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Agricultural Economics Research, Policy and Practice in Southern Africa

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ragr20

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To cite this article: Prince B. Annor, Simeon Kaitibie & Michael C. Lyne (2024) GlobalGAP compliance costs in Ghana's small-scale pineapple farming sector, Agrekon, 63:1-2, 82-96, DOI: 10.1080/03031853.2024.2374730

To link to this article: https://doi.org/10.1080/03031853.2024.2374730

Published online: 15 Jul 2024.

AGREKON
2024, VOL. 63, NOS. 1–2, 82–96
https://doi.org/10.1080/03031853.2024.2374730

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GlobalGAP compliance costs in Ghana's small-scale pineapple farming sector

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ABSTRACT

When farmers implement GlobalGAP they incur specific input costs that arise from quality requirements of the technology. However, due to the difficultly in observing and measuring food quality, previous empirical studies seldom analysed the relationship between quality improvements in food production and total costs of production. They assumed that product quality itself was exogenous and hence had no effect on productive efficiency or cost of production. This study estimates the impact of GlobalGAP on costs of production while accounting for fixed cost improvements and quality endogeneity. Data were obtained from GlobalGAP-certified small-scale pineapple farmers in Ghana. The hypothesis that product quality was exogenous was tested and rejected. Consequently, a quality-adjusted translog cost function was used to identify the main contributors to cost increases on small-scale GlobalGAP-certified pineapple farms. The estimated function exhibited economies of size, implying that most small-scale adopters are unable to increase output and benefit from lower average costs. Production costs arising from improvements in quality imposed by GlobalGAP are most sensitive to changes in plantlet price, followed by wages, agrochemical price and expenditure on capital items. Smaller small-scale farmers are much more sensitive to increases in capital expenditure than are larger small-scale farmers. Key policy recommendations include joint ventures to increase nursery capacity and competition in the market for plantlets, scrutiny of mandatory fees impacting the cost of imported labour-saving inputs, facilitating sharing arrangements between smallholders to lower the cost of on-farm infrastructure, and research to identify constraints preventing certified farmers from exploiting size economies.

ARTICLE HISTORY
Received 6 February 2024
Accepted 26 June 2024

KEYWORDS
Food safety standards; smallholders; compliance costs; product quality; translog cost function

JEL CLASSIFICATIONS
D24, O13

1. Introduction

Food safety standards can be categorised into two broad classes – public and private standards. Public food standards are set by international bodies and national governments (e.g., the Codex Alimentarius and KenyaGAP), whilst private food standards (PFS) are set by private organisations (e.g., specific retailers) or coalitions of private organisations (e.g., Global Good Agricultural Practices (GlobalGAP) and British Retail Consortium). Although both public and private food standards are

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intended to promote food quality and safety, the former are widely regarded as being less stringent as they tend to be diluted by other national interests (Lammerding 1997; Vandemoortele and Deconinck 2014; Wouters and Geraets 2012). As a result, PFS have become increasingly important in safeguarding food quality and safety (Barrett et al. 1999; 2022; Ouma 2010), particularly in the past three decades following significant international incidents of food-borne pathogens and diseases (Henson and Caswell 1999; Newell et al. 2010).

GlobalGAP is the most extensively used PFS in global fruit and vegetable supply chains (Henson et al. 2011; Rao et al. 2021). Opinions on the impact that PFS have on farmers and export production in developing countries are mixed. Some researchers argue that compliance with PFS acts as a catalyst in transforming food supply chains by upgrading farming practices and product quality, thereby improving smallholder competitiveness in global food markets (Asfaw et al. 2009a; Henson and Jaffee 2006; Henson et al. 2011; Kleemann et al. 2014; Ouma 2010). Others view standards as a barrier to trade (Fiankor et al. 2021) as tighter requirements increase production costs, making participation less affordable, particularly for smallholders (Augier et al. 2005; Martinez and Poole 2004; Maskus et al. 2005; Reardon et al. 2003; Schuster and Maertens 2015; Unnevehr 2000). With respect to GlobalGAP, and its forerunner EurepGAP, the weight of empirical evidence supports the notion of smallholder exclusion (Humphrey 2017).

The Ghanaian case in this study aligns with the view that tighter food safety standards increase production costs making it difficult for small-scale farmers to engage in export-oriented production. Ghana's horticultural industry generates significant export earnings and employment opportunities for producers, processors and traders (Mensah and Brummer 2015). However, pineapple exports declined after 2004, and smallholder participation in the export market declined sharply after 2007 when GlobalGAP was introduced (FAO 2023; Kuwornu and Mustapha 2013). Smallholders accounted for more than 50% of Ghana's pineapple exports when the volume of exports peaked in 2004 (Gatune et al. 2013), but their share dropped to 30% in the late 2010s (Kpare 2016) raising concerns about the nature and magnitude of compliance costs on small pineapple farms. GlobalGAP adoption requires significant investment in fixed improvements such as chemical and equipment storage facilities, and recurring fixed costs linked with employee training, record keeping and farm surveillance by internal and external auditors (Yudin and Schneider 2012). As a result, average production costs are relatively high for smallholders who adopt GlobalGAP as they are unable to spread incremental fixed costs over a large harvest. This makes GlobalGAP a less attractive investment for smallholders, discouraging their adoption and participation in export markets. In their recent study, Quartey et al. (2023) estimated that only 17% of 345 small-scale pineapple farmers surveyed in four of Ghana's leading export pineapple production districts were GlobalGAP certified. Annor et al. (2023) found that adoption of GlobalGAP by small-scale famers sampled in two of these four districts reduced the net incomes of smallholders cultivating less than one hectare of pineapples.

