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COMPONENTS OF FARM-LEVEL PRODUCTIVITY IN INTEGRATED CROP-LIVESTOCK FARMING SYSTEMS IN GHANA: THE ROLE OF MIX EFFICIENCY

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Abstract

This paper investigates the components of farm-level total factor productivity (TFP) and examines the role of mix efficiency in integrated crop-livestock systems in Ghana. A Färe-Primont productivity index is estimated and decomposed into various efficiency components. The result suggests that, mix inefficiency is consistently greater than technical and scale inefficiency. However, input-mix inefficiency was found to be higher than output mix inefficiency which suggests that crop-livestock farmers are relatively able to obtain gains in productivity from altering their output mixes more than altering input mixes. Future research and development efforts on mix efficiency in crop-livestock farming and agriculture in general need to take account of examining input-mix inefficiency. Strategies to improve productive efficiency in the Ghanaian agriculture should also emphasize improvements in mix efficiency such as policies that induce farmers to alter their input and output mixes.
Keywords*: Mix efficiency, integrated crop-livestock systems, productivity analysis.*
JEL Codes*: D24, Q12*

1. Introduction

Productivity increases are essential to the growth of an economy as it enhances the competitiveness of producers within the economy. The components of farm-level total factor productivity (TFP) and the role of mix efficiency are examined in integrated crop-livestock farming systems in Ghana. Ghanaian agriculture is characterised by the inability of farmers to alter inputs and output mixes once production begins, and this is of great concern. Subsequently, examining the role of mix efficiency provides useful insights for understanding which inputs and outputs mixes can be explored to obtain gains in productivity in crop-livestock systems. In this study, farm-level data is used to compute the Färe-Primont total factor productivity (TFP) index and decomposed into various efficiency measures. The role of mix efficiency as a component of TFP in the context of integrated crop-livestock farming is further discussed.

TFP has until recently been decomposed into technical change, technical and scale efficiency. However, recent advances have led to further decomposition into technical, scale and mix efficiencies (O'Donnell, 2012). Mix efficiency refers to changes in input or output mixes that result in an increase in productivity. Mix efficiency is aimed at increasing TFP by reallocating input or output combinations, whereas, allocative efficiency leads to the selection of input mixes which leads to minimum costs but may not necessarily increase productivity (Kumbhakar and Tsionas, 2005; O'Donnell, 2014).

In this study, mix efficiency is referred to as a measure that increase productivity from changes in input or output mixes; hence, we refer to a decrease in productivity resulting from such changes as mix inefficiency. Most farmers in Sub-Saharan Africa are naturally in an environment where livestock production is highly and positively correlated with crop production (Owen, *et al*., 2004; Owen, *et al*., 2005). As a result, they tend to be vulnerable to mix inefficiency, also because of the high dependence on family labour and rainfall. In addition, in the short run, basic production inputs such as land, labour and capital tend to be limited for these farmers. Furthermore, time lags in the adoption of improved technologies, and risks associated with input allocation and could also increase input-mix inefficiency (Hadley, *et al*., 2013). On the output side, the adaptation of crops and livestock to certain production conditions such as water requirements, drought tolerance and the market demand for the products could limit the extent to which output mixes could be changed to enhance productivity. To understand the dynamics of mix efficiency in a holistic manner, we investigate it from both input-oriented and output-orientations in crop-livestock systems. This will allow for better understanding of changes in which inputs and outputs combinations could lead to increase overall productivity among smallholder farmers in Ghana.

Additionally, productivity gains can be achieved through policies such as taxes and subsidies especially if farmers are able to explore synergies through efficient input and output mixes. In this case, farmers may substitute certain inputs and outputs mixes for the other in response to certain policies and, in the process, obtain an increase in farm productivity. A typical example of such policy in Ghana is the fertilizer subsidy programme which has the incentive to permit cost savings in production. In this paper, the data envelopment analyses (DEA) approach the TFP and mix efficiency, examined using both the output and input orientations. This will inform demand-driven micro-level, district/regional-based agricultural policies that have direct relevance on productivity at both district and farm levels.

This paper adds to the empirical evidence of the contributions of mix efficiency to total factor productivity particularly in an integrated crop-livestock context. It further presents a comprehensive approach to understanding the dynamics of mix efficiency by evaluating from both the output and input orientations. This provides useful insights for future agricultural research and development by identifying whether changing input mixes or output mixes is desirable for increasing crop-livestock productivity. Information spawned from the study can aid research and policy in terms of the relevance of whether input or output oriented mix efficiency can easily be adjusted to improve crop-livestock productivity.

