Processor Linkages and Farm Household Productivity: Evidence from Dairy Hubs in East Africa

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ABSTRACT

Linking smallholder farmers to large enterprises could be a powerful mechanism to improve input and output markets as well as other productivity-enhancing services for liquidity constrained smallholders. Dairy hubs promoted by East African Dairy Development project are collective farmer-owned milk bulking and/or chilling plants through which farmers get access to output markets and inputs as well as other services necessary for their dairy enterprises. The hubs act as a linkage between large processors and smallholder dairy farmers. They enable farmers to supply milk to large dairy processors who are emerging key players in the East African dairy industry. In addition to the different forms of linkages with large processors, these hubs also differ in their level of growth toward sustainability. In light of this background, this work aims to provide evidence on the effects, at farm level, of different types of linkages with processor that dairy hubs adopt. Moreover, though hub sustainability is directly linked to the producer organization’s efficiency level, our results show that it does not sufficiently translate to more productive farmers. These findings call for concerted efforts by development agents in the dairy sector, policy makers, and even large processors to intervene in order to support improved farm performance. As evident from the study, one direct policy tool at the disposal of these agents is extension messages. [EconLit citations D24; L25; Q12]. © 2017 The Authors. Agribusiness Published by Wiley Periodicals, Inc.

1. INTRODUCTION

East African economies are still agriculture-based (Ranja, 2003; Salami, Kamar, & Brixiov, 2010), in the light of rapidly developing service sector (World Bank, 2015). Agricultural sector accounts for about 75% of the labor force in these countries, underscoring its importance in job creation and poverty reduction across countries (Salami et al., 2010). Within this sector, livestock contributes about 40% of the global value of agricultural output and supports

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the livelihoods and food security of almost a billion people (FAO, 2009). In particular, livestock sector’s share is between 20% and 50% to agricultural value added produce in African countries—with a continental average of 26%. It is expected that this sector becomes the largest contributor to agriculture as economic development progresses as a result of a growing demand for high-value food items, including meat and dairy products (Nouala, Pica-Ciamarra, Otte, & N’guetta, 2011). In the bounds of livestock sector, the progress of the dairy sub-sector is important for rural development in several Sub-Saharan African (SSA) regions (Alive, 2007).

In SSA, Eastern Africa has the highest concentration of indigenous (a native or characteristic specie of the area) and improved variety (exotic or crosses from exotic and indigenous breeds) of cattle (Kurwijila & Bennett, 2011). Within Eastern Africa, East Africa is endowed with natural resources that also include highlands with moderate tropical climate that makes them particularly suitable for cattle raising (Kurwijila & Bennett, 2011). East Africa’s agriculture is dominated by smallholder farmers who occupy the majority of land and produce most of the crop and livestock products (Salami et al., 2010). Kenya is one of the major regional producer, processor, and exporter of dairy products. It is estimated that milk production in East Africa is about five million tons per year, of which 60% is produced in Kenya (Kurwijila & Bennett, 2011). Although the country has established a competitive dairy industry (World Bank, 2013) and ahead of all the other countries in per capita milk consumption and supply, milk supply is still lower than its potential.

The challenges in dairy farming are largely similar across other developing countries and include, among others: inappropriate cattle breeds for dairy production, diseases, variable quality and high cost of inputs, low adoption of technologies in dairy industry, low capacity utilization among processors, inadequate capacity of farmers, extension providers and research institutions, limited market access, and inadequate provision of financial services (Makoni, Mwai, Redda, Zijpp, & Lee, 2013). Despite large constraints in accessing productive assets, finance, technology, and markets, smallholders manage over 80% of the world’s estimated 500 million small farms and provide over 80% of the food consumed in a large part of the developing world (IFAD & UNEP, 2013). Among other factors, reduced investment support and marginalization of small farms in economic and development policy threaten this contribution, leaving many smallholders vulnerable as agriculture is their major source of income (IFAD & UNEP, 2013).

Smallholder farmers consider collective action, one form of cooperation or group marketing, which helps them to gain better access to input and output markets and a way to reduce their transaction costs (Ortmann & King, 2007). To be fully effective, smallholder producer organizations (POs) need to be linked with external economic and policy actors, such as private enterprises and governments in order to support their members in gaining access to markets, build their skills to access and use appropriate information and knowledge to innovate and adapt to changing environment (Karimov, 2014), and build their capacity to analyze production systems, identify problems, test possible solutions, and eventually adopt the practices and technologies most suitable for improved farming (Herbel, Crowley, Haddad, & Lee, 2012). Specifically, linking smallholder farmers to large enterprises, through contracts and other forms of institutional arrangements, facilitates access to output markets, dairy inputs, and other productivity-enhancing services, especially for liquidity-constrained smallholder farmers. This enhances the viability of farmers’ agribusiness enterprises. Increased agricultural productivity, combined with viable agribusiness that adds value to farmers’ production and improved access to markets, can drive broader economic growth across the continent and vastly improve food security (AGRA, 2013).

As an intervention to help establish sustainable POs through which farmers can access markets for their milk and solve other challenges in dairy farming, dairy hubs (also loosely referred to as “hubs”) have been supported in Kenya and Uganda by the East African Dairy Development (EADD) project since 2008. The project was also implemented in Rwanda 2008–2012; in

1Kenya, Tanzania, Uganda, Rwanda, and Burundi form the East African Community (a regional economic integration block).
Tanzania, the project was started in 2014. The project facilitates access by smallholder dairy farmers to milk markets, production inputs, and dairy-related services while also enhancing production capacity of farmers through extension services. EADD project, implemented by a consortium of international non-profit organizations, aims to increase dairy production and improving dairy farmers’ net income, through the hub approach.