Empirical studies discussed later in this paper (Asfaw et al. 2009b; Graffham and Vorley 2005; Muriithi et al. 2011) show that GlobalGAP compliance significantly increases smallholder production costs when fixed costs are considered. These studies estimated the financial costs of GlobalGAP compliance, but they did not assess the impact of quality improvements on costs despite a well-established literature linking increased operating costs or attendant productivity losses to improvements in food safety or quality (Antle 2000). This is a notable gap in the literature as policymakers need to target interventions at the most important drivers of quality-enhancing compliance costs. The gap is bridged in this study, which aims to identify inputs that contribute the most to higher production costs when GlobalGAP is implemented on small-scale pineapple farms in Ghana.

Many structural cost function studies in the food industry and beyond (e.g., Boland et al. 2001; FSIS 1996; Robinson and Phibbs 1990) have characterised product quality as an exogenous unobserved variable that is assumed to be uncorrelated with other exogenous variables. In this case, standard cost functions can produce consistent estimates of important parameters. However, this assumption is almost certainly incorrect as quality is typically endogenous and is explained by the right-hand-side exogenous variables of the firm's production function (Gertler and Waldman

1992). Antle (2000) used a quality-adjusted cost function to investigate quality endogeneity in a study of Hazard Analysis and Critical Control Points (HACCP) compliance while focusing only on the relationship between HACCP compliance and variable costs of production. Fixed costs were ignored as they accounted for less than 10% of the total cost of implementing HACCP. By contrast, fixed costs account for a significant share of GlobalGAP compliance costs (Asfaw et al. 2009b; Kuwornu and Mustapha 2013). Therefore, this study considers total costs of production, including fixed costs which were measured as annualised expenditure on fixed improvements, durable assets and fixed recurring costs.

This research is relevant because it is important to inform interventions aimed at helping Ghana's small-scale pineapple farmers cope with the costs of GlobalGAP compliance. Compliance is expected to promote food quality and safety more generally, and to improve smallholder access to export markets for a range of products. Section 2 of this paper locates our research within a small but growing body of literature examining the costs of GlobalGAP compliance incurred by small-scale farmers, highlighting its contribution to methodology and its potential for well-targeted policy recommendations. Section 3 describes the methods and data used in the research. Section 4 presents and discusses empirical findings, while Section 5 draws conclusions and offers policy recommendations. Although this study focuses on the sensitivity of production costs to inputs used by small-scale pineapple farmers in Ghana to meet GlobalGAP requirements, the methods presented in Section 3 could be usefully applied in other settings where PFS compromise smallholder participation in premium markets. This includes countries like South Africa where domestic supermarkets offer promising opportunities for inclusion (Dannenberg 2013; Manderson 2015).

2. GlobalGAP compliance costs on small farms

GlobalGAP is a private food standard that has been adopted globally and is generally acknowledged as the most significant production standard in the supply chain for fresh produce (Henson et al. 2011; Rao et al. 2021). GlobalGAP replaced the former EurepGAP standard in 2007 with the aim of broadening farmers' focus on production to include a thorough understanding of the wider health and safety ramifications of their operations and products on consumers. It is a comprehensive standard that covers all aspects of agricultural operations, including site selection, preparation, harvesting, and on-farm processing (Humphrey 2008). Certified growers must meet the minimum requirements specified for key criteria to mitigate adverse effects of their production practices on food quality and safety (Yudin and Schneider 2012).

Adopting GlobalGAP can promote farmers' access to premium markets as it offers assurance of food quality and safety. However, meeting GlobalGAP specifications requires substantial investment in fixed improvements and recurring costs. Although costs vary by country, the cost elements are relatively similar across countries. In Ghana, compliance costs typically incurred by GlobalGAP adopters include investment in fixed improvements (disposal pit, toilet, changing room and separate storerooms for chemicals, equipment, and produce) and recurring costs for protective clothes, farm surveillance, soil testing and fumigation, plastic mulching, traceability, training and certification (Kuwornu and Mustapha 2013). In practice, exporters often help smallholders to meet certification costs through part-funding and technical services, whilst donors and government agencies assist with training, information and advice relevant to GlobalGAP standards (Asfaw et al. 2009b; Kersting and Wollni 2012; Kleemann et al. 2014). Despite these services provided by the private sector and government, the remaining costs incurred by farmers pose a significant financial burden, especially for smallholders.

Most studies reporting smallholder costs of compliance with the former EurepGAP standard show that these costs are substantial (Muriithi et al. 2011). Graffham and Vorley (2005), for example, estimated that the investment (capital) cost of EurepGAP compliance accounted for 5–33% of the gross margin estimated for donor-supported small-scale vegetable farmers in Zambia, and 26–60% of the gross margin estimated for non-supported smallholders. Recurring maintenance costs added a further 1–8% and 9–53% for donor supported and non-supported smallholders, respectively.

More recent studies report similar results for GlobalGAP compliance. In her Kenyan study of 103 small-scale French bean farmers, Muriithi et al. (2011) estimated that GlobalGAP compliance added US$1836 to annual production costs incurred by a smallholder operating independently, and US$680 to annual production costs incurred by a member of a GlobalGAP-certified group comprising 30 smallholders. These cost increases were large enough to result in negative net returns given yields and prices observed at the time of the study. Also in Kenya, Asfaw et al. (2009b) estimated that the cost of GlobalGAP compliance accounted for 30% of crop revenue earned by small-scale vegetable farmers in their sample of 149 certified respondents, with most (90%) of this additional cost attributed to fixed improvements and equipment. Certification fees alone accounted for 11% of gross income in a sample of 226 small-scale Chilean raspberry growers (Handschuch et al. 2013), and a study of 236 small-scale pineapple farmers in Ghana attributed 16% of total production costs solely to the fixed costs of GlobalGAP compliance (Annor et al. 2023).