The rest of the study proceeds as follows: Section two presents a review of relevant literature on efficiency and productivity in agriculture. Section three discusses the methodology employed to compute the TFP indices and subsequent efficiency decompositions. Section four presents a description of our data. The empirical results and discussion of the results are presented in Section five. Finally, Section six presents the conclusions and policy recommendations.

1.1 Total Factor Productivity in Agriculture

A number of studies have examined ways of improving the productivity and efficiency of farming systems in developing countries (Abdulai et al., 2013; Asante et al., 2014; Donkoh et al., 2013; Ogundare, 2014; Bravo-Ureta, et al., 2014; Temoso, Villano & Hadley, 2016; O'Donnell, 2014). Especially because of its relevance in view of the current trends in climate change that has led to reduction in viable arable land for production in developing economies (World Bank, 2014).

To estimate mix efficiency, TFP index numbers are computed and further decomposed into various measures of efficiency including scale efficiency, technical efficiency and mix efficiency. The TFP indices can be estimated using SFA and DEA approaches (Kumbhakar et al. 2014; O'Donnell, 2014; Coelli *et al.* 2005). TFP refers to the ratio of aggregate output to aggregate input. A number of indices has been proposed and applied to estimate TFP including Paasche, Laspeyres, Fisher, Tornquist, Lowe, Färe-Primont and Hicks-Moorsteen TFP indices. Extensive discussions on the merits and demerits of these indices into various efficiency measures are discussed in O'Donnell (2011; 2012; 2014) and empirical applications using DEA has comprehensively been explored (Coelli, *et al.*, 2002; Coelli and Rao, 2005; Rahman and Salim, 2013).

In this paper, the Färe-Primont TFP index is computed and decomposed into its components. The Färe-Primont TFP satisfies all regularity conditions of index numbers. It also does not depend on assumptions about the nature of the production technology, the firm's optimising behaviour, structure of markets, returns to scale and prices (O'Donnell, 2012). Furthermore, the Färe-Primont index can be decomposed into six finer efficiency measures, namely, technical change, technical efficiency change, scale efficiency change, mix-efficiency change, residual mix-efficiency change and residual scale-efficiency change (output or input-oriented) and their respective levels. The Färe-Primont TFP index is computed using the DEA approach.

2. Methodology

2.1. Analytical framework

This paper uses the DEA linear programming to estimate the production technology and related levels of productivity and efficiency (including technical efficiency, scale efficiency, and mix efficiency) in both input and output orientations using the Färe-Primont TFP index (O'Donnell, 2011). This index is used because it satisfies all desirable regularity conditions of index numbers and the fact that it does not require price data for its computations. The subsequent section summarises the Färe-Primont index as proposed by O'Donnell, 2011 and a description of how mix efficiency and other associated efficiencies are estimated.

2.1.1. The Färe-Primont TFP index

Following O'Donnell (2010), we define the TFP index for a multi-input, multi-output farm in a single time period as:

$$TFP_i \equiv \frac{Y_i}{X_i} \tag{1}$$

where $Y_i = Y(y_i)$ is an aggregate output, $X_i = X(x_i)$ is an aggregate input, and Y(.) and X (.) are nonnegative, nondecreasing and linearly homogeneous aggregator functions. The associated index number that measures the TFP of firm *i* relative to the TFP of firm *h* in the same period is given as:

$$TFP_{h,i} \equiv \frac{Y_i}{X_i} = \frac{Y_i / X_i}{Y_h / X_h} = \frac{Y_{h,i}}{X_{h,i}} \tag{2}$$

where $Y_{h,i} = Y_i / Y_h$ is an output quantity index and $X_{h,i} = X_i / X_h$ is an input quantity index.

O'Donnell (2011) shows that the estimated aggregate outputs and inputs can be represented by the following nonnegative, nondecreasing and linearly homogenous Färe-Primont aggregator functions as:

$$X_{(x)} = D_I(x_0, y) \tag{3}$$

$$Y_{(y)} = D_O(x_0, y) \tag{4}$$

where x and y are vectors of input and output quantities, respectively, and $D_I(.)$ and $D_O(.)$ are the Shepherd input and output distance functions(Shephard, 1970), respectively, representing the production technology available in a given period. According to O'Donnell (2010, p. 539), the homogeneity and monotonicity properties of these functions makes them natural candidates of an input and output aggregator function. Then, following O'Donnell (2011), the associated Färe-Primont TFP index number is given as follows:

$$TFP_{h,i} = \frac{D_O(x_0, y_i)}{D_O(x_0, y_h)} \frac{D_I(x_h, y_0)}{D_I(x_i, y_0,)} \tag{5}$$

