Food & Nutrition Journal

GAVIN PUBLISHERS

Review Article

Farm Size and Productivity Nexus Farmers' Welfare in Burundi

Sanctus Niragira[1*], Jan Brusselaers[1], Jeroen Buysse[2], Jos Van Orshoven[3], Jean Ndimubandi[1], Marijke D'Haese[2]

[1]Department of Rural Development, University of Burundi, Burundi

[2]Department of Agricultural Economics, Ghent University, Belgium

[3]Department of Earth & Environmental Science, University of Leuven, Belgium

[*]**Corresponding author:** Sanctus Niragira, Department of Rural Development, University of Burundi, Burundi. Tel: +25771509242; Email: Niragsnctus@gmail.com

Abstract

This paper presents an economic analysis of small-scale agricultural production efficiency and household welfare in Burundi. We used recent advances in data envelopment analysis (robust DEA) to generate standard and bootstrap-bias-corrected technical efficiency scores for a nationwide sample of farms in the country. Next the correlation between these farm efficiency scores and household poverty levels was checked. Finally, an instrumental variable approach was used to assess the link between household welfare and farm productivity. Findings highlight that smaller farms are more efficient than the larger farms. Yet, given their small size, this efficiency level is not sufficient to raise the farm income above the poverty line which raises concerns about small farms' viability. Most of them are too small and agriculture can no longer provide a realistic livelihood for the household to earn a living. As a consequence, most of the land-constrained household are poor and food insecure despite their higher productivity. Both consumption and income appear as increasing functions of the farm size. As such, it is hard to appreciate how the inverse relationship between farm size and land productivity can strengthen nearly landless households or how livelihoods can be sustained in small scale farms of Burundi. Fundamental changes in the farming systems and agricultural policy are necessary to increase the scope for sustainable smallholder-led agriculture and its spill-over effects on the country's economy.

Introduction

The potential of smallholder agriculture to create employment in rural areas, to generate income, and to contribute to household food security has been well documented in many developing countries [1,2]. Since 1964, when Schultz formulated the "poor-but-efficient" hypothesis, smallholder farmers attracted the attention of researchers, donors and decision makers alike. By agreeing that small-scale farmers are more rational, compared to the large landowners in allocating their scarce resources, improving the livelihoods of these households becomes a central aim of agriculture-led development. An impressive body of literature confirms that small-scale farms are efficient by showing an inverse relationship between farm size and yield [3,4]. Better efficiency on small-scale farms is partly attributed to the abundant family labour per unit of land. Family workers are typically more motivated than hired workers and provide self-supervised high quality labour [5].

In addition, small farms achieve higher productivity with lower capital input compared to large farms, which is very important in countries where land and capital are scarce relatively to labour [6] and markets for credit and inputs are imperfect.

Empirical evidence suggests that support to small farms should not only be motivated by efficiency reasons but also because family farms are needed to maintain stability in the community, to secure sustainability of agricultural production and to stimulate local rural economic growth. Productive activities on small-scale farms as well as their labour mobilization, consumption patterns, ecological knowledge and common interests in long-term maintenance of the farm as a resource, contribute significantly to a stable and lasting local economy [7]. Smallholder farms contribute to reducing unemployment, provide a more equitable distribution of income and generate an effective demand for products and services from other sectors of the economy [8]. By spending substantial shares of the extra income on locally produced non-agricultural goods and services, they contribute to markets and

---

production of often labour-intensive goods [2,9,10].

In turn, these demand-driven growth linkages provide better income-earning opportunities for the most vulnerable groups including nearly landless farmers and workers. Hence, both direct and indirect effects arising from supporting small farms contribute to the overall reduction in rural poverty and food insecurity [1,6] as these households account for large shares of the rural poor [11]. Moreover, growth in the smallholder farm sector adds to a more vibrant rural non-farm economy which in turn could constrain the rural-urban migration [6]. However, the viability of smallholder farms today is greatly challenged. They are confronted with trade-distorting agricultural policies and the shift toward increasingly integrated and consumer driven markets as part of market liberalization and globalization [6,12,13]. Also access to sufficient land is a great concern [14].

In many poorer countries, the continuous spatial subdivision of landholdings has reached levels where a growing number of subsistence farms are unable to achieve their primary goal to secure the families' food and income [15]. Hence, a pertinent question is if and how farm size affects the ability of the farmers to provide a decent living to the household and further ensure communities' long-term economic sustainability? According to Hazell, the minimum acceptable size of a farm depends on the possibility in complementing income from farm activities with non-farm income [6]. At a certain level of farm size division, farms could get so small that production becomes too low to warrant their farming activity. Non-farm income is then needed to survive, but non-farm income earning opportunities may be very scarce especially in the rural areas of least developed countries. Jayne et al. (2003) [14] emphasised the growing number of landless and nearly landless farms leading ultimately to a rapid exodus from the countryside despite the low accommodation capacity and high rates of unemployment in African cities.