It is important to identify and address the drivers of cost increases in any campaign that seeks to promote smallholder adoption of GlobalGAP standards. This requires estimation of the farm-level cost function. Maskus et al. (2005) used a transcendental logarithmic (translog) cost function to estimate the effects of export market standards on production costs using firm-level data (159 firms) from 16 developing countries. They found that the standards imposed by major importing countries raised short-term production costs because firms had to hire more labour and make new capital investments. Similarly, Antle (2000) employed a translog cost function to investigate the impact of HACCP implementation on production costs in the United States' meat processing industry using plant-level data from the 1992 Census of Manufactures. Antle's study is relevant because it used a quality-adjusted translog cost function developed by Gertler and Waldman (1992) to account for a likely relationship between food product quality standards and the productive efficiency of meat processing firms. Of further relevance is that the cost of food safety regulation per pound of meat was found to be size neutral except for the smallest processing plants. This result was predictable because the fixed costs of implementing HACCP are modest and the total cost comprises mostly (≈ 90%) variable costs. The situation is quite different when the fixed costs of compliance are high and output levels are low, as in this study which seeks to identify cost drivers that government and industry stakeholders can address to promote GlobalGAP adoption on small pineapple farms in Ghana. The method of analysis described in Section 3 follows Antle (2000, 1999) and Gertler and Waldman's (1992) quality-adjusted translog cost function.

3. Materials and methods

3.1 Sampling technique and data collection

A multistage sampling procedure was followed to select a sample representative of small-scale pineapple farmers operating in areas with high export potential. Following Clarke (2010), small-scale farmers were defined as those operating farms no larger than five hectares. First, two districts, Akuapem South and Awutu Senya-West, were purposively chosen based on the volume of pineapple output, the involvement of small-scale farmers in pineapple production, and intensity of GlobalGAP adoption. These districts are in the southern horticultural belt of Ghana and share common socio-economic and ecological attributes. Akuapem South and Awutu Senya-West are Ghana's largest and second largest districts for commercial pineapple production. Their proximity to Ghana's two major exporting hubs, Tema Harbour and Kotoka International Airport, makes them competitive in export pineapple production. These districts also host many estate farms that manage out-grower and contract schemes to procure additional pineapples from certified smallholders. Second, five communities with the largest populations of small-scale pineapple farmers were selected within each district. Sampling frames were constructed by listing all the small-scale pineapple farmers in each selected community. Third, farmers were drawn randomly at the same rate (43%) from each list, generating a useable sample of 546 cases. Of these, 236 were GlobalGAP-certified farmers and they provided the information used in this analysis of compliance costs. Both written and verbal consent was sought from respondents prior to data collection and the confidentiality of their data was assured. Human ethics approval for this work was granted by the Lincoln University Human Ethics Committee (ref: HEC2021-22) on 7 July 2021.

Data relating to household, farmer and farm characteristics (including pineapple yields, prices and expenses) were gathered in personal interviews conducted with household heads from July to September 2021. Crop data were specific to the 2019/2020 production season. Responses were recorded in a structured questionnaire and supplemented with personal observations made by the enumerators when they visited each respondent.

3.2 Empirical model specification

This section develops a cost function for a competitive market where farmers producing quality differentiated pineapples are price takers. Their production process generates output y with quality q. Quality is usually produced when farmers adopt and maintain GlobalGAP standards. Following Antle (2000, 1999) the quality-adjusted cost function for pineapple production is specified as.

$$C(y, q, \mathbf{w}, K) = VC(y, q, \mathbf{w}, K) + QC(q, \mathbf{w}, K) + FC(K), \quad (1)$$

where VC is variable cost of production which depends on both output y and product quality q (e.g., costs associated with the use of approved agrochemicals and extra labour needed to comply with GlobalGAP). QC is quality control cost, a separate variable cost that is independent of y but depends on q (e.g., costs of farm surveillance, soil and product tests, and record keeping), FC is a fixed cost component of capital K (e.g., investment in on-farm fixed improvements and equipment, training costs and recurring certification costs) measured as annualised expenditure, and $\boldsymbol{w}$ denotes a vector of exogenous input prices. The cost function can be estimated using a variety of functional forms, including Cobb–Douglas, constant elasticities of substitution, variable elasticity of substitution, and the translog (Chaudhary et al. 1998). We used the translog function to estimate C. The translog function is widely used in empirical cost studies owing to its flexibility and tractability (Greene 2012, 312).

The translog cost function integrates the input demand functions into the output supply function and employs input prices rather than input quantities (Chaudhary et al. 1998). We considered prices of key inputs including labour w_L, pineapple plantlet w_A, agrochemical w_M, and expenditure on capital items K. Other inputs such as fuel, electricity, and water account for a very small share of pineapple production costs in Ghana and their prices were omitted from our empirical cost function. We specified the translog cost function as.

$$\begin{aligned} lnC = {} & \propto_0 + \propto_y lny + \propto_q lnq + \propto_l lnw_L + \propto_a lnw_A \\ & + \propto_m lnw_M + \propto_k lnw_K + \frac{1}{2}\beta_{yy}(lny)^2 \\ & + \beta_{yq} lnylnq + \beta_{yl} lnylnw_L + \beta_{ya} lnylnw_A + \beta_{ym} lnylnw_M + \beta_{yk} lnylnK \\ & + \frac{1}{2}\beta_{qq}(lnq)^2 + \beta_{ql} lnqlnw_L + \beta_{qa} lnqlnw_A + \beta_{qm} lnqlnw_M + \beta_{qk} lnqlnK + \frac{1}{2}\beta_{ll}(lnw_L)^2 \\ & + \beta_{la} lnw_L lnw_A + \beta_{lm} lnw_L lnw_M + \beta_{lk} lnw_L lnK + \frac{1}{2}\beta_{aa}(lnw_A)^2 + \beta_{am} lnw_A lnw_M \\ & + \beta_{ak} lnw_A lnK + \frac{1}{2}\beta_{mm}(lnw_M)^2 + \beta_{mk} lnw_M lnK + \frac{1}{2}\beta_{kk}(lnK)^2. \end{aligned} \quad (2)$$

