., Jamison, D. T., & Lau, L. J. (1980). Farmer education and farm efficiency: a survey. *Economic Development and Cultural Change*, *29*(1), 37–76.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22(1)*, 3–42.

MoFA. (2010). *Agriculture in Ghana: Facts and Figures*. Accra: Statistical, Research and Information Directorate, Ministry of Food and Agriculture.

MoFA. (2011). *Agriculture in Ghana: Facts and Figures*. Accra: Statistical, Research and Information Directorate, Ministry of Food and Agriculture.

Nafukho, F. M., Hairston, N., & Brooks, K. (2004). Human capital theory: implications for human resource development. *Human Resource Development International*, *7*(4), 545–551.

Odusola, A. F. (1998). Human Capital Investment and the Empires of Economic Growth: The Nigerian Experience. In *Rekindling Investment for Economic Development in Nigeria*. Nigerian Economic Society (NES) Proceedings.

Pinckney, T. C. (1995). Human Capital and Agricultural Productivity. In *Policy and Rural Development: Two Communities in East Africa*. Williamstown, MA: Williams College Press.

Pingali, P. (2007). Agricultural growth and economic development: a view through the globalization lens. *Agricultural Economics*, *37*(1), 1–12.

Rivera, W. M. (1998). Agricultural extension as adult education: institutional evolution and forces for change. *International Journal of Lifelong Education*, *17*, 260–264.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*(10), 1002–1037.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(2), 571–602.

Salifu, A., Francesconi, G. N., & Kolavalli, S. (2010). A review of collective action in rural Ghana (No. 998). International Food Policy Research Institute (IFPRI).

Schuh, G. E., & Angeli-Schuh, M. F. (1989). *Human capital for agricultural development in Latin America*. The Inter-American Institute for Cooperation on Agriculture (IICA), Program Papers Series no. 11.

Schultz, T. W. (1961). Investment in human capital. *American Economic Review*, *51*(1), 1–17.

Shi, W., & Tao, F. (2014). Vulnerability of African maize yield to climate change and variability during 1961–2010. *Food Security*, *6*(4), 471–481.

Sienso, G., Asuming-Brempong, S., & Amegashie, D. P. K. (2013). Estimating the efficiency of maize farmers in Ghana. In *4th International Conference of the AAAE*. Cape Town, Hammamet, Tunisia.

Tripathi, A., & Prasad, A. R. (2008). Agricultural productivity growth in India. *Journal of Global Economy*, *4*(4), 322–328.

Umo, J. U. (2007). *Moving Nigeria into the new economy: A human capital perspective*. Presidential Address to the 48th Annual Conference of Nigeria's Economy.

Wouterse, F. (2015). Can human capital variables be technology changing? An empirical test for rural households in Burkina Faso. *Journal of Productivity Analysis*, 1–16.

Yang, D. T. (1998). Education in production: measuring labour quality and management. *American Journal of Agricultural Economics*, *79*(3), 764–772.

Zubović, J. (2009). Development of human capital as a tool for improving productivity of agricultural sector – case of Serbia. In *113th EAAE Seminar on the Role of Knowledge, Innovation and Human Capital in Multifunctional Agriculture and Territorial Rural Development*. Belgrade, Serbia.