Against this background, this study assesses the link between farm size, productivity and household welfare in the context of highly fragmented landholdings of Burundi. Demographic pressure has caused shortages of agricultural lands. In addition, the intensive cultivation led to serious soil erosion and fertility problems [16], and therefore put limits on the scope of sustainable intensification. Yet, the agricultural sector is considered to be the backbone of the country's economy and its problems hence call for comprehensive public interventions [17].

A study by Verschelde (2013) [18] in two Northern provinces of Burundi found an inverse relationship between farm size and land productivity while showing a strong correlation between farm size and household food security [18]. This inverse relationship has been confirmed for other smallholder farming systems too. The findings may not come as surprise if one assumes the limits of scale economies due to limited mechanisation, input use and

market. Yet, how small, a small farm is allowed to be as to secure household survival? For numerous households, farm income is not sufficient to properly remunerate the farmer's work nor to support household food and non-food needs [17]. Therefore, even though smaller farms are considered more productive, the key question for the farm family is in the end whether the total income generated and food produced allows them to feed their families and to cross the poverty line.

Higher farm productivity may allow an exit from poverty, if the size of production and the income generated is sufficiently large; or in other words if the farms are of a minimal size [19]. Access to land is generally regarded as a key issue for sustainable livelihoods in Burundi [20]. Scholars view access to land as a significant determinant of food security, vulnerability to risks and shocks, and income potential [21]. A particular question is also how efficiency levels influence welfare given a certain farming system and land area. This relationship may differ from the one between land area and efficiency. This basically answers the question whether it is possible for a household to gain welfare through improving the farming system's efficiency given the land it has available.

The link between the inverse relationship of farm size and efficiency, and a discussion on minimum scale to secure sufficient quantities of food for the family, is not often made. We want to close this gap in literature. This study makes at least two contributions to literature. First it analyses the production levels and efficiency of production in terms of energy and macronutrient levels. The production and income recalculated in food availability and accessibility allow investigating farm production from a nutrition-sensitive agriculture perspective. We calculate the relationship between farm size, efficiency levels, production size, income and food security. Second, we add a question of minimum scale to the inverse relationship literature. As far as we know this has been overlooked in literature so far. We use a dataset of information collected by the Ministry of Agriculture from farms across Burundi. We apply a Data Envelopment Analyses (bootstrapped to increase robustness of the results) to calculate efficiencies which are then compared to absolute levels of production and income. We estimate how increase in efficiency, given the land area, can influence farm household's welfare levels. The key welfare variable for this study is farm income per adult equivalent. Despite that income is considered less desirable in measuring consumption-based welfare, it is generally accepted as a key indicator of household economic activity and welfare [14].

Study Methodology

Data

This study uses data from a recent agricultural survey available from the National Statistical Bureau of Burundi (ISTEEBU).

The nationally representative survey was conducted in the 16 provinces of the country on a sample of 2560 farm households during the cropping year 2011-2012. In each of the 16 provinces, 20 collines (administrative demarcation) were randomly selected and in each colline, 8 farm households were randomly chosen to participate in the survey. The main purpose of the survey was to update agricultural statistics in the country. The survey included 14 sections with questions related to farm production, household characteristics, income generating activities and livestock keeping. Households were visited several times during all three agricultural seasons. The data on agriculture was complemented by data on living-conditions collected by the World Bank on the same farm household sample. For some variables, we noticed measurement and encoding errors which prevented identification and therefore merging of the datasets[1]. Farm households which could not be matched were removed from the dataset, resulting in a sample of 2130 farm households. Note that the province of Bujumbura mairie (which is the most important urban area in the country) was not considered in the survey due to the relatively minor role it plays in agricultural production of the country.

Variables Included in the Study

Not all available data were used in this study. Only variables related to household size and composition, agricultural investments and annual production were considered. Household composition is given in number of adult equivalents taking into account the household structure. The Adult Equivalents are created to normalize the nutritional needs of different family members in a household based on age and gender [22,23]. Pregnancy and breastfeeding were not included in the study due to lack of related information in the dataset. With regard to farm production, we valued food crops production at their market prices, irrespective of whether crops were sold, consumed by the household or exchanged through social networks[2]. The quantity of each crop was multiplied by an average market price[3] of the respective crop because individual farm-gate prices were missing. They are highly volatile while only very limited amounts of produce are sold in most farm households. We consider that this price represents the real amount of money that farmers would have to pay to acquire the products on the market. Annual production was also valued in terms of calorie and food macronutrients (proteins and fat contents) in order to aggregate the production in a single unit that can be compared with the household food needs. Production quantity of each crop was multiplied by respective approximate content in calories, proteins and fat issued by FAO[4].The production of banana was taken separately because banana can be considered a semi-cash crop as it is mostly used to produce the locally well-known and highly marketed banana wine/beer [24]. Cash crops are coffee, tea and cotton, and related income and non-farm income were reported by farmers during the interviews.