The hubs are a form of collective marketing mechanism that provide linkages for market access and input acquisition to dairy farmers through the economies of scale in bulk selling of milk, access to input credit as well as other dairy-related services, and convenient payment arrangements that are beneficial to farmers’ circumstances (Gelan & Muriithi, 2010). Specifically, the hubs are farmer-owned and managed (through dairy farmer POs) milk collection centers with chilling and/or bulking facilities where smallholder farmers can deliver milk; the milk from these farmers is bulked to form large quantities of milk that is either sold directly or chilled before being sold to processor, traders, or direct consumers. In addition, through the hubs, the farmers can access dairy-related inputs, services such as animal health services and products, feeds, breeding services, and financial services (for instance, village banks and input credit). Milk collection and marketing form the central core of the hubs and is augmented by making different services and input accessible to farmers.2

In its second phase of implementation (EADD phase II), EADD has supported over 50 hubs in selected sites (milksheds) in Kenya, Uganda, and Tanzania. The project countries and sites were selected based on several criteria that define their potential in dairy and market access (see Mutinda, Baltenweck, & Omondi, 2015). The project aims at having all the supported dairy hubs on a path to sustainability and eventually becoming self-sustaining by the end of the project’s implementation period which is scheduled for 2018.

As elaborated by Rao, Omondi, Karimov, and Baltenweck (2016), the hubs remain purely farmer-owned with development partners (EADD) only playing a facilitative role through capacity building at both farmer and hub management level, and sharing of lesson (from performance evaluations) that can enhance farm and hub level performance and thus move hubs toward sustainability. PO sustainability assessment studies are conducted by EADD as part of hub performance evaluations and are based on a tool developed around 7 key pillars (dimensions) of sustainability (Table 1).

On the other hand, the hubs, by organizing access to inputs and milk markets, reduce transaction costs both for suppliers (farmers) and buyers of milk (processors/traders/local consumers) thus improving margins from dairy production (Rao et al., 2016). Through bulking and chilling, the hubs enable farmers to supply milk to large dairy processors, who are the main players in the dairy output market, and other market outlets. Different forms of linkages with large processors have been established by the hubs. Some hubs sell milk exclusively to processors, i.e., “pure processor” approach hubs whereas others sell milk to diverse outlets with large processors being just one of the clients, i.e., “mixed-linkage” approach hubs. As explained by Rao et al. (2016), selling to more than one outlet is a risk-managing strategy through which hubs may take advantage of potentially higher prices in non-processor outlets. Although processor prices may be low, the option offers stable prices and hence more stable revenue flows for associated farmers throughout the year, non-processor prices are subject to wide fluctuations that may erode gains from periods of higher milk prices. Consequently, depending on the share of hub’s milk going to non-processor outlet, farmers attached to such hubs may experience lower prices on average and hence lower revenues. Differences in market outlets therefore imply differences in revenues that a hub can generate and also differences in the certainty, by farmers, of a stable flow of incomes. We hypothesize that these differences would trickle down to farmers in terms of revenues that farmer receive from sale of milk, certainty of an income stream, and

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2The access can either be through PO-owned input shops and hired technicians or through affiliation arrangements by the POs with private providers. The inputs are therefore physically and financially accessible to farmers through different arrangements, for instance, cash, input credit, or check-off system, which is a form of input–output interlocking transaction. For emerging hubs with low milk volumes for bulking, the services and input provision is centered around particular services or service providers instead of a milk collection center.
TABLE 1. Key Sustainability Pillars of Dairy Hubs

| Dimension | Sub-Dimensions |
|-----------|----------------|
| 1. The hubs’ engagement with output market | Milk quality; Market reliability; Suppliers |
| 2. Effective and transparent PO leadership and management | Representation and participation; Effective PO supervision and control; Effective PO management |
| 3. Access to dairy inputs and services (i.e., level of PO’s engagement in enabling farmer’s access to inputs and services) | Dairy feeds and feeding; Genetics; Herd health; Extension services; Financial services |
| 4. POs’ relationship with external environment | Partnership with actors; Corporate social responsibility; Risk management |
| 5. Member loyalty to the POs | Patronage; Member investment; Ownership; Member loyalty programs |
| 6. Financial health of the hubs | Profitability; Liquidity; Capital structure |
| 7. On-farm impact on farm households | Economic impact; Social impact; Environmental impact |

consequently the farmers ability to access inputs, thus impacting on the performance of their smallholder dairy enterprises. In addition to the different forms of linkages, the hubs differ in the level of development (i.e., growth stages toward sustainability).

This study provides evidence on the farm impacts of different types of linkages between smallholder dairy farmers and large processors through dairy hubs. Using data collected from smallholder dairy farm households living within the hubs’ catchment areas in Kenya and Uganda (hubs participants and non-participants), we compare farm performance (technical efficiency) of smallholder dairy farmers participating in hubs that have different processor linkages (i.e., “pure processor” linkage versus “mixed linkage” approach). Moreover, comparisons are made between the performances of smallholder dairy households by level of hub development (level of hub sustainability). Overall, findings show no strong influence at farm levels that can be attributed to different forms of linkages that dairy hubs adopt. Hub maturity is linked to the PO efficiency level but does not sufficiently translate to more productive farmers.