Applying Shephard's lemma, the cost shares of inputs – labour S_L, plantlet S_A, agrochemical S_M and capital S_K are given as

$$S_L = \propto_l + \beta_{yl} lny + \beta_{ql} lnq + \beta_{ll} lnw_L + \beta_{la} lnw_A + \beta_{lm} lnw_M + \beta_{lk} lnK \quad (3)$$

$$S_A = \propto_a + \beta_{ya} lny + \beta_{qa} lnq + \beta_{aa} lnw_A + \beta_{la} lnw_L + \beta_{ak} lnK + \beta_{am} lnw_M \quad (4)$$

$$S_M = \propto_m + \beta_{ym} lny + \beta_{qm} lnq + \beta_{mm} lnw_M + \beta_{lm} lnw_L + \beta_{mk} lnK + \beta_{am} lnw_A \quad (5)$$

$$S_K = \propto_k + \beta_{yk} lny + \beta_{qk} lnq + \beta_{kk} lnw_k + \beta_{lk} lnw_L + \beta_{mk} lnw_M + \beta_{ak} lnw_A. \quad (6)$$

We imposed symmetry ($\beta_{ij} = \beta_{ji}$) and linear homogeneity restrictions in input prices such that $\propto_l + \propto_a + \propto_m + \propto_k = 1$, $\beta_{yl} + \beta_{ya} + \beta_{ym} + \beta_{yk} = 0$ and $\beta_{ql} + \beta_{qa} + \beta_{qm} + \beta_{qk} = 0$. To avoid perfect multicollinearity when the model is estimated with its full complement of share equations, the adding up restriction was imposed by excluding one of the share equations, in this case, share Equation (4) for plantlets (S_A).

The relevance of product quality in determining the structure of production and undertaking related-policy analyses is well documented in the economics literature on quality-adjusted cost functions. Antle (2000), following earlier work by Gertler and Waldman (1992), stressed that quality is typically endogenous, implying that it is imposed by the firm and thus, linked to exogenous factors in the firm's cost function. However, since quality is unobserved and difficult to measure (Paudyal et al. 2017), many studies ignore it altogether and estimate quality exogenous cost models (e.g., Boland et al. 2001; FSIS 1996). In such situations, estimates of model parameters are prone to bias and inferences may be misleading. In addition, assuming that quality is exogenous implies that product quality has no effect on the firm's productive efficiency (Antle 2000); therefore, significant cost increases accompanying GlobalGAP implementation are assumed not to constrain production. To address these concerns, we developed both quality-adjusted and quality exogenous cost models. We specified the quality-adjusted cost model using observable quality demand factors as instruments for quality on the basis that these variables do vary across farms and hence can be used to identify cost function parameters (Antle 2000). The quality exogenous model, on the other hand, excluded all quality terms from the cost and share equations. We further tested for potential quality endogeneity with the null hypothesis that the coefficients of quality and its interaction terms are equal to zero.

Following Gertler and Waldman (1992), quality is represented as a function of observable demand factors; product price p, exogenous input prices (labour w_L, plantlet w_A, agrochemical w_M and capital expenditure K) and other variables affecting demand like per capita household income H and Q_m the quantity mix, which measures the share of export quality pineapple in the farm's total pineapple output. To develop the quality adjusted cost function, we follow the approaches of Antle (2000) and Rosen (1974). Our analysis assumes that farmers are price-takers in the output market. Consequently, in a competitive industry with product differentiation, the demand function for pineapple is represented as $y^d = D(p, q, \boldsymbol{z})$, with its market supply represented as $y^m = M(p, q, \boldsymbol{w}, K)$ where $\boldsymbol{z}$ is a vector of other variables that affect demand, and the remaining terms are as defined above. Both demand and supply functions satisfy conventional properties. In addition, product demand is an increasing function of quality, $D_q > 0$ while market supply is a decreasing function of quality, $M_q < 0$. In equilibrium, equating supply and demand and solving for quality produces the quality function $q = F(p, \boldsymbol{z}, \boldsymbol{w}, K)$. Thus, the equilibrium quality function is specified as.

$$lnq = \lambda_0 + \lambda_p lnp + \lambda_{qm} lnQ_m + \lambda_h lnH + \propto_l lnw_L + \propto_a lnw_A + \propto_m lnw_M + \propto_K lnK. \quad (7)$$

Income elasticity of demand for quality should be positive for a normal good. However, according to Rosen (1974) derivatives of q with respect to $\boldsymbol{z}$ (e.g., household income H) produce signs that are opposite to those in the demand function.

We imposed restrictions to aid parameter identification and estimation. Following Gertler and Waldman (1992), we dropped the quadratic form of quality (β_{qq}) in the cost function from further consideration to reduce the number of regressors; in addition, the quadratic term is less important than the first order term (β_q) which can be used to measure quality on its own. As is common to all latent variable models, this model is identified only up to an arbitrary factor of proportionality (Aigner et al. 1984). The reason is that the latent quality variable has no unit of measurement.

Without loss of generality, an arbitrary normalisation sets a metric for quality and completes the identification of the model; hence, one of the parameter estimates of quality interaction terms, in this case the interaction between quality and labour price ($\beta_{ql} = 1$), is normalised to 1. In addition, the intercept of the latent quality variable is not identified, hence λ_0 in the quality function is normalised to zero. The estimates of the cost function are invariant to the normalisation. We derive the analytical model by substituting for quality (Equation 7) in the cost, and cost share equations (i.e., Equations 2, 3, 5, and 6). The ensuing system of equations was estimated via the nonlinear seemingly unrelated regression (NLSUR) in SAS.