Land size, labour and cost of purchased inputs (agricultural expenditures) were included as production factors. For land, the total farm area that was used for growing crops in the three cropping seasons of the 2011-2012 agricultural year was calculated. The impact of land fragmentation was assessed because a single farm in Burundi consists of numerous spatially separated parcels. Whereas some authors consider land fragmentation as an obstacle that causes inefficiencies in production and hence reduces income of farmers, others view it as an advantage for farmers to mitigate risk and optimise the cropping activities calendar [25]. Land fragmentation was captured by Simmons index which is the sum of different plot areas squared divided by the square of total cropping area $\sum S_i^2 / (\sum S_i)^2$; with S_i: area of plot i). This index varies between zero and one, with the higher values indicating lower fragmentation [25].

Two different sources of labour were considered, namely family labour measured as the number of adult family workers, and hired labour expressed in labour expenditure. Although the former is an imperfect proxy of the effective time spent by family workers on the farm household, it was used as we lacked more detailed data. Most of farm work is done by family members. Due to the absence of an alternative labour market to agriculture, over-employment on own farms is very common. One may assume that the marginal productivity is almost zero in such case which makes it difficult to calculate the opportunity cost for labour. The extra labour is sometimes hired, but paid very low wages. Hence, the true value of the labour is very difficult to quantify and the wage levels are used as proxies.

Purchased inputs concerned expenditures for seeds and chemicals. Generally, seeds and seedlings used in agricultural production in Burundi are mostly local varieties taken from previous harvests. Yet, farmers often complement the seed stock with purchases or simply buy all the seeds if the quantity (previously) harvested was not sufficiently enough to deduct the seeds. Farmers may also choose to buy improved seeds to enhance productivity. Farmers buy fertilizers and pesticides even though at less extent.

Analytical Framework

The model presented in this paper is based on a Data Envelopment Analysis that generates efficiency scores for each farm in the sample related to the best performing peer farm. These efficiency scores are then compared to the poverty levels by farm size. We improve the traditional DEA and poverty measures in three ways: first, we used robust DEA model to generate standard and bootstrap-bias-corrected technical efficiency scores among farms. We used an approach for bootstrapping proposed by Simar and Wilson (2000) [26] which simulates the effect of noise in the data on efficiency evaluation. Given the stochastic nature of the

agricultural production and the possible occurrence of outliers, this more robust modelling approach significantly improves the estimation of predicted behaviour of scarce resource use in different policy contexts or in different production activities.

Second, the P-alpha measure of poverty, developed in 1984 by Foster, Greer and Thorbecke, was used to define the poverty levels (poverty incidence, gaps and severity) among farm households. We used a poverty threshold estimated for Burundi by Bundervoet (2006) [27] as the poverty line. Based on a consumption bundle deemed adequate to satisfy basic needs, the food poverty line was estimated at 14.95 USD[5] per adult equivalent per month to which a minimum amount of 3.3 USD per month for non-farm needs was added. This sums up to 18.25 USD per adult equivalent [27]. With an exchange rate of 1238 BIF[6] to the USD, the overall poverty line was defined at 22 593.5 BIF per adult equivalent per month or 271 122 BIF (219USD) per adult equivalent per year.

Third, a regression analysis was implemented to assess the driving factors of household welfare measured as household income per adult equivalent. An Instrumental Variable (IV) regression approach was used to deal with reversed causality between farm efficiency and household welfare causing problems of endogeneity. This IV approach is used for confounding control [28]. The principle is that variables correlated with some outcomes through their effect on other variables, are explicitly excluded from some equations and included in others [29] in a system of equation known as structural equations models.

Efficiency analysis

We used a non-parametric procedure to estimate the farms' production frontier. Non-parametric approaches are sometimes preferred over parametric methods because the latter requires assumptions such on the mathematical specification of the functional form of the production [30]. DEA methods have gained greater momentum after the pioneering work by Charnes et al. (1978) [31] for a Constant Return to Scale (CRS) version of DEA, which was later extended by Banker et al. (1984) [32] to a Variable Return to Scale (VRS) DEA framework. The individual technical efficiency scores are calculated using mathematical programming techniques where the solutions satisfy inequality constraints of all decision making units involved.

The CRS restriction assumes that all farms in the analysis are performing at an optimal scale. However, technical efficiency scores reported under CRS are biased by scale efficiencies. The Variable Return to Scale (VRS) implies that each unit is compared to a 'peer group' consisting of a linear combination of efficient production units with similar size [33]. This study uses a VRS specification.