2.1.2. Measures of efficiency

The computed TFP index in equation 5 is further decomposed into finer measures of efficiency. Based on the index, O'Donnell (2011 p. 4) suggests that most economic measures of efficiency can be defined as the ratios of TFP measures. Thus, within the aggregate quantity framework, the estimated TFP index is decomposed into alternative measures of efficiency in terms of orientation as:

$$TFPE_n = ITE \times IME \times RISE = ITE \times ISE \times RME \tag{6}$$

$$TFPE_n = OTE \times OME \times ROSE = OTE \times OSE \times RME \tag{7}$$

where the input- and output-oriented technical efficiencies (ITE/OTE) measures, the minimum/minimum possible aggregate input/outputs to produce a given level of aggregate output/inputs. As noted by O'Donnell (2014), the input-oriented and output-oriented mix efficiencies (*IME/OME*) measures the potential increase/decrease resulting from economies/diseconomies of scope in input use/output combinations. Residual scale efficiencies (*RISE/ROSE*) denote the ratio of TFP at a technically efficient and mix-efficient point to TFP at a point of maximum productivity, and the residual mix efficiency (*RME)* "can be viewed as the component that remains after accounting for pure technical and pure scale efficiency effects" (O'Donnell, 2014, p. 263).

2.2. Estimating the Färe-Primont Index and Mix Efficiency Using DEA

The Decomposition of Productivity Index Numbers (*DPIN 3.0*[1]) program is used to estimate the production technology and associated efficiency measures using Data Envelopment Analysis (DEA) linear programming (LP) (O'Donnell, 2011). Following O'Donnell, (2011), the main assumption underpinning the use of DEA is that the (local) input/output distance function representing the technology available for a given period is represented by:

[1] DPIN is a computer software program developed by O'Donnell (2010) to estimate and decompose productivity index numbers. For details, see O'Donnell (2010, 2011).

$$D_I(x_i, y_i) = (x_i^{'}\eta)/(y_i\phi - \delta) \tag{8}$$

$$D_O(x_i, y_i) = (y_i^{'}\alpha)/(\gamma_i + x_i^{'}\beta) \tag{9}$$

The standard input-oriented DEA problem involves selecting values of the unknown parameters in equation (8) to maximize $ITE_i = D_I(x_i, y_i)^{-1}$. Whereas in the output orientation, $OTE_i = D_O(x_i, y_i)^{-1}$ is minimized by selecting values of the unknown parameters in equation (9), thus resulting in the following LPs:

$$D_I(x_i, y_i)^{-1} = ITE_i^{-1} = \max_{\phi,\delta,\eta}\left\{y_i\phi - \delta : Y^{'}\phi \le \delta l + X^{'}\beta; x_i^{'}\eta = 1; \phi \ge 0; \eta \ge 0\right\} \tag{10}$$

$$D_O(x_i, y_i)^{-1} = OTE_i^{-1} = \min_{\alpha,\gamma,\beta}\left\{\gamma + x_i^{'}\beta : \gamma l + X^{'}\beta \ge Y^{'}\alpha; y_i^{'}\alpha = 1; \alpha \ge 0; \beta \ge 0\right\} \tag{11}$$

where Q is a $J \times M$ matrix of observed outputs, X is a $K \times M$ matrix of observed inputs, l is an $M \times 1$ unit vector, and M denotes the number of observations used to estimate the frontier (O'Donnell, 2011, p. 8). The *DPIN 3.0* software program uses variants of these two LPs to compute productivity indices and measures of efficiency.

Specifically, *DPIN 3.0* estimates the Färe-Primont aggregates by first solving the following LPs (O'Donnell, 2011):

$$D_I(x_0, y_0)^{-1} = ITE_0^{-1} = \max_{\phi,\delta,\eta}\left\{y_0\phi - \delta : Y^{'}\phi \le \delta l + X^{'}\beta; x_0^{'}\eta = 1; \phi \ge 0; \eta \ge 0\right\} \tag{12}$$

$$D_O(x_0, y_0)^{-1} = OTE_0^{-1} = \min_{\alpha,\gamma,\beta}\left\{\gamma + x_0^{'}\beta : \gamma l + X^{'}\beta \ge Q^{'}\alpha; y_0^{'}\alpha = 1; \alpha \ge 0; \beta \ge 0\right\} \tag{13}$$

The estimated aggregate outputs and inputs for the Färe-Primont index are obtained by

$$X_i = (x_i^{'}\eta_0)/(y_0^{'}\phi_0 - \delta_0) \tag{14}$$

$$Y_i = (y_i^{'}\alpha_0)/(\gamma_0 + x_0^{'}\beta) \tag{15}$$

where $\alpha_0, \beta_0, \gamma_0, \delta_0, \eta_0, \phi_0$ solve equations (14) and (15). *DPIN 3.0* uses sample mean vectors as representative input and output vectors in equations (14) and (15), respectively. The representative technology in this LP is the technology obtained under the assumption of no technical change and allows the technology to exhibit variable returns to scale. In situations case where technology is assumed to exhibit constant returns to scale, then *DPIN 3.0 sets* $\gamma = \delta = 0$ (O'Donnell, 2011).