2. METHOD

2.1 Sampling and Data Collection

Cattle-keeping households in EADD-supported hubs catchment areas were surveyed as part of a baseline survey for the second phase of EADD project (EADD phase II). Two key performance indicators for EADD, increasing productivity (i.e., milk production per cow) and income from milk production, were the main response variables used in estimating the required sample size. Due to the large number of hubs in Uganda, stratification by cattle production system (intensive versus extensive/semi-intensive) was done, for Uganda, in order to estimate the required sample size that is sufficient to elicit the desired response. Though the baseline survey was conducted in Kenya, Uganda, and Tanzania, we did not include Tanzania in this study because it was a new project country with most of the hubs not established or just starting. Consequently, all the dairy hubs supported by EADD phase II in Kenya (8 in total) and a sample of the hubs (24 out of 33) in Uganda were included in a household survey conducted between October and December 2014.

Geo-spatial random sampling technique was used to randomly select the smallholder dairy farm households living within each of the hubs’ catchment area in Kenya and Uganda, respectively. The hubs’ catchment area covered Nandi East, Nandi North, Nandi south, Sotik, Narok South, Trans Nzoia, and Wareng districts in North and South Rift, Kenya. In Uganda, the hub catchment areas spanned across 13 districts, i.e., Isingiro, Ibando, Kiruhura, Ssembabule, Masaka, Mukono, Jinja, Kayunga, Kamuli, Kyankwanzi, Wakiso, Kiboga, and Mityana districts. In total, 993 cattle-keeping farm households, 322 from 8 EADD-supported hubs in...
Kenya and 671 from 24 EADD-supported hubs in Uganda, were included in the analysis. Using a structured questionnaire, data on household socio-demographic characteristics, livestock assets, milk production and utilization, and input use were collected from these households through personal interviews.

In addition to the household survey data, information regarding market outlets used by the dairy hubs, their linkages with processors and other market outlets, were collected between September 2014 and January 2015, from monthly business reports submitted to EADD by the hubs. A PO sustainability assessment study, conducted in March 2015, was used to obtain information on the hubs’ levels of sustainability.

2.2 Data Analysis

This study used cross-sectional farm level data to analyze the effects of the processor linkage and levels of hub development on the performance of dairy farms. Economic performance can be assessed using efficiency measures such as technical efficiency (TE) and productivity (Coelli, Rao, O’Donnell, & Battese, 2005). Consequently, to assess the relationship between the types of linkages between large-scale processors and the dairy hubs on one hand and farm level impact on the other hand, we estimate TE of the smallholder dairy farmers alongside other descriptive statistics.

Using the data collected from the PO sustainability assessment study and the household survey, we compare TE of farmers in dairy hubs that have different types of linkages with processors. Two types of linkages are explored: (i) “pure processor linkage” whereby all the milk is sold to dairy processors, (ii) “mixed linkage” approach where milk is sold to a mixed set of buyer, i.e., local consumers/traders/processors.

2.2.1 Technical Efficiency Estimation. TE relates to the degree to which a farmer produces the maximum feasible output from a given bundle of inputs, or uses a minimum feasible amount of inputs to produce a given level of output (Farrell, 1957). The alternative approaches to measuring productive efficiency suggested in literature are grouped into parametric frontiers and non-parametric frontiers (i.e., techniques where the functional form of the efficient frontier is pre-defined or imposed a priori and those where no functional form is pre-established but one is calculated from the sample observations in an empirical way (Murillo-Zamorano, 2004)).

Non-parametric frontiers do not impose a functional form on the production frontiers and do not make assumptions about the error term. The non-parametric approach has been traditionally assimilated into Data Envelopment Analysis (DEA), which is a linear-programming-based technique developed by Charnes, Cooper, and Rhodes (1978). As mentioned, efficiency frontier is constructed with the help of linear programming technique that puts most efficient farms in the frontier ray. The distance between this ray and the location of other farms which are not in this ray provides efficiency measure. Unlike stochastic frontier approach (a parametric approach that deals with stochastic noise and permits statistical tests of hypotheses pertaining to production structure and the degree of inefficiency), DEA does not require any assumption about any functional form and hence, does not distinguish between technical inefficiency and statistical noise effects. The main advantages of the DEA approach are that it avoids parametric specification of technology as well as the distributional assumption for the inefficiency term (Sharma, Leung, & Zaleski, 1999). Moreover, DEA results are very sensitive to outliers (Cesaro, Marongiu, Arfini, Donati, & Capelli, 2009). Any approach has its advantages and disadvantages. Wadud and White (2000) point out that the choice of methodology must be based on the available data and the question under investigation. Usually there is no common way in the choice of particular method and is decided in a case by case merit (Karimov, 2013). In this study, we adopt a DEA framework.
We constructed the DEA model assuming that each dairy farm household produces a quantity of output \((y_i)\) using multiple inputs \((x_i^*)\), and each farm \((i)\) is allowed to set its own set of weights for both inputs and output. The data for all farm households are denoted by the \(K \times N\) input matrix \((X)\) and \(M \times N\) output matrix \((Y)\). Using piecewise technology, an input-oriented measure of TE can be calculated for the \(i\)th farm as the solution to linear programming (LP):

\[
\begin{align*}
\theta x_i + x & \geq 0 \\
\theta & \leq 1 \\
\lambda & \geq 0
\end{align*}
\]