Mathematically, the model is represented as follows [34], given column vectors of p inputs (denoted by $x \in \mathbb{R}_{+}^{p}$) and of q

q outputs (denoted by $y \in \mathbb{R}_{+}^{q}$), the production set of physically attainable points (x, y) is given by:

$$\Psi = [(x,y) \in \mathbb{R}_{+}^{p+q} | x \text{ can produce } y)] \qquad (1)$$

This can be described as either an input-oriented set (minimizing the proportional input variables while remaining within the envelopment space) defined as $\forall y \in \Psi$,

$$X(y) = [(x \in \mathbb{R}_{+}^{p} | (x, y) \in \Psi] \qquad (2)$$

Or an output oriented set (maximizing the proportional increase in the output vector) defined as $\forall y \in \Psi$,

$$Y(x) = [(y \in \mathbb{R}_{+}^{q} | (x, y) \in \Psi] \qquad (3)$$

The choice of any particular orientation only has a minor influence upon the reported efficiency scores [35]. The radial (input-oriented) efficiency boundary (efficient frontier) is then defined by:

$$\partial X(y) = [x | x \in X(y), \theta x \notin X(y) \forall 0 < \theta < 1] \qquad (4)$$

The Farell input measure of efficiency for a production unit working at level (x_0, y_0) is defined as:

$$\theta(x_0, y_0) = \inf[\theta | x_0 \in X(y_0)] \quad = \inf[\theta | (\theta x_0, y_0) \in \Psi] \qquad (5)$$

And given an output level y, and an input mix (a direction) expressed by the vector x, the efficiency level of inputs is determined by: $x^{\partial}(y) = \theta(x,y) x$, which is the projection of (x, y) on the efficient boundary $\partial \Psi$, along the ray x and orthogonal to the vector y.

The same algorithm can be applied to the output space where the output boundary $\partial Y(x)$ is defined for all $x \in \Psi$; as:

$$\partial Y(x) = [y | y \in Y(x), \prec y \notin Y(x) \forall \prec > 1] \qquad (6)$$

Then the Farell output measure of efficiency for a production unit working at level (x_0, y_0) is defined as:

$$\prec (x_0, y_0) = \sup[\prec | (x_0, \prec y_0) \in \Psi] \qquad (7)$$

The efficient level of output, for the input level x and for the direction of the output vector determined by y is given by $y^{\partial}(x) = \prec (x,y) y$.

Note that the frontier Ψ is unique; $\partial X(x)$ and $\partial Y(y)$ are two different ways of describing it [34,36].

Robust optimization

All deviations from the frontier are considered as inefficiencies in the standard DEA which makes the approach unable

to accommodate measurement errors and it is extremely sensitive to outliers [36,37]. To overcome those problems, researchers started to incorporate stochastic considerations into DEA models [26,34,38-41]. The bootstrapping approach was first introduced to the standard DEA model by Simar (1992). Henceforth, the stochastic programming based on robust optimization became a common approach to handle uncertainty and is preferred due to its applicability [42]. Based on statistically well-defined models, the method allows for robust estimation of the production frontier as well as of the corresponding efficiency scores [33,43]. Bootstrapping investigates the reliability of the data by creating a pseudo-replicate data set using Monte Carlo approximation, which provides a better estimation of parameters of the interest. The bootstrap distribution will mimic the standard unknown sampling distribution of the estimators of interest resulting in changes in the ranking of bias-corrected efficiency scores from the standard efficiency scores. The DEA bootstrapping process is well documented in [26,34].

The robust DEA model was used to estimate input-oriented measures of technical efficiency with variable return to scale. The production activities are disaggregated into following inputs: area cropped, agriculture investment (expenditure on seeds, labour, fertilizers and pesticides), and labour expressed in number of adult persons (active) in the household; and three outputs: food production (calories), total banana production (kg) and cash crop incomes (section 3.2.2provides more details on the inputs and outputs).

Household poverty assessments

To evaluate poverty levels among farm households, we used the P-alpha measure of poverty or the poverty gap index first developed by [44]. The index is based on the normalised income gap and a predetermined poverty line. With $y = (y_1, y_2, \dots, y_n)$ a vector of household (individual) incomes and $z > 0$ the poverty line, the expression $g_i = z - y_i$ indicates the income shortfall of the ith household. The number of poor households (income $< z$) is $q = q(y,z)$ while $n = n(y)$ is the total number of households. The poverty measure P is given by the following expression [44]:

$$P(y,z) = \frac{1}{nz^2}\sum_{i=1}^{q} g_i^2 \tag{9}$$

With $H = \frac{q}{n}$ the headcount ratio, $I = \sum_{i=1}^{q} g_i^2 /(qz)$ the income-gap ratio, the squared coefficient of variation C_p^2 measures inequality and is defined as:

$$C_p^2 = \sum_{i}^{q}(\bar{y} - y_i)^2 / q\bar{y}_p^2, \quad \text{where} \quad \bar{y}_p = \sum_{i}^{q} \frac{y_i}{q}, \quad \text{then}$$
$$P(y;z) = H[I^2 + (1-I)^2 C_p^2] \tag{10}$$

C_p^2 is obtained when n and $\bar{y}$ are substituted for q and z in the definition of P.

For households whose income is below the poverty line, poverty measures can be calculated from the following general equation [44]:

$$P_\alpha = \frac{1}{n}\sum_{i=1}^{q}(\frac{z-y_i}{z})^\alpha \tag{11}$$

The quantity in parentheses is the proportional shortfall of expenditure or income to the poverty line for households living below that line. The parameter α can be viewed as a measure of poverty aversion: a larger α gives greater emphasis to the poorest households in the community. For $\alpha = 0$, the measure P_0 is simply the headcount ratio H, where there is no aversion to poverty. When $\alpha = 1$, P_1 gives the depth of poverty or poverty gap $(H.I)$. By setting $\alpha = 2$, the measure of P is obtained, which is commonly known as the poverty severity [44-46].