2.3. Data

This paper uses cross-sectional data systematically collected from smallholder crop-livestock producing households in the Atebubu-Amantin (*hereafter*, A-A) and Ejura-Sekyedumase (*hereafter,* E-S) districts of the forest-savannah transition agro-ecological zone using carefully designed semi-structured questionnaires. The data collected included values and quantities of outputs and inputs necessary for estimating TFP and its associated efficiency measures.

A multi-stage sampling technique (purposive and random sampling) was used to obtain the respondents for the study. The forest-savannah transition agro-ecological zone was purposively selected. This zone presents the ultimate agro-climatic environment for the production of most of the common staples and also for livestock production. The two districts were also selected purposively because of their high sheep and goat density, high potential for crop-livestock integration, low market access, high poverty index, along with proximity to existing good sheep and goat practice centres (MoFA, 2010). Twelve communities were randomly selected from a list of crop-livestock producing communities in each district. A minimum of 25 households were randomly selected in each community. In all, 608 farm household were interviewed. The computation and further decomposition of the Färe-Primont TFP index required aggregated data. A description of the input and output data series are presented below.

2.3.1. Outputs

Crop output includes quantities harvested in 2013[2] for cereals (maize and rice), pulses and vegetables (cowpea and groundnut), and roots and tubers (yam and cassava) from both districts. All these variables are measured in physical quantities (i.e., kilograms), and the fact that they are cross-sectional data collected at a point in time, hence, they are largely free from aggregation issues that arise from using value equivalents expressed in constant prices (Thirtle *et al.*, 2003; Coelli and Rao, 2005; Rahman and Salim, 2013).

Livestock outputs consisted of sheep equivalents of all the livestock raised by the households. Numbers of these animals were converted into sheep equivalents using the following conversion factors: 8.0 for Cattle, 1 for sheep and goats, and 0.1 for poultry. The conversion figures used in this study corresponds very closely with those used in Coelli and Rao (2005) and Hayami and Ruttan (1970). In effect the livestock units in sheep equivalent at the end of the season was considered as the livestock output. In all, three output variables are used; *cereals* (maize and rice), *other crops* (yam, cassava, cowpea, groundnut and vegetables) and *livestock*.

2.3.2. Inputs

Area (in acres): The area under all the crops included in the output series above as well as the land area under livestock was considered as the land area under cultivation.

Labour: The amount of labour (in man days) used in the cultivation of each of the crops and rearing of livestock were aggregated to obtain the labour variable.

Livestock units[3]: The livestock units in sheep equivalents at the beginning of the season were considered as the livestock input. This variable was computed with the same criteria as the one described in livestock output above. The only variation here was that the numbers of animals that the households had at the beginning of the season was used in computing the input.

2.3.3. Other Inputs[4]

Because crop-livestock producers are smallholders, the quantities of inputs such as fertilizer, pesticides, and herbicides were very low or in some cases non-existent. In view of this, expenditure on the various crops and livestock managed over the season were computed and used as input expenses. In addition, depreciated costs of hand-held tools such as cutlasses,

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[2] In Ghana, there are two growing seasons per year. Thus, the year refers to the both growing seasons.

[3] The use of livestock units as inputs is consistent with other studies (see for example, Coelli and Rao, 2005; Hayami and Ruttan, 1970)

4 Irrigation and tractors are not included as inputs because irrigation is non-existent among the sample farmers and tractors are mostly hired and paid for; hence, it is captured in the production expenses, as described above.

hoes and other implements were also included. Thus, other input series that are included are cereal expenses, expenses on other crops and expenses on livestock.