In Equation (1), \(\theta\) is the TE score having a value \(0 \leq \theta \leq 1\). If the value equals 1, the farm is on the frontier. The vector \(\lambda\) is an \(N \times 1\) vector of weights which defines the linear combination of the peers of the \(i\)th farm. The constant returns to scale (CRS) model is only appropriate when the farm is operating at an optimal scale (Coelli et al., 2005). However, factors such as imperfect competition and financial constraints may prevent a farm from operating at an optimal scale (Nargis & Lee, 2013). Most developing countries are characterized by market imperfections due to high transactions costs and imperfect information (de Janvry, Fafchamps, & Sadoulet, 1991). Dairy farms in the study area are not an exception. Consequently, Equation (1) was transformed to the variable returns to scale (VRS) technology model by adding the convexity constraint: \(N1\lambda = 1\), where \(N1\) is an \(N \times 1\) vector of ones and \(\lambda\) is an \(N \times 1\) vector of constant.

The output variables in the DEA analysis included milk yields (per cow per day), and income from sale of cattle and fodder. On the other hand, the inputs included: labor costs (man hours, both family and hired labor), animal health costs (i.e., routine preventive and curative measures), breeding costs (artificial insemination and/or bull services), feeds and feeding costs (i.e., cost of purchased fodder, costs of purchased or homemade supplementary feeds, feed-processing service costs, area of grazing land, area under the main fodder, i.e., Napier grass and costs of water), and other costs (costs of attending training and costs of extension services). All the costs were estimated on an annual basis per tropical livestock units (TLU) a farmer owns. TLU is livestock numbers converted to a common unit using TLU equivalents (see Table A1 in Appendix for the conversion rates used). This is the most common method of comparing livestock of different sizes and species in the tropics and is based on the body weight of a cow weighing 250 kg compared to other animals.

Technical efficiencies of the farms were estimated from a single stage with multi-input and multi-output DEA framework.

3. RESULTS AND DISCUSSION

3.1 Dairy Hubs’ Profile in Kenya and Uganda

Descriptive analysis reveals that approximately 31,700 smallholder dairy farmers were registered as suppliers in the dairy hubs in the two countries by March 2015 (Table 2). In total, these dairy hubs supplied processors and other market outlets with an average of 82,700 liters of milk per day (between September 2014 and March 2015). The dairy hubs in Kenya were all chilling plant hubs with 2 of the hubs adopting “pure processor linkage” approach and 6 hubs adopting “mixed linkage” approach. Nine (9) hubs in Uganda adopted a “pure processor linkage” approach. In both countries, these hubs were at different levels of sustainability.

3.2 Socio-Economic Characteristics of Farmers in Kenya and Uganda

Dairy farmers in the two countries had a mean age of 51 years and an education level of about 7 years of schooling. These farmers (household heads) had, on average, 21 years of farming
experience, out of which 16 years are in dairy farming. The farm households were composed of approximately 6 members and kept an average of 10.45 TLUs of cattle. However, as shown in Table 3, the farmers in Uganda had significantly lower education level and farming experience compared to their Kenyan counterparts. Moreover, the farmers in Uganda had a significantly larger household size and herds of cattle than Kenyan farmers.

In terms of participation in EADD-supported producer organizations (the dairy hubs), it is worth noting that participation in the dairy hubs, either by delivering milk or accessing services offered by the hubs or hub-affiliated service providers, is not restricted to membership in the hubs, i.e., non-members of the POs can also deliver their milk to the hub and access the services, albeit at slightly different terms of payment arrangements. It is also worth noting here that an analysis of the data used in this study revealed that 100% of hub participants delivered milk to the hubs but about 20% of the participants did not use any services from the hubs.

The information presented in Table 3 seeks to explore the differences between participants versus the rest of the population. The results shown in the table reveal that the strongest (highly significant) factor that differentiates the households is the cattle (TLU) owned by the households. Participants in EADD hubs have significantly higher number of cattle than their non-participating counterparts ($t = -4.47, 320df p < 0.01$ for Kenya and $t = -8.05, 669df p < 0.01$ for Uganda).

However, within the participant group, it was expected that participation in EADD-supported hubs would not necessarily imply explicit uniformity among farmers because, in addition to other household socio-economic factors, the hubs adopt different type of linkages with their buyers and are at different levels of sustainability. From the total sample size of 993 farm households in Kenya and Uganda, 362 households (83 in Kenya and 279 in Uganda) live within the catchment areas of hubs that operate under a “pure processor linkage” approach. On the other hand, 631 farmers (239 in Kenya and 392 in Uganda) live within the catchment areas of hubs that operate under a “mixed linkage” approach (i.e., linked to local consumers/traders and/or processors). Within each country, the only variables (among the selected variables presented in Table 3) that showed the strongest significant difference between these two groups of households is herd size and Household Head’s number of years of schooling in Uganda.