Results and Discussion

Descriptive Statistics on Farm Household

The sample of 2130 farm households retained for the study was divided into four land quartiles in order to illustrate the possible relationship between landholding on the one hand and household characteristics, farm stewardship and productivity, and households' living conditions on the other hand. We first give an overview of the basic characteristics captured by the data (Table 1). The standard deviations are given in parentheses and significant results from comparisons are indicated by letters abcd (superscripts) to highlight quartile of farms which differs from the selected one (a, b, c and d stand for Quartile I, Quartile II, Quartile III and Quartile IV respectively).

	Overall mean	Farm size categories				F-test
		Quartile I	Quartile II	Quartile III	Quartile IV	
Age of the head of household (years)	43.47 (15.56)	42.90 (14.76)	43.35 (15.54)	44.22 (16.09)	43.39 (15.85)	0.667
Household size (number of persons)	5.26 (2.35)	4.51[bcd] (2.08)	5.08[acd] (2.30)	5.45[abd] (2.30)	5.97[abc] (2.40)	38.827***
Farm household workers (number)	2.47 (1.20)	2.10[cd] (0.80)	2.34[cd] (1.079)	2.56[abd] (1.28)	2.86[abc] (1.39)	40.243***
Dependency ratio (%)	51.31 (30.36)	52.07 (30.81)	50.44 (29.04)	50.84 (32.39)	51.88 (29.14)	0.362
Household adult equivalents	4.21 (1.96)	3.47[bcd] (1.59)	4.04[acd] (1.87)	4.37[abd] (1.95)	4.97[abc] (2.09)	58.668***
						χ²-test
Gender household head (% male)	78.03	76.2	73.1	80.9	80.8	13.254**
Symbols indicate significant differences at ***: p-value ≤ 0.01, **: p-value ≤0.05, *: p-value ≤ 0.10						

Table 1: Basic household characteristics (n=2130; sd. in parentheses).

The average age of the household head was 42 years with minor variations over the quartiles. Households were mainly headed by men and the average household size was 5 people per household. Two to three members worked on the farm. The number of active persons provides a good indication of the labour availability in the farms since the family labour is likely to be the largest labour source for many rural households. To assess the household needs, the household size was converted into adult equivalent units based on the number of persons, their age and gender. On average households counted 4.21 adult equivalents, with the largest households found amongst the largest landowners (Table 2). The table introduces basic statistics on the farming practices by land quartile. We consider area used for crop production which is the total amount of land that a household cultivated during rainy and dry seasons in the corresponding year. Fallow land and marginal land used for grazing animals or reforestation were excluded from the analysis. Results reveal that households depend on less than one hectare of land (0.71 ha on average) for agricultural production.

	Overall mean	Farm size categories				F-test
		Quartile I	Quartile II	Quartile III	Quartile IV	
Agricultural land (hectare)	0.71 (0.58)	0.19[bcd] (0.06)	0.41[acd] (0.06)	0.70[abd] (0.10)	1.51[abc] (0.63)	1690.56***
Seed expenditure (USD)	23.39 (35.57)	14.63[cd] (24.38)	20.57[cd] (24.80)	25.40[abd] (33.91)	32.95[abc] (50.26)	26.173***
Labour expenditure (USD)	26.23 (26.22)	9.33[bcd] (24.37)	18.39[acd] (38.06)	28.44[abd] (46.61)	48.78[abc] (71.57)	65.440***

Expenditure on chemicals (USD)	10.57 (25.22)	5.92[bcd] (20.94)	10.13[ac] (21.92)	12.95[ab] (26.00)	13.29[a] (30.29)	9.859***
						χ²-**test**
Extension training (%yes)	10.00	6.90	10.30	8.10	14.60	20.497***
Anti-erosion methods(%yes)	38.40	30.40	38.70	43.50	41.00	18.572***
Access to credit (% yes)	5.30	4.90	5.60	4.70	5.80	0.977
Membership agro- cooperative (% yes)	13.80	13.10	13.90	14.30	13.70	0.312
Symbols indicate significant differences at ***: p-value ≤ 0.01, **: p-value ≤0.05, *: p-value ≤ 0.10						

Table 2: Agricultural investment and production techniques (n=2130; sd. in parentheses).

Clearly, Burundian farmers are poor, they use very little inputs for a subsistence production on a highly fragmented (average number of plots is 6, range from 1 to26) landholding. The basic input for agricultural production is land of which the size is limited due to an ever-increasing population. The distribution of land over the sample is rather unequal which results in a high number of very small-scale farms. An estimated 47% of the households in the sample had access to less than 0.5 hectare of agricultural land. Investments in agricultural production (agricultural expenditures) seem to be closely correlated with farm size with larger farms allocating more resources and spending more on inputs, but the overall levels of agricultural expenditure remain very low. The average yearly expenditure on seeds, labour and chemicals which included both fertilizers and pesticides amounted to 23.39, 26.23 and 10.57 USD respectively.