2.4. Descriptive Statistics of the Variables Used in the Analyses

Descriptive statistics of the sample respondents are presented in Table 1. Overall, the mean cereal output was 5,161 kg; however, the value for the Ejura-Sekyedumase (E-S) district (6,441 kg) was relatively greater than that in the Atebubu-Amantin (A-A) district (3,898 kg). On the other hand, the mean quantity of outputs from the other crops cultivated by the sample households in the A-A district (6,569 kg) was almost double the mean quantity obtained in the E-S district (3,030 kg). This was not surprising because the E-S district is noted as the major zone for cereal production. It hosted the biggest national (state) farm in the country for cereals and has good resources for cereals production. During the time of the national farming after independence, many people migrated to the area to participate in the national farm agenda proposed by the then president.

Table 1. Descriptive Statistics of the Input and Output Variables

Variables	A-A (*N*=306)	E-S (*N*=302)	ALL (*N*=608)
Output series			
Cereals (kg)	3898.30 (4945.95)[a]	6441.39 (7430.08)	5161.48 (6425.48)
Other crops (kg)	6569.06 (8564.74)	3029.87 (5078.18)	4811.11 (7265.18)
Livestock (numbers)	22.97 (26.93)	24.30 (24.64)	23.63 (25.81)
Inputs series			
Land (hectares)	3.95 (3.83)	3.96 (5.28)	3.96 (4.60)
Labour (man-days)	1800.13 (1834.55)	862.69 (1063.02)	1334.50 (1572.10)
Livestock units (numbers)	18.08 (22.94)	18.92 (19.77)	18.50 (21.41)
Cereals Expenses (GH₵)	756.98 (821.97)	1008.19 (1246.22)	881.76 (1060.86)
Other crops expenses (GH₵)	1966.04 (2698.41)	663.35 (1697.48)	1318.98 (2347.87)
Livestock expenses (GH₵)	480.12 (762.49)	492.41 (659.97)	486.23 (712.85)

Notes: [a] Figures in parentheses denote the respective standard deviations. A-A denotes Atebubu-Amantin district. E-S denoted Ejura-Sekyedumase district.

Consequently, most of the farmers obtained training in cereal production that has been part of their generations since (MoFA, 2010). On the whole, there is minimal variation in the livestock numbers across the districts, with an overall average of 24 sheep equivalents per household. In all, the area cultivated averaged about 4.0 hectares, and did not vary greatly across the two districts.

Labour use was relatively higher in the A-A district (1800) than in the E-S district (863) with an overall average of about 1335 man-days. There was minimal variation in the livestock inputs for both districts, with an overall average of 18.5 sheep equivalents. The overall mean expenditure on cereals production was GH₡ 881.8 and was much higher in the E-S district (GH₡ 1,008.2) than in the A-A district (GH₡ 757.0). On the other hand, expenditure in the production of other crops was relatively greater in the A-A district (GH₡ 1,966.0) than in the E-S district.

3. Empirical Results and Discussion

The results of the efficiency scores obtained from the decomposition of the Färe-Primont TFP index are presented in Table 2, where the deviation below unity is a measure of the extent of inefficiency. In general, the average TFP is 52 per cent and is significantly higher in the E-S district (56 per cent) than the A-A district (48 per cent). Given the mean optimal TFP of 77 per cent, the results indicate that, in general, crop-livestock farmers are operating below the maximum possible level of productivity given the available inputs and technology. This suggests that, there are some inefficiencies accounting for this and preventing them from reaching the optimal productivity level with the current inputs and technology being used. Thus, given the current inputs and technology, there is the possibility of increasing productivity by 29, 21 and 25 per cent in A-A and E-S districts and the two districts pooled, respectively.

Table 2. Estimated Farm-Level TFP and Associated Efficiency Measures

Measures of efficiency	A-A (*N*=306)[§]	E-S (*N*=302)	All (N=608)	z-stat[†]
Total factor productivity (TFP)	0.48 (0.14)	0.56 (0.10)	0.52 (0.13)	-7.82[a]
Total factor productivity efficiency (TFPE)	0.62 (0.18)	0.72 (0.17)	0.67 (0.18)	-7.82[a]
Output-oriented technical efficiency (OTE)	0.87 (0.15)	0.91 (0.10)	0.89 (0.13)	-2.28[b]
Output-oriented mix efficiency (OME)	0.88 (0.14)	0.94 (0.11)	0.91 (0.13)	-4.75[a]
Residual output Scale Efficiency (ROSE)	0.82 (0.16)	0.87 (0.10)	0.84 (0.14)	-4.09[a]
Input-oriented technical efficiency (ITE)	0.87 (0.15)	0.91 (0.11)	0.89 (0.13)	-2.52[b]
Input oriented mix efficiency (IME)	0.79 (0.19)	0.88 (0.12)	0.84 (0.16)	-6.51[a]
Residual Input Scale Efficiency (RISE)	0.91 (0.08)	0.92 (0.09)	0.91 (0.08)	-5.46[a]

Notes: [§] Figures in parentheses denote the respective standard errors. A-A denotes the Atebubu-Amantin district. E-S denotes the Ejura-Sekyedumase district. [†]denote a Mann-Whitney *z-statistic* (Banker et al., 2010), for testing the significant differences in the DEA scores of the two districts. [a] and [b] denotes significance at the 1% and 5% level, respectively. The mean optimal TFP is 0.77.