The estimated parameters of the quality-adjusted cost function, which individually have little economic meaning, were used to compute cost elasticities that provide insights into the overall impact of input price increases on production costs (Binswanger 1974). Cost elasticities with respect to output (E_y), quality (E_q), factor inputs – labour (E_L), plantlet (E_A), agrochemical (E_M) and capital (E_K) are given by the functions.

$$E_y = \propto_y + \beta_{yy} lny + \beta_{yq} lnq + \beta_{yl} lnw_L + \beta_{ya} lnw_A + \beta_{yk} lnK \tag{8}$$

$$E_q = \propto_q + \beta_{yq} lny + \beta_{ql} lnw_L + \beta_{qa} lnw_A + \beta_{qk} lnK \tag{9}$$

$$E_L = \propto_l + \beta_{yl} lny + \beta_{ql} lnq + \beta_{ll} lnw_L + \beta_{la} lnw_A + \beta_{lk} lnK \tag{10}$$

$$E_A = \propto_a + \beta_{ya} lny + \beta_{qa} lnq + \beta_{aa} lnw_A + \beta_{la} lnw_L + \beta_{ak} lnK \tag{11}$$

$$E_M = \propto_a + \beta_{ym} lny + \beta_{qm} lnq + \beta_{am} lnw_A + \beta_{lm} lnw_L + \beta_{am} lnK \tag{12}$$

$$E_K = \propto_k + \beta_{yk} lny + \beta_{qk} lnq + \beta_{kk} lnw_k + \beta_{lk} lnw_L + \beta_{ak} lnw_A. \tag{13}$$

4. Results and Discussion

4.1 Descriptive statistics of participating farmers

Table 1 presents statistics computed for the sample of 236 GlobalGAP-certified small-scale pineapple farmers. The demographic statistics compare favourably with estimates reported by Quartey et al. (2023) and Kleemann et al. (2014) in their respective studies of GlobalGAP and organic-certified pineapple farmers in Ghana. Household heads have a mean age of 46 years and 80% are men. They completed a modest 7.3 years of formal schooling, but averaged 13 years of experience as pineapple growers and eight years as certified GlobalGAP growers. There is little variation in mean family size (6 persons) suggesting that these households had similar access to family farm labour.

One-third of these farm households engaged in market contracts with exporters, and almost two-thirds used extension services. On average, they cultivated approximately one hectare of pineapples using 48,715 plantlets, 156 l of agrochemicals, 212 man-days of labour, and capital items costing GH₵4794 to produce 58,507 kg of pineapples at a farmgate price of GH₵1.22 per kilogram. Prices of plantlets, agrochemicals and labour averaged GH₵0.18 per plantlet, GH₵33 per litre and GH₵42 per man-day, respectively. Quantity mix, an indicator of quality-differentiated product, averaged 85% implying that GlobalGAP adopters produce mainly high-quality export pineapples. Mean household income was GH₵8134 per person.

In estimating production costs, we considered key inputs for pineapple production and GlobalGAP certification. These included costs of labour, plantlets, agrochemicals and expenditure on capital items. Total annual production cost averaged GH₵27,187 per hectare. Pineapple plantlets accounted for the largest share of total costs (32%), followed closely by labour (31%), agrochemicals (20%) and capital (17%). Kleemann (2016) found similar results where pineapple plantlets contributed the largest share of total production costs, followed by agrochemicals, labour and capital for pineapple smallholders in Ghana.

Table 1. Variable definitions and summary statistics.

Variable	n	Definition	Mean	SE
Explanatory variables				
Age household head	235	Age of de-facto household head (years)	46.41	0.67
Gender household head	236	Gender of household head (1 = male, 0 = female)	0.80	0.03
Formal education	235	Formal education (years)	7.28	0.24
Household size	236	Household size (number of people)	5.75	0.13
Experience in farming	233	Experience in pineapple farming (years)	12.79	0.47
GlobalGAP membership	225	Years of GlobalGAP certification membership	8.44	0.16
Contract membership	227	Contract membership (1 = yes, 0 = no)	0.34	0.03
Extension service	228	Access to extension service (1 = yes, 0 = no)	0.64	0.03
Household income *(H)*	232	Household income per capita	8,134.26	536.89
Pineapple farm size	232	Area planted to pineapples (ha)	0.98	0.04
Plantlet (*A*)	232	Pineapple plantlet quantity (count/ha)	48,714.91	1,649.52
Plantlet price (w_A)	232	Pineapple plantlet price (GH₵/count)	0.18	0.00
Labour (*L*)	232	Labour (man days/ha/year)	212.29	7.75
Labour price (w_L)	232	Price of labour (GH₵/day)	41.63	0.24
Agrochemical (*M*)	232	Agrochemical quantity (l/ha)	156.16	2.07
Agrochemical price (w_M)	232	Price of agrochemical (GH₵/l)	33.24	0.23
Quantity mix (Q_m)	232	Share of export quality pineapple in total pineapple output	0.85	0.01
Capital (*K*)	236	Cost of capital (GH₵/ha)	4,793.60	190.31
Pineapple output (*y*)	232	Pineapple yield (kg/ha)	58,507.32	1,139.36
Pineapple price (*p*)	232	Pineapple price (GH₵/kg)	1.22	0.04
Dependent variable				
Production cost	232	Cost of production per hectare (GH₵/ha)	27,187	524.94
Cost shares				
Labour (S_L)	232	Share of labour cost in total production cost	0.31	0.00
Plantlet (S_A)	232	Share of plantlet cost in total production cost	0.32	0.01
Agrochemical (S_M)	232	Share of agrochemical cost in total production cost	0.20	0.00
Capital (S_K)	232	Share of capital expenditure in total production cost	0.17	0.00

Note: GH₵ is Ghanaian currency (US1 = GH₵6.01).