When differentiating hub participants (81 in Kenya and 112 in Uganda) into those linked to POs following a “pure processor” approach compared to the “mixed linkage” approach, results showed little difference: mean household size was larger ($t = 1.97, 79df, p > 0.1$) in Kenya among those linked to POs following “pure processor linkage” approach. In Uganda, the mean level of education was lower ($t = -2.62, 110df, p > 0.05$) and mean herd size larger ($t = 1.98, 110df, p > 0.05$) in households linked to POs following “pure processor linkage” approach. Except for the said variables, these households are near-similar in terms

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**TABLE 2. Description of the Dairy Hubs in Kenya and Uganda, by Marketing Strategy and Hub Types (March 2015) (EADD Data)**

| Form of Linkage | Country | Pure Processor Linkage | Mixed Linkage |
|-----------------|---------|------------------------|---------------|
|                 | Kenya   | Uganda                 | Kenya         | Uganda        |
| Number of dairy hubs | 2       | 9                      | 6             | 15            |
| Number of registered suppliers | 6,507   | 1,483                  | 21,534        | 2,230         |
| Volume of milk (liters) supplied to market outlets per day | 11,435   | 41,007                 | 21,805        | 8,539         |
| Number of hubs in Stage 1 and 2 of sustainability (young/immature) | 0       | 3                      | 0             | 9             |
| Number of hubs in Stage 3 of sustainability (emerging) | 1       | 3                      | 3             | 3             |
| Number of hubs in Stage 4 of sustainability (advanced) | 1       | 3                      | 3             | 3             |
| Number of hubs in Stage 5 of sustainability (fully sustainable) | 0       | 0                      | 0             | 0             |
| Household/Farm Characteristics | Kenya (means) | Uganda (means) | Mean All (n = 993) |
|-------------------------------|--------------|----------------|-------------------|
|                               | Participants (n = 81) | Non-participants (n = 241) | All (n = 322) | Participants (n = 112) | Non-participants (n = 559) | All (n = 671) | Mean All (n = 993) |
| **Household head's age**      | 50.44        | 50.17          | 50.24            | 53.27          | 51.00            | 51.38            | 51.01            |
|                              | (1.69)       | (0.91)         | (0.80)           | (1.34)         | (0.61)           | (0.56)           | (0.46)           |
| **Household head's number of years of schooling** | 9.64         | 8.73           | 8.96             | 7.63           | 5.94            | 6.22            | 7.11             |
|                              | (0.49)       | (0.33)         | (0.27)           | (0.56)         | (0.19)***        | (0.219)         | (0.16)***         |
| **Household head's number of years of farming experience** | 23.85        | 22.90          | 23.14            | 20.11          | 19.69           | 19.76           | 20.85            |
|                              | (1.85)       | (0.99)         | (0.87)           | (0.91)         | (0.45)          | (0.41)          | (0.40)***         |
| **Household head's number of years of dairy farming experience** | 21.41        | 20.34          | 20.61            | 15.10          | 13.57           | 13.82           | 16.02            |
|                              | (1.93)       | (1.01)         | (0.90)           | (0.97)         | (0.40)          | (0.37)          | (0.40)***         |
| **Household size (number of household members)** | 5            | 5              | 5                | 7              | 7               | 7               | 6                |
|                              | (0.22)       | (0.13)         | (0.11)           | (0.32)         | (0.13)          | (0.12)          | (0.0)***          |
| **Total cattle owned (Tropical Livestock Unit)** | 6.27         | 3.90           | 4.50             | 33.90          | 9.09            | 13.23           | 10.40            |
|                              | (0.65)       | (0.22)***      | (0.24)           | (3.30)         | (1.21)***       | (1.20)          | (0.83)***         |

*Note:* *, **, *** indicate significance at 10%, 5%, and 1%, respectively. Standard errors are indicated in parenthesis.
TABLE 4. Means of Variables Used in the DEA Model, by Country and Processor Linkage

| Kenya                                     | “Pure processor linkage” hubs | “Mixed linkage” hubs | Mean of all |
|------------------------------------------|-------------------------------|----------------------|-------------|
|                                          | n = 83                        | n = 239              | n = 322     |
| Total lactation yield (liters) per cow per lactation day | 7.90 (0.75)                  | 6.80 (0.46)          | 7.09 (0.39) |
| Total annual revenue from dairy (USD) per TLU owned | 13.73 (4.42)                 | 23.55 (11.52)        | 21.02 (8.63) |
| Total labor man-hours for all dairy activities | 34.75 (10.07)                | 25.87 (2.70)         | 28.16 (3.28) |
| Total acres of Napier grass for feeding | 0.13 (0.04)                  | 0.22 (0.06)          | 0.19 (0.04) |
| Total land allocated for grazing | 3.21 (2.38)                  | 0.55 (0.04)          | 1.24 (0.61)* |
| Total other cost of dairying (USD)***    | 130.52 (57.92)               | 96.32 (21.23)        | 105.13 (21.67) |

| Uganda                                    | “Pure processor linkage” hubs | “Mixed linkage” hubs | Mean of all |
|------------------------------------------|-------------------------------|----------------------|-------------|
|                                          | n = 279                       | n = 392              | n = 671     |
| Total lactation yield (liters) per cow per lactation day | 5.57 (12.85)                 | 2.78 (0.26)          | 3.94 (0.23)*** |
| Total annual revenue from dairy (USD) per TLU owned | 63.74 (63635.1)              | 404.12 (303.57)      | 262.59 (177.45) |
| Total labor man-hours for all dairy activities | 12.88 (1.69)                 | 19.78 (1.89)         | 16.91 (1.32)*** |
| Total acres of Napier grass for feeding | 0.01 (0.00)                  | 1.97 (1.59)          | 1.15 (0.93) |
| Total land allocated for grazing | 2.40 (0.60)                  | 3.83 (2.34)          | 3.23 (1.39) |
| Total other cost of dairying (USD)***    | 29.50 (2.54)                 | 60.39 (24.18)        | 47.54 (14.17) |

Note: *, **, *** indicate significance at 10%, 5%, and 1%, respectively.