This can be made possible by improving on the total factor productivity efficiency (TFPE[5]). The results further indicate that, in terms of output, the key components of farm-level TFPE in crop-livestock systems are output-oriented technical efficiency (OTE), output-oriented mix efficiency (OME) and residual output scale efficiency (ROSE). However, from the input side,

[5] TFPE are efficiency measures which constitutes TFP, thus enhancements in these measures ultimately improves TFP.

TFPE constituted of input-oriented technical efficiency (ITE), input-oriented mix efficiency (IME) and residual input scale efficiency (RISE). Consequently, TFPE is the product of the decomposed efficiency measures such as the OME, OTE and ROSE for the output orientation, and IME, ITE and RISE for the input orientation.

The OTE measures how much TFP can be increased by increasing technical efficiency of outputs. Overall, the mean OTE was found to be 89 per cent; however it was greater in the E-S district (90.8 per cent) than in the A-A district (87.2 per cent).

This variation could be explained by the differences in the underlying production technologies across the districts. Given that district E-S is closer to the regional capital where most research stations and universities are located, it is expected that improved production technologies will diffuse into the district faster than it will for district A-A. The ROSE which is a measure of output scale efficiency was found to be 84 per cent and was greater in the E-S district (86.6 per cent) than in the A-A district (81.8 per cent). This suggests that scale inefficiencies are substantive in crops-livestock production across the districts (13.4 and 18.2 per cent for E-S and A-A Districts, respectively). This implies that farmers in district E-S could enhance farm productivity by improving their scale of production by only 13 per cent with the given input and output mixes whereas their counterparts in districts A-A can do so by increasing their scale by as much as 18 per cent. Unlike district E-S where most of the arable lands are plain lands, the district A-A is characterised by rich arable vegetation with extensive intermittent patches of trees, which tend to inhibit the incentive for improving the scale of production and consequently, the relatively low ability for farmers in the district to obtain productivity improvements through scale economies.

The OME measures the extent wo which changing mix of outputs leads to increases in TFP and is estimated, on average, at 91 per cent. It is, however, 88.3 per cent for A-A district and 93.5 per cent for the E-S district. The results show that mean output-oriented mix efficiency was consistently greater than the mean technical and scale efficiency measures in crop-livestock systems; thus, indicating a relatively lower output-oriented mix inefficiencies than scale and technical inefficiencies (Table 2).

The ITE measures the increases in TFP resulting from changes in input use while holding output fixed. In all, the mean ITE was found to be 87.0, 90.7 and 88.8 per cent, for the A-A district, the E-S district and the pooled. These values indicate that, in the short run, there is the capacity of improving the efficiency of input use in crop-livestock farming by 13, 9.3 and 11.2 per cent in the A-A district, the E-S district and the pooled, respectively. The relatively good road infrastructure and network and the proliferation of inputs markets in district E-S compared with that of district A-A also limits farmers' access to productive input and hence could influence overall productivity in crop-livestock production.

The mean residual output scale efficiency, measures the increases in TFP resulting from increasing the levels(scale) of input use at a given output and is estimated on average at 84 per cent for the pooled districts, but greater in the E-S district (89 per cent) than in the A-A district (79 per cent) (Table 2).

Comparing the results for the measures of efficiency from the output orientation indicate that, on average, OME and OTE contributed significantly to TFPE whereas ROSE contributes only marginally. This suggests there is a relatively low contribution from scale improvements towards productivity in crop-livestock farming; but rather, improvements in productivity is mostly through mix and technical efficiencies from the output orientations. Similarly, in terms of inputs, the major contributors to TFPE were ITE, IME and RISE constituting 89, 84 and 91 per cent, respectively. Contrary to the output orientation case, this indicates that scale and technical efficiency have contributed more significantly towards productivity in crop-livestock production than mix efficiency. This suggests that there is great potential for increasing farm-level productivity among crop-livestock farmers by increasing mix efficiency. This finding suggests that producers are not producing at the point of maximum productivity even though they are technically, mix, or scale efficient in their use of inputs when producing outputs.