Smallholder farmers also lack access to extension and research services, as well as access to credit. Only 5% of the sample reported to have received credit during the cropping year of the survey. Despite the fact that farmers consistently reported a need for credit, microcredit rarely reached them. Commercial banks are reluctant to lend to farmers due to a lack of collateral. Agricultural cooperative, which could improve the access to credit [11] are not well developed neither. Only a small number of farmers interviewed were member of cooperative. In addition, despite the new institutional engagement of the government to expand the extension service, few farmers were aware of it. Since 2005,

2803 extension agents received training and were sent to every colline which brings them in walking distances of most farmers. Yet, only 10% of the farmers' population interviewed indicated to have received agricultural training during the cropping year 2011-2012 while almost one third had applied erosion control on their fields. Technology transfer and adoption are still problematic in the country due to weak linkages between research services and extension. In addition, the extension agents are often poorly trained and less motivated [47]. This is confirmed for other African countries where it was shown that the traditional communication approach following research had low impact on technology adoption of the users [48].

Household Income and Food Production

The agro-ecological diversity of the country allows for a great variety of crops to be grown and farms mix several crops on their plots. Of the fifty-three crops reported in the survey, the shares in overall production (per land quartile) often most important crops are reported here (Figure 1). Crops like wheat, banana, beans, potatoes and peanut were mainly produced on larger farms while small landowners had larger shares in rice production, peas and cassava. However, these results need to be interpreted carefully because some crops such as rice are mainly grown in the agro-ecological zones with high population density and hence small landholdings. Likewise, wheat is grown in the highland regions where population density is still low.
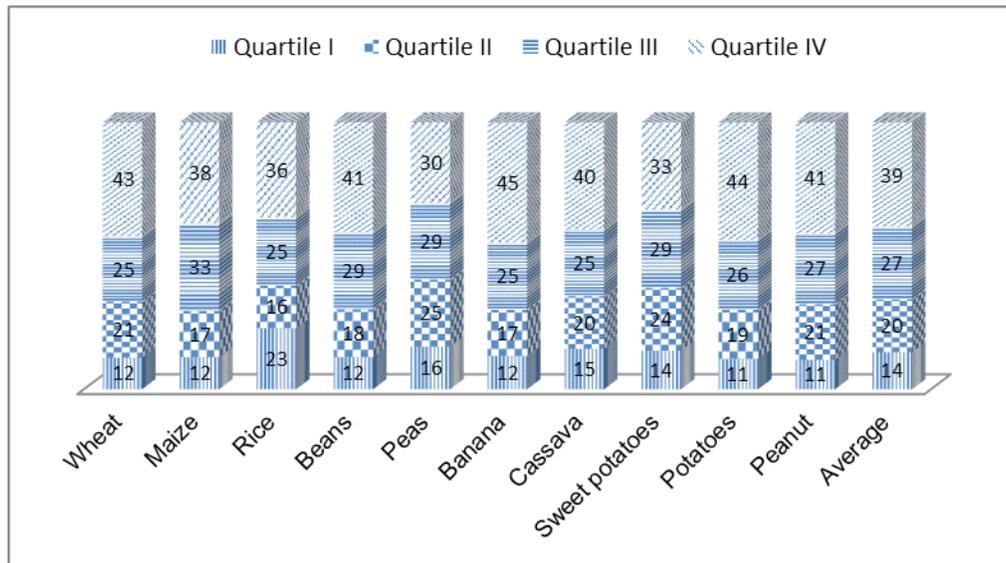
Figure 1: Farm quartiles and their respective shares in overall production per crop (%).

Globally, the farms in the two quartiles with the smallest landholdings produced together less (34%) than the farms in the fourth quartile (39%). The contribution to the overall production of the third land quartile is low compared to the fourth quartile but significantly higher than the contribution of the second quartile (20%). The first quartile contributes very little to the total food production (14%). The annual household income (Table 3), measured as a sum of the market value of food crops, the cash crop revenue and the non-farm income, is very low. On average household income is estimated at 650.63 USD per year. This should cover both food and non-food needs of the family (5 to 6 persons on average). The value of net crop and farm income (gross income minus expenditures on input) per hectare, a measure of partial land productivity, decreases with increasing land size. Whereas land productivity is higher for smallholders, the labour productivity (farm income per unit of labour) is higher for larger landholdings. These findings might be influenced by the cost of hired labour which is more temporary and hard to capture in terms of farm labourers.