4.2 Effect of quality on cost of production

Table 2 presents the parameter estimates of quality-adjusted and quality exogenous cost functions. Both models are statistically significant but there are differences in the signs and magnitudes of parameter estimates between the models, suggesting that estimating one for the other could lead to misleading estimates. Thus, it is necessary to conduct a test for quality exogeneity. We postulate that quality exogeneity holds if $\propto_q$, β_{yq}, β_{qm} and β_{qk} are all significantly different from zero. The null hypothesis of quality exogeneity was rejected (Wald $\chi^2 = 8429$; $p = 0.000$), suggesting that the quality-adjusted cost function is more appropriate. This result also implies that GlobalGAP implementation imposes attendant costs that are likely to constrain the farm's productive efficiency. For these reasons, our discussion of results focuses on the quality-adjusted cost function and the inputs most responsible for rising production costs.

The quality-adjusted cost function has five parameter estimates corresponding to quality and all of them are significantly different from zero. The imposition of linear homogeneity allows the cost function to exhibit concavity with respect to most of the factor prices. In the quality function, the parameter estimate for household income is negative but should be interpreted as positive following Rosen's (1974) explanation of the derivatives of q with respect to $\boldsymbol{z}$. The income elasticity of demand for quality is therefore estimated to be positive, as expected for a normal good. Parameters estimated for quantity mix and pineapple price are not statistically significant.

This study further investigates the quality attributes of the production technology by assessing parameter estimates of quality interactions with both factors and output. The negative interaction terms between quality and factor prices indicate that higher factor prices may lead to a lower marginal cost of quality. Similarly, the negative interaction term between quality and capital suggests that for a given level of output, increasing capital lowers the marginal cost of quality. Finally, the negative interaction term between output and quality suggests that higher levels of output

Table 2. Parameter estimates for translog cost functions.

	Quality-adjusted		Quality exogenous	
Dependent variable: production cost (GH₵/ha)	Parameter	SE	Parameter	SE
Intercept	−3.63	7.56	−5.70	7.51
Ln(Output)	1.48	1.36	1.71	1.35
Ln(Quality)	0.49*	0.27	–	–
Ln(Labour price)	−0.23**	0.11	2.03***	0.24
Ln(Plantlet price)	0.00	0.05	−1.40***	0.16
Ln(Agrochemical price)	1.20***	0.09	0.86***	0.13
Ln(Capital)	0.04*	0.02	−0.49***	0.10
$(\text{Ln(Output)})^2$	−0.01	0.12	−0.01	0.12
Ln(Output)*Ln(Quality)	−0.01**	0.00	–	–
Ln(Output)*Ln(Labour price)	−0.22***	0.03	−0.19***	0.02
Ln(Output)*Ln(Plantlet price)	0.24***	0.01	0.26***	0.01
Ln(Output)*Ln(Agrochemical price)	0.01	0.01	−0.05***	0.01
Ln(Output)*Ln(Capital)	−0.02**	0.01	−0.02***	0.01
Ln(Quality)*Ln(Plantlet price)	−0.31***`	0.03	–	–
Ln(Quality)*Ln(Agrochemical price)	−0.46***	0.03	–	–
Ln(Quality)*Ln(Capital)	−0.23***	0.01	–	–
$(\text{Ln(Labour price)})^2$	0.38***	0.08	0.06**	0.02
Ln(Labour price)*Ln(Plantlet price)	−0.04	0.04	−0.07***	0.01
Ln(Labour price)*Ln(Agrochemical price)	−0.28***	0.05	0.04*	0.02
Ln(Labour price)*Ln(Capital)	−0.06***	0.01	−0.02***	0.00
$(\text{Ln(Plantlet price)})^2$	0.18***	0.01	0.16***	0.01
Ln(Plantlet price)*Ln(Agrochemical price)	−0.08***	0.02	−0.04***	0.01
Ln(Plantlet price)*Ln(Capital)	−0.06***	0.01	−0.05***	0.00
$(\text{Ln(Agrochemical price)})^2$	0.38***	0.05	0.07***	0.02
Ln(Agrochemical price)*Ln(Capital)	−0.02***	0.01	−0.07***	0.00
$(\text{Ln(Capital)})^2$	0.14***	0.00	0.14***	0.00
Quality function				
Ln(Pineapple price)	−0.23	0.19		
Ln(Quantity mix)	−0.00	0.10		–
Ln(Household income per capita)	−0.07***	0.02		–

Note: ***, ** and * imply statistical significance at 1%, 5% and 10% levels respectively, and Ln denotes natural log.

reduce the marginal cost of quality. These outcomes are possible in the short run when certified pineapple farms are producing below capacity. This phenomenon is exhibited in the aggregate in Figure 1, where the quality adjusted production technology (as well as the quality exogenous production technology) shows decreasing marginal cost and hence economies of size. The cost elasticity of output was estimated to be positive but less than unity ($E_y = 0.04$), further emphasising diminishing marginal cost and hence size economies, a phenomenon evident in other smallholder studies (e.g., Etienne et al. 2019; Kunzekweguta, Rich and Lyne 2017; Müller and Theuvsen 2015; Mwangi and Kariuki 2015; Nakhumwa and Hassan 2003) and usually attributed to liquidity and management constraints.

The aggregate relationship between cost and quality is of policy relevance. The results graphed in Figure 2 show that constant increases in quality incur successively larger increases in production costs ($E_q = 1.13$). This finding is consistent with evidence reported earlier that Ghana's pineapple exports, and smallholders' share of these exports, both declined markedly after the introduction of GlobalGAP in 2007. Revisions of the GlobalGAP standard that result in more stringent quality requirements are likely to exclude more small-scale pineapple from Ghana's traditional export markets unless compliance costs can be mitigated. Section 4.3 identifies the most important cost drivers affecting our sample of certified small-scale pineapple famers.