1USD = 90.05 KES, 2739.55 UGX, and 1726.28 TZS—average rate for November 2014. Standard errors are indicated in parenthesis.

"sale of fodder, livestock products and services; "extension, training, animal health, breeding, fodder and concentrate purchases, and feed processing costs.

of their socio-demographic characteristics, implying that any differences in their productivity and input use could be stemming from other factors other than the said socio-demographic characteristics. Therefore, subsequent analysis focused on whether or not, the type of hub-processor linkages (i.e., “pure processor” linkage approach versus “mixed linkage” approaches) with farmers, indirectly through the dairy hubs, had significant influence on productivity and input use at farm level. Subsequent subsections discuss the results of this analysis.

3.3 Farm Performance

This section presents descriptive statistics of variables used in the estimation (Table 4) as well as TE analysis (Tables 5 and 6).

3.3.1 Variables Used in the Estimation of Technical Efficiencies. The estimation of TE at farm level involved singling out variables that form outputs and inputs in the dairy enterprise. In this study, the output variables included total milk yield per cow per lactation day and total income from sale of cattle and fodder in the 12 months preceding the survey. Inputs include labor costs (measured in man-hours), animal health and breeding costs, feeds and feeding costs (i.e., purchased concentrates and fodder, feed processing costs and own-produced fodder and forage—grazing land and acreage of Napier grass planted), and other costs (training, extension, and water) incurred in the same period. All inputs are totals for the 12 months preceding the survey and were measured per number of cattle kept (in TLU). From a sample
size of 993, TE estimates were derived for 523 farmers who had lactating cows at the time of the survey. The results in Table 4 reveal that, apart from land allocated for grazing, there is no statistically significant difference in farmers’ characteristics across the hub-processor linkages in Kenya. In Uganda, farmers living around hubs that adopt “pure processor linkage” approach have comparatively higher yields and spent more on labor compared to farmers around hubs following a mixed approach. However, there is no significant difference between farmers linked to the two different forms of linkages in terms of access to inputs that hubs promote (i.e., breeding, animal health, and purchased feeds—presented in Table 4 as total other cost of dairying).
3.3.2 Technical Efficiency Differentials among Dairy Farms in Kenya and Uganda. From the DEA results obtained in this study, Table 5 shows the distribution of TE scores estimated for the 523 farms (233 from Kenya and 290 from Uganda—out of which 65 and 77 were hub participants of the hubs in Kenya and Uganda, respectively). TE scores were classified into four intervals to show possible clustering of efficient or inefficient dairy farms across the dairy hubs. Farms with efficiency scores of 0.25, for instance, would need to increase output by 75% to reach the efficiency frontier without any increase in the level of inputs used in the process of production. In Kenya, there were fewer farmers with low TE estimates among those participating in hubs with a “pure processor” linkage approach, i.e., 23.53% of hub participants in “pure processor” linkage approach hubs had efficiency level of 0.25 or less, compared to 35.42% of active members of hubs with a “mixed linkage” approach. The same trend is observed for Uganda as well as when considering all farmers within the hubs catchment areas (Table 5).

However, mean TE (Table 6) differed significantly ($p < 0.05$) only among hub participants in Kenya, with those linked to “pure processor” linkage approach hubs being more efficient than those liked to “mixed linkage” approach hubs. There was no statistically significant difference when considering the entire sample population in Kenya, and in all farmer categories in Uganda.

One observation with great implications is that 43% and 35% of hub participant households within hubs with “mixed linkage” approach in Uganda and Kenya, respectively, had TE scores less than 25%. Although these numbers are still lower in comparison to numbers related all farmers within the hub catchment area, it requires joint efforts to understand the reasons behind this observation. As seen from the findings in Table 4, farmers in hubs with “mixed linkage” approach, particularly in Uganda had significantly lower yields and incurred higher labor costs. This insinuates the need for more focused interventions that focus on increasing farmers’ managerial skills and also enhancing dairy farm management practices that reduce labor input inefficiency among the farms. These would in turn result in better yields and increased TE levels. In general, it is important to note that there is a need for further research to investigate factors associated with lower efficiency levels within the mixed linkage approach.

Efficiency in an organization is one of the determinants of the organization’s sustainable growth (Jegers, 2003), consequently hub sustainability is directly linked to the producer organization’s efficiency level. In regards to dairy hubs’ growth toward sustainability, the sustainability assessment exercise (see Table 1 for the dimensions) categorizes POs into 5 stages of growth toward sustainability, with stage 5 representing a fully mature hub that is able to operate on its own without external support. Stages 3 and 4 represent near-mature POs whereas stages 1 and 2 represent young and immature POs, respectively. As seen in Table 2, hubs in Kenya were all in stages 3 and 4 whereas Uganda had hubs in the whole array of different stages of development except stage 5. Irrespective of the linkages with processors, it is interesting to assess whether farmers linked to hubs at different stages of maturity show different levels of TE. Statistical test (one-way ANOVA) revealed no significant differences between farmers (both participants and all farmers) in terms of their mean TE.3

These results present information that has implication not only directly to EADD project but also to a wider audience composed of like-minded development efforts in dairy sector. The evidence presented here, that hub sustainability does not necessarily trickle down to farm sustainability in terms of improved performance, showcases the justification for EADD and other dairy development agents supporting similar establishments to re-think of their effort toward achieving both farm sustainability and hub sustainability. While making efforts to support the emergence and growth of sustainable hubs, efforts should be made to also support dairy farmer in improving their performance.