Farm income (USD)	Overall mean	Farm size categories				F-test
		Quartile I	Quartile II	Quartile III	Quartile IV	
Market value food crops (USD)	551.99 (535.41)	271.17[bcd] (312.36)	435.82[acd] (402.89)	615.58[abd] (533.08)	885.27[abc] (629.41)	156.788***
Cash crop income (USD)	16.04 (47.17)	9.37[d] (37.96)	15.10[d] (45.88)	14.90[d] (40.54)	24.81[abc] (59.97)	9.996***
Non-farm (including off-farm) income (USD/year)	82.60 (244.91)	99.99 (290.98)	80.85 (253.47)	74.60 (203.46)	74.95 (222.56)	1.268**
Annual farm household income (USD/year)	650.63 (595.69)	380.53[bcd] (426.55)	531.77[acd] (479.65)	705.09[abd] (585.28)	985.03[abc] (681.44)	117.669***
Share of non-farm (off-farm) income (%)	29.69 (24.93)	44.08[bcd] (28.93)	29.59[ad] (23.47)	23.99[a] (19.52)	18.50[ab] (18.50)	40.757***

Land productivity (USD/ha)	1043.73 (1331.31)	1598.19[bcd] (2190.19)	1064.97[ad] (997.76)	889.63[ad] (753.75)	621.87[abc] (474.00)	54.962***
Labour productivity (USD/worker)	283.33 (276.70)	193.22[bcd] (216.97)	250.17[acd] (244.10)	308.43[abd] (278.20)	381.68[abc] (321.09)	48.266***
Symbols indicate significant differences at ***: p-value ≤ 0.01, **: p-value ≤0.05, *: p-value ≤ 0.10						

Table 3: Household annual income (n=2130; sd. in parentheses).

Some studies link low income levels to a vicious circle of over-exploitation of land leading to continuous nutrient mining and loss of soil organic matter, and further reductions in the returns to fertilizer use [49]. Burundi is one of countries with the lowest levels of fertilizer use in Africa as on average only 7.4 kg of fertiliser are applied per hectare of arable land (Worldbank, 2013)[7]. This is confirmed by the results in table 2 that on average, only 10.57 USD are spent on fertilizers and pesticides. With this amount of money, a farmer can afford to buy only 8.1 kg of fertilizers (if the price of 1.3 USD/kg is assumed, subsidies not included)[8]. Farmers survive mainly on their agricultural produce but also on work for wage and self-employment activities throughout the year. The market value of production (food crops and cash crops) increases with farm size whereas non-farm/off farm income is important for household with small farms. Large numbers of small farms seem to be too small to provide a subsistence living. Roughly 36% of the surveyed households had one or more members engaged in non-farm employment. An average household gets 30% of its income from non-farm earnings. This ranges from 19% in large farms (fourth quartile) to 44% in nearly landless farms (first quartile). They try to diversify the household's livelihoods in order to increase income security, food security and risk coping ability. Yet, non-farm income and employment opportunities seemed insufficient to adequately compensate for the low farm income. Local labour markets are not well developed, and only occasional ill-paid off-and non-farm employment is not able to improve the food security situation of the households.

Household Food Security

This section presents the food security of the farm households. While food production was captured by household surveys, only food expenditures were reported during the interview[9]. Therefore, food accessibility indicator is used in order to consider both food production and purchases. We estimated the quantity of food that households could buy (calories and macronutrients) if they would have to spend all the income to food. Income is considered as the sum of market value of the farm production (food and cash crops) and off-farm income.

Bundervoet (2006) [27] used the local and actually observed rural household behaviour to determine a consumption bundle deemed adequate to satisfy basic consumption needs. The reference food basket was expressed in terms of calories and ultimately assigned a monetary value. The food poverty line was calculated at 14.95USD/month (0.498 USD/day) to cover 2500 kcal per adult equivalent (daily), which enabled us to calculate the calories that each farm household in the sample could buy with its total income. Table 4 presents figures on percentage of households who meet the minimum requirements as prescribed by WHO. Only 32% of the sample households had enough income to cover the caloric needs of the household.

	Overall mean	Farm size categories				F-test
		Quartile I	Quartile II	Quartile III	Quartile IV	
Energy[α](kcal/adult equivalent/day)	2474 (32.40)	1842[cd] (19.70)	2226[cd] (28.00)	2654[abc] (35.20)	3172[abc] (46.90)	25.959***
Income[β](USD/adult equivalent/year)	177.54 (25.20)	132.20[cd] (16.90)	159.80[cd] (20.70)	190.47[abd] (27.40)	227.69[abc] (35.60)	25.959***
Symbols indicate significant differences at ***: p-value ≤ 0.01, **: p-value ≤0.05, *: p-value ≤ 0.10 α: the reference value is the food poverty line (2500kcal per adult equivalent a day =14.95USD/30days) β: the reference value is the overall poverty line (18.25 USD/month x 12 months =219 USD/year)						

Table 4: Food security by farm size categories.

Efficiency and Poverty in Smallholder Farms

Efficiency levels

This section presents the results of the farm efficiency analysis. The mean efficiency score was 0.53 for the standard DEA and 0.49 for bias-corrected-scores. A t-test was used to compare the standard and bias-corrected scores. A significant difference between them at 95% confidence interval (8.417***) was found, which indicates that the sample distribution was slightly influenced by stochastic effects. The distribution over the sample of farms organised by land deciles showed similar trends for both standard and bias-corrected efficiency scores.