4.3 Factor contributions to total cost of production

It is characteristic of all flexible functional forms that interpreting parameters is often challenging due to the many linear, quadratic and cross product terms. To aid the interpretation of the

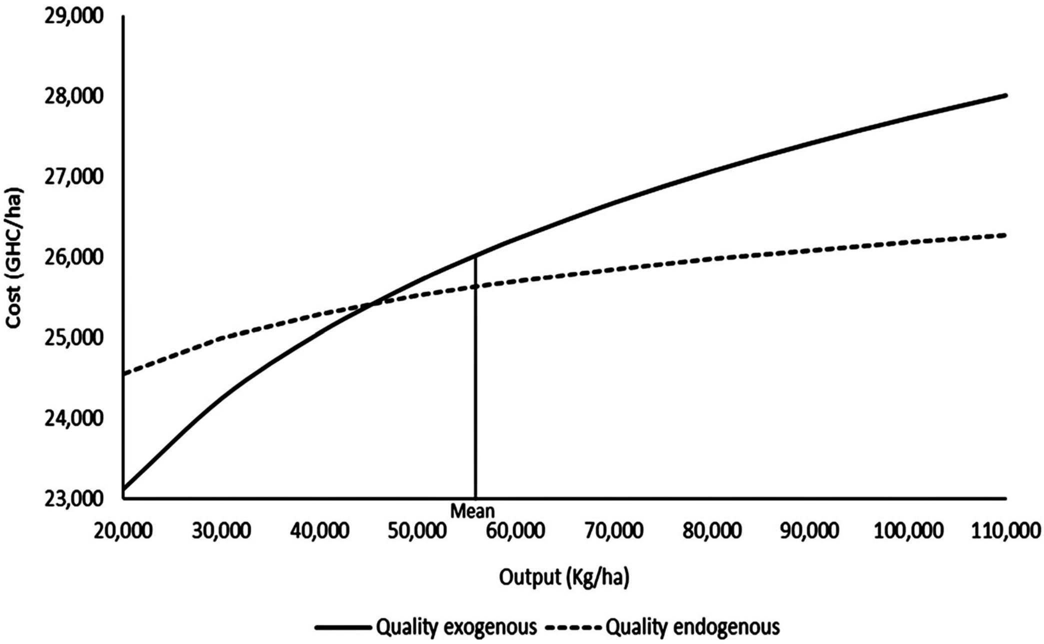

Figure 1. Quality endogenous and quality exogenous output cost curves.

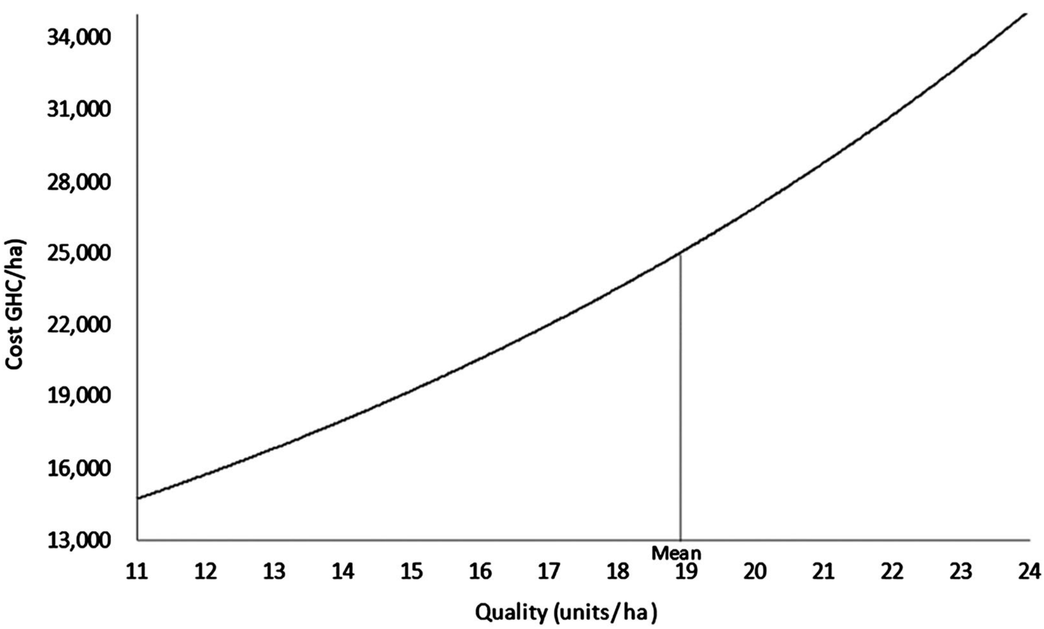

Figure 2. Quality cost curve.

output in Table 2, we estimated cost elasticities for both quality-adjusted and quality exogenous cost models. Table 3 presents cost elasticities with respect to output, quality and input prices.

Cost elasticities with respect to input prices are all positive but less than unity, indicating that increases in factor prices increase production costs but at decreasing rates. Production cost is most sensitive to plantlet price, which has cost elasticity of 0.42, followed by wages and the price

Table 3. Cost elasticities with respect to output, quality and input prices ($n = 232$).

	Quality-adjusted	Quality exogenous
Output (E_y)	0.04	0.11
Quality (E_q)	1.13	–
Plantlet price (Ew_A)	0.42	0.32
Labour price (wage) (Ew_L)	0.31	0.30
Agrochemical price (Ew_M)	0.20	0.20
Capital (E_K)	0.17	0.17

Note: Cost elasticities are computed using parameter estimates in Table 2.

of agrochemicals with cost elasticities of 0.13 and 0.20 respectively. This ranking follows the cost shares reported in Table 1 and matches the ranking reported by Kleemann (2016) in her study of smallholder pineapple production costs in Ghana. GlobalGAP certification requires plantlets that are relatively expensive, and pineapple farming is labour intensive with many on-farm operations, such as weeding and pest control, performed manually rather than with agrochemicals. Labour intensity increases when farmers comply with GlobalGAP as certification requires additional labour and management time for monitoring and surveillance, record keeping and reporting, and ongoing training and consultation with technical experts.