The results demonstrate that mean input-oriented mix inefficiency was consistently greater than mean technical and scale inefficiency in crop-livestock systems. This suggests that indeed, farmers have greater potential of changing the combination of their inputs to enhance overall productivity that doing same by changing their output mixes during the production period. their input mixes Thus, input-oriented mix inefficiency is of great concern in crop-livestock farming systems; hence, research and development efforts on mix efficiency in crop-livestock systems should focus on issues relating to the input orientation. The implication is that crop-livestock farmers in Ghana are quite successful in improving pure technical and scale efficiencies but not mix efficiency in both output and input orientations. Thus the ability to derive benefits from increasing outputs and input mixes is relatively low. This is largely due to the inherent fixity in inputs as opposed to outputs. Farmers tend to stick to their input mixes simply because of their inability to vary them possibly due to the relative prices of the respective input mixes relative to available alternative input mixes.

3.1. Distribution of Mix Efficiency

The distributions of output-mix and input-mix efficiencies for the sample households are presented in Figures 1 and 2, respectively. In general, the distributions of both the output- and the input-oriented mix efficiencies are negatively skewed, indicating that, crop-livestock farmers are relatively efficient in changing their input and output mixes to exploit gains in productivity.

However, the specific distributions are quite different for each orientation. For instance about 95 per cent of the sample households have output-oriented mix efficiency greater than 0.5. Within this range, however, about 72 per cent have output-oriented mix efficiency above 0.9 whereas the remaining 23 per cent have output-oriented mix efficiency between 0.5 and 0.8. This is because farm households generally have more flexibility in output mixes; therefore, they are able to vary output mixes more easily even with the same amount of inputs to obtain an increase in productivity.

For example, with a fixed amount of labour, capital and land, it is highly possible for farmers to alter their output mixes to achieve a desired objective. However, the extent to which farmers can change their output mixes obviously depends on their available resources, the demand for the products, market prices, and the relative importance of these products to households for food security and household income. This distribution further suggests that greater proportions of the sample households are close to the maximum output-oriented mix efficiency level. Interventions towards improving output-mix efficiency among crop-livestock farmers if well implemented is likely to have a greater impact on the majority of the crop-livestock farmers.

On the other hand, only 3 per cent of the households had input-mix efficiency of 1.0. Preliminary field investigation suggests the presence of rigidity in input-mix choices; consequently, there is limited ability to alter input mixes in accordance with changes in the production process among farmers and this could account for the low proportion of farmers having unity score for IME. For instance, most of crop-livestock farmers use traditional production technologies with the subsequent fixity in quantity of basic inputs such as land labour, fertilizer, herbicides and pesticides during the production process. There is a relatively large amount of input usage at the beginning of the cropping season to take advantage of soil moisture or rainfall; this could be a feature that explains this observation. For example typically, crop-livestock farmers use more than half of their inputs during planting periods. Although, 89 per cent of the respondents had input-mix efficiencies within the range 0.5-1.0, their distribution across the districts was not consistent. As expected, it was much higher in the E-S district (95 per cent) than in the A-A district (83 per cent) with input-mix efficiency scores ranging between 0.5 and 1.0.