The results observed in this study are congruent to the findings and conclusions by Rao et al. (2016). Rao et al. observed significant impact on dairy and total household income for households attached to hubs that adopted a “pure processor linkage.” Moreover, the study observed that the average treatment effect is larger on total household incomes as compared

3Though the actual test results are not presented here, the $F$-statistics had $p$-values greater than 0.1.

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to dairy incomes and could be attributed to a multiplier effect of dairy revenue, i.e., dairy revenues being used as capital in other household income generating activities thus enlarging the total effect of dairy revenues on household income. This clearly indicates that although the impacts of different forms of linkages with large processors produce a significant impact on incomes at household level, this income is not necessarily re-invested in dairy through efficient use of resources. This is also evident from the household survey data collected in this study which showed that although 100% of participants delivered milk to the hubs, about 20% of them (participants) did not use any services from the hubs. In other words, participation in the hub (through milk delivery) does not directly translate into input use from the hub. Thus, the implication here is that even though linking farmers to large enterprises produces positive impacts on income, the trickle effect of this increased income to the households’ productivity and efficient input use in the dairy enterprise is not evident.

4. CONCLUSION

The purpose of the analysis in this study was to investigate the influence of the linkage between farmers and large enterprises, through collective action (POs that manage dairy hubs), on farm level TE. Although the study uses data generated from a random sample drawn from the hubs’ catchment area, implying lower numbers of participant farmers, with a large sample, the farmer distribution (participants vs non-participants) reflects the actual reality on the ground, making the results of this study more generalizable. Results of the study reveal that there is generally, no strong influence observed at farm levels that can be attributed to different forms of linkages that dairy hubs adopt. In other words, whether hubs link exclusively to large dairy processors or follow a diversified market outlets strategy, it does not translate (either positively or negatively) to farm-level productivity and input use differential. Similarly, hub maturity is linked to the PO efficiency level but does not sufficiently translate to more productive farmers. With evidence from a related study (Rao et al., 2016), the implication drawn from these studies is that even though linking farmers to large enterprises produces positive impacts on income, there is no evidence of the trickle effect of this increased income to the households’ productivity and input use in the dairy enterprise. Because the integration of smallholders into the supply chain is important, with their exclusion from the supply chain being politically unacceptable and socially undesirable, it is imperative to assess and design linkages between large dairy processors and the producer organizations that translate into increased farm productivity. Large processors should be informed that their long-term sustainability depends on performance at farm level and as such, efforts should be made by these processors to reach beyond the hubs in order to elevate farm performance. Moreover, the striking evidence from this study that a considerable proportion of farmers participating in hubs with “mixed linkage” approach are relatively inefficient draws strong implications not only for EADD but also for similar development efforts and policy makers. Consequently, policy and strategic actions around better ways of supporting increased and efficient use of inputs at farm level are necessary to improve farmer performance in input utilization. This directly relates to organizing effective extension and advisory services especially targeting but not limited to hubs that adopt “mixed linkage” approach. This will help improving access to information and increasing adoption of recommended extension messages by participant farmers.

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APPENDIX

TABLE A1. Tropical Livestock Units (TLU) Equivalents

| Livestock type                  | TLU |
|---------------------------------|-----|
| Cow                             | 1.00|
| Bull                            | 1.20|
| Heifer (plus immature males)    | 0.70|
| Calf                            | 0.50|
| Goat                            | 0.15|
| Sheep                           | 0.15|
| 100 chickens (one chicken= 0.006) | 0.60 |

Source: (WHO, 2005)

REFERENCES

AGRA (Alliance for a Green Revolution in Africa). (2013). Africa Agriculture Status Report: Focus on Staple Crops. Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA). Retrieved from agralliance.org/download/533977a50dbc7/. Accessed on September 13, 2015.

Alive. (2007). Dairy Sector Development in Sub-Saharan Africa (Alive Policy Note (October 2007)) (p. 11). Alive - Livestock Africa (Partnership for Livestock Development, Poverty Alleviation and Sustainable Growth). Retrieved from http://www.alive-online.org/data/files/policynote-dairysectordevelopment.pdf. Accessed on September 12, 2015.

Cesaro, L., Marongiu, S., Arfini, F., Donati, M., & Capelli, G.M. (2009). Methodology for Analysing Competitiveness, Efficiency and Economy of Scale: Use and Applications of DEA. Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture (FACEPA).

Charnes, A., Cooper, W.W., & Rhodes, R. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6):429–444.

Coelli, T.J., Rao, P.D.S., O’Donnell, C.J., & Battese, G.E. (2005). An Introduction to Efficiency and Productivity Analysis (2nd ed., p. 350). New York: Springer Science + Business Media LLC.

de Janvry, A., Fafchamps, M., & Sadoulet, E. (1991). Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained. *Economic Journal*, 101(409):1400–1417.