Capital expenditure accounts for the smallest share of production cost and has the lowest cost elasticity ($E_K = 0.17$). However, this cost share, and hence the cost elasticity of capital, was expected to be higher on smaller farms in the sample as virtually all capital expenditure relates to costs that do not vary directly with output (Table 4). The factor cost elasticities reported in Table 5 shows a marked difference in the importance of capital expenditure as a driver of production costs on smaller and larger small-scale pineapple farms.

Table 5 compares farms of size less than 1 ha with the remaining sample farms of size 1–5 ha. Cost elasticities computed for the prices of plantlets, labour and agrochemicals are similar across the two farm size groups. This was expected as both groups use the same production technology and the costs of using these inputs vary with output. Capital expenditure, on the other hand, has a substantial fixed cost component resulting in a higher cost share and higher cost elasticity on smaller farms. Using a cut point of 1 ha, the cost elasticity of capital in the smaller farm size group ($E_K = 0.20$) is almost double that in the larger size group ($E_K = 0.11$) resulting in different rankings of cost drivers on smaller and larger certified small-scale pineapple farms. Expenditure on fixed improvements and durable assets required to meet GlobalGAP requirements is clearly of greater concern to pineapple farmers at the lower end of the farm size spectrum. It is evident in Table 4 that small-scale farmers reduce their capital expenditure by sharing expensive infrastructure like storerooms for chemicals and equipment. This creates opportunities for further cost reduction through

Table 4. Capital expenditure.

	Item	Annualised cost[2] (GH₵/ha)	Costs added by certification
Fixed improvements	Changing room	1,239.57	✓
	Workers' toilet	1,240.42	✓
	Chemical store[1]	520.52	✓
	Equipment room[1]	415.65	✓
	Disposal pit	413.30	✓
	Water and irrigation improvement	184.54	✓
Movable assets	Disposal bin	208.85	✓
	Sprayer	390.48	
	Cutlass	128.26	
	Hoe	52.02	
Total capital expenditure		4,793.61	100.0

Notes: [1] denotes capital items shared by a farmer group. [2] Annual costs of fixed improvements and durable assets were computed using the capital recovery method with a real annual discount rate of 5%. Shared improvements are expected to last much longer (20 years) than on-farm improvements (5 years) owing to their durable materials.

Table 5. Size heterogeneity of quality-adjusted factor cost elasticities.

	Smaller farms (≤1 ha)	Larger farms (1–5 ha)
Plantlet price (Ew_A)	0.40	0.45
Labour price (wage) (Ew_L)	0.31	0.31
Agrochemical price (Ew_M)	0.18	0.23
Capital (E_K)	0.20	0.11
n	152.00	80.00

Note: Cost elasticities are computed using parameter estimates in Table 2.

interventions that support shared infrastructure. Policy recommendations are considered in Section 5.

5. Conclusion and recommendations

Previous studies have shown that production costs increase substantially when smallholders comply with GlobalGAP compliance, and that fixed costs account for a significant share of these additional costs. However, there is little information about the impact that specific inputs used by GlobalGAP-certified farmers have on production costs. Such information would help policymakers to target interventions at the most important drivers of quality-enhancing compliance costs and make adoption of GlobalGAP more affordable to smallholders and less expensive for taxpayers who fund these interventions.

Given that quality is latent and difficult to measure, few structural cost function studies have accounted for quality, leading to inconsistent parameter estimates and poor inferences. Moreover, the assumption that quality is exogenous implies, erroneously, that GlobalGAP implementation does not affect the farm's productive efficiency, even though the additional costs of production could be prohibitive – especially on small farms. This study adds to the literature by developing a quality-adjusted cost function to analyse the cost of pineapple production for small-scale GlobalGAP-certified farmers in Ghana. Cost of production comprises variable inputs costs and expenditure on capital items. Capital expenditure was measured as the annualised cost per hectare of fixed improvements and durable assets.

Study findings show that parameter estimates and elasticities from the quality-adjusted model and the quality exogenous model are different. Consequently, ignoring quality endogeneity is likely to generate misleading results. Certified small-scale pineapple farmers are most sensitive to increases in plantlet price, followed by wages, agrochemical prices and expenditure on capital items. However, smaller small-scale farmers are much more sensitive to increases in capital expenditure than are larger small-scale famers. The findings also show that certified small-scale producers are unable to exploit size economies, a likely manifestation of liquidity and management constraints. At the same time, improvements in product quality are increasingly costly to achieve. These small-scale pineapple farmers would benefit from interventions that lower the cost of plantlets and labour-saving agrochemicals, while interventions that reduce capital expenditure would be of particular value to smaller small-scale pineapple farmers struggling to make profits in the export market.

These findings lend support to the following recommendations: First, the government should seek joint ventures with exporters and large-scale corporate growers to increase nursery capacity and price competition in the market for plantlets. Second, industry organisations (e.g., Sea-Freight Pineapple Exporters of Ghana) should engage with the government to review the cost of importing agrochemicals and farm machinery and equipment. These costs include tariffs and multiple fees imposed by government agencies for inspections and permits. Third, consideration should also be given to formalising, facilitating and co-funding cost-sharing arrangements between smallholders for expensive infrastructure. Lastly, more research is needed to establish the extent and causes of constraints that are preventing certified small-scale farmers from exploiting size economies in GlobalGAP-certified pineapple production.

Acknowledgements

We acknowledge and extend thanks to the research assistants and respondents who participated in the sample survey.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Lincoln University.

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