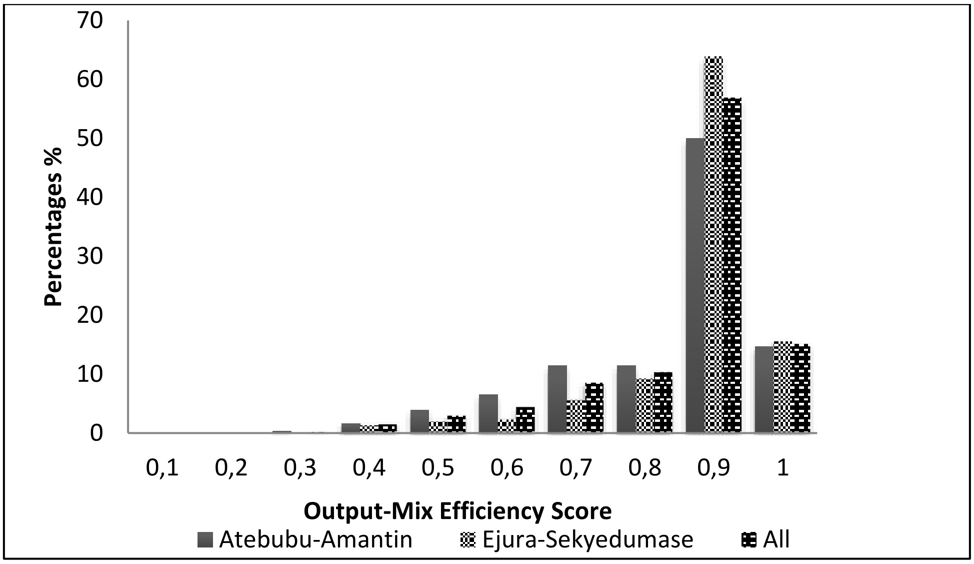

Figure 1. Distribution of Output-Oriented Mix Efficiencies

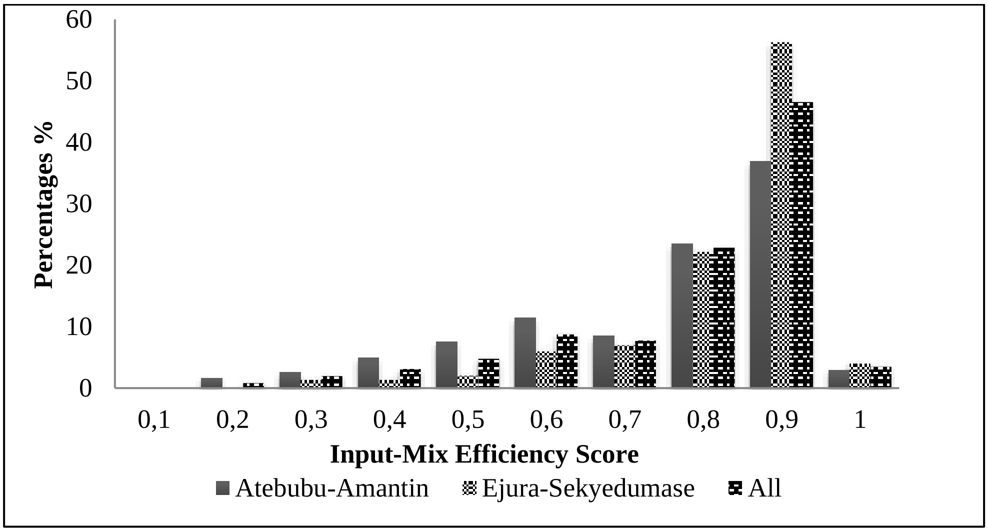

Figure 2. Distribution of Input-Oriented Mix Efficiencies

4. Conclusions and policy implications

This paper examines farm-level total factor productivity in crop-livestock farming systems and investigates the role of mix efficiency in TFP using farm-level data on 600 farm households.

The results indicate that mean output-oriented mix inefficiency is lower than the mean technical and scale inefficiency in crop-livestock production. Given the input orientation, however, the means of ITE, RISE and IME are 88, 91, and 84 per cent, respectively, demonstrating that the mean input-oriented mix inefficiency is consistently greater than mean technical and scale inefficiencies in crop-livestock production.

This suggests that crop-livestock farmers are relatively more output-oriented mix efficient than being input-oriented mix efficient. The implication is that, generally, the ability of crop-livestock farmers to translate gains from changing output mixes into gains in productivity is much greater than their capacity to change input mixes into increases in productivity. The result suggests the need for research and development to exploit opportunities for enhancing mix efficiency from the input orientation in integrated crop-livestock systems. Taking into account the discreet role of mix efficiency in agriculture and crop-livestock farming in particular, such efforts should also allow for the possible sources of mix inefficiency and possibly model the influence of these factors on mix efficiency.

The generally high input mix inefficiency depicts that crop-livestock farmers are faced with a considerable level of rigidities in varying inputs mixes to capture productivity increases, conversely, in terms of output, the results suggests that farmers are better able to vary their output mixes to improve productivity. The results validate the finding that in addition to technical and scale inefficiency, mix inefficiency is another important performance measure to consider in crop-livestock production. The result contributes to and supports the assertion of the relative contributions of technical, scale and mix inefficiency in farm-efficiency measures. Accordingly, pragmatic strategies by policy makers and other development partners who seek to improve productive efficiency in the Ghanaian agriculture should also emphasize improvements in mix efficiency. Our results indicate that inherent rigidities in the production systems limit the economic activities of crop-livestock producing households in the country. Thus, in the short run, there is an incentive for producers to increase productivity through investments in new technologies. However, restrictions in production inherent in the managerial choices for example, crop rotation, crop-livestock management practices are also challenging to alter in the short run. In the wake of these rigidities, it is essential for research, extension and development agencies to explore ways of increasing productivity in the crop-livestock sector. Exploring relevant policies that has the incentives for altering input and output mixes will ultimately enhance crop-livestock productivity.

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