FAO. (2009). The State of Food and Agriculture: Livestock in the Balance. Rome, Italy: Food and Agricultural Organization of the United Nations (FAO). Retrieved from http://www.fao.org/docrep/012/i0680e/i0680e.pdf. Accessed on September 10, 2015.

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, 120(3):253–290.

Gelan, A., & Muriithi, B. (2010). Measuring and Explaining Technical Efficiency of Dairy Farms: A Case Study of Smallholder Farms in East Africa. In Africa and the Global Food and Financial Crises (Vol. 3). Cape Town, South Africa: The African Association of Agricultural Economists (AAAE). Retrieved from http://ageconsearch.umn.edu/bitstream/96187/2/AAAE%20%20%2016_11_2010%20AG%20%20BM.pdf. Accessed on September 10, 2015.

Herbel, D., Crowley, E., Haddad, N.O., & Lee, M. (2012). Good Practices in Building Innovative Rural Institutions to Increase Food Security. Rome: Italy: IFAD (International Fund for Agricultural Development) and FAO (Food and Agricultural Organisation of the United Nations).

IFAD (International Fund for Agricultural Development), & UNEP (United Nations Environment Programme). (2013). Smallholders, Food Security and the Environment. Rome: Italy: IFAD. Retrieved from http://www.unep.org/greeneconomy/Portals/88/Mongolia%20WED/smallholders_report.pdf. Accessed on October 10, 2015.

Jegers, M. (2003). The sustainable growth rate of non-profit organisations: The effect of efficiency, profitability and capital structure. *Financial Accountability & Management*, 19(4):309–314. http://doi.org/10.1111/1468-0408.00176

Karimov, A.A. (2013). Productive efficiency of potato and melon growing farms in Uzbekistan: A two stage double bootstrap data envelopment analysis. *Agriculture*, 33(3):503–515.

Karimov, A.A. (2014). Factors affecting efficiency of cotton producers in rural Khorezm, Uzbekistan: Re-examining the role of knowledge indicators in technical efficiency improvement. *Agricultural and Food Economics*, 2(7).

Kurwijila, L., & Bennett, A. (2011). Dairy Development Institutions in East Africa: Lessons Learned and Options. Rome, Italy: Food and Agricultural Organisation of the United Nations (FAO). Retrieved from http://www.fao.org/docrep/013/k9649e/k9649e00.pdf. Accessed on October 10, 2015.

Makoni, N., Mwai, R., Redda, T., Zijpp, A. van der, & Lee, J. van der. (2013). White Gold; Opportunities for Dairy Sector Development Collaboration in East Africa (No. CDI - 16-006). Wageningen, the Netherlands: Centre for Development Innovation, Wageningen UR (University and Research Centre). Retrieved from http://edepot.wur.nl/307878. Accessed on October 1, 2015.

Murillo-Zamorano, L.R. (2004). Economic efficiency and frontier techniques. *Journal of Economic Surveys*, 18(1):33–45.

*Agribusiness* DOI 10.1002/agr
Mutinda, G., Baltenweck, I., & Omondi, I.A. (2015). Setting up Sustainable Dairy Business Hubs: A Resource Book for Facilitators. Nairobi, Kenya: International Livestock Research Institute (ILRI). Retrieved from https://cgspace.cgiar.org/bitstream/handle/10568/73061/manual21.pdf?sequence=3&isAllowed=y. Accessed on December 12, 2015.

Nargis, F., & Lee, S.H. (2013). A non-parametric efficiency analysis of boro and aman rice production in selected areas of the mymensingh district in Bangladesh. *Journal of Food, Agriculture & Environment, 11*(3 & 4):717–724.

Nouala, S., Pica-Ciamarra, U., Otte, J., & N’guetta, A. (2011). Investing in Livestock to Drive Economic Growth in Africa: Rationales and Priorities (Alive Policy Note (April 2011)) (p. 8). ALive - ALive Livestock Africa (Partnership for Livestock Development, Poverty Alleviation and Sustainable Growth). Retrieved from http://www.alive-online.org/data/files/policynote-investinginlivestock.pdf. Accessed on September 09, 2015.

Ortmann, G.F., & King, R.P. (2007). Agricultural cooperatives II: Can they facilitate access of small-scale farmers in South Africa to input and product markets? *Agrekon, 46*(2):219–244.

Ranja, T. (2003). National Entrepreneurship in the Export and Horticultural Products in East Africa (Working Paper Series No. 8) (p. 21). Economic and Social Research Foundation. Retrieved from http://www.esrftz.org/global/output/WPS08_Ranja_Horticulture.pdf. Accessed on October 10, 2015.

Rao, E.J.O., Omondi, I.A., Karimov, A.A., & Baltenweck, I. (2016). Dairy farm households, processor linkages and household income: The case of dairy hub linkages in East Africa. *International Food and Agribusiness Management Review, 19*(4):95–108.

Salami, A., Kamar, A.B., & Brixiov, Z. (2010). Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities (Working Paper Series No. 105 - April 2010) (p. 50). Tunis, Tunisia: African Development Bank. Retrieved from http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/WORKING%20105%20%20PDF%20d.pdf. Accessed on September 10, 2015.

Sharma, R.K., Leung, P., & Zaleski, M.H. (1999). Technical, allocative and economic efficiencies in swine production in Hawaii: A comparison of parametric and nonparametric approaches. *Agricultural Economics, 20*(1):23–35.

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