The rest of this paper uses the bias-corrected-efficiency scores. The results corroborate the low productivity findings which were also addressed in a recent report of the International Monetary Fund's [49]. The study highlighted an important need to improve the farming systems of Burundi. Profit maximisation models would yield higher efficiency scores [43]. The following graphs illustrate the distribution of the efficiency scores by the factors affecting productivity at farm level. The efficiency scores are largely influenced by the number of adult people working on the farm (Figure 2).
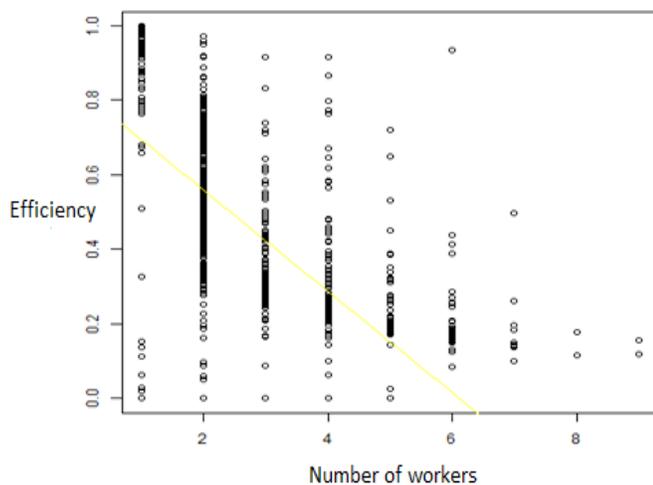

Figure 2: Household labour and farm efficiency.

The highest efficiency levels were found among households with fewer adults and active people in the household. Labour productivity was low when the number of workers was high while the land to be cultivated was relatively small. This reflects the high level of underemployment in the study area reported in previous studies [35,50,51]. Likewise, the distributionof efficiency scores shows a decreasing trend as the farm size increases. Figure 3 shows how efficiency levels of small farms result in different frontiers due to the variable return to scale assumptionimplying that each unit is

compared to a 'peer group'. The general trend is that the level of efficiency is higher for farms with small landholdings (Figure 3).
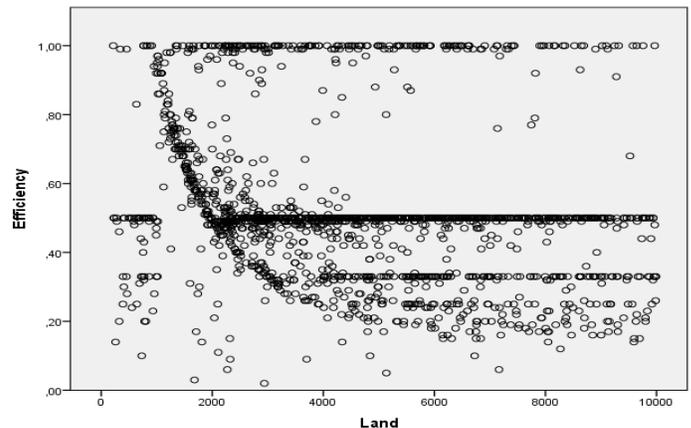

Figure 3: Farm size (m²) and efficiency levels in small-scale farms.

These results suggest an Inverse Relationship between farm size and productivity often highlighted in literature [3,5,18]. IR has been explained by imperfect factor markets leading to suboptimal resource allocation at the farm level. Labour market imperfection is often cited as a cause of low productivity on large farms due to supervision cost of hired labour. Also methodological issues are raised [18]. Another reason often put forward in literature is that IR emerges from other variables often omitted from the analysis [52]. In the case of Burundi, land fragmentation is high with an average Simmons index of 0.21. Farmers own many parcels (6 plots on average) spatially dispersed all over village areas, in neighbouring villages and in distant villages. Due to the distance from the farmstead to the plot, parcels at greater distance are cultivated less intensively. Poor infrastructure, potential theft and the cost linked to the implementation of soil conservation work result into farmer's low motivation to invest in distant plots [25]. This entails differences in land quality and therefore differences in soil productivity which clearly could affect the farm's output levels [53]. Numerous empirical studies also confirmed that soil quality affects the IR between farm size and productivity [52,54,55]. Including these variables in the efficiency analysis did not cancel the IR in an earlier study on Burundi [18].

Distribution of efficiency score by landholding

This section shows the comparison of efficiency score over the categories of farms grouped in land deciles. The use of land deciles intended to give a more detailed view on the distribution of efficiency scores across sizes of landholdings. They range from 0.41 in the largest decile and 0.63 in the lowest decile showing that small landholdings are farmed more efficiently. A one-way ANOVA yielded an F-statistic equals to 20.776***, indicating that there are statistically significant differences between the land deciles in the mean efficiency scores. Yet these results cannot show which of

the specific groups differ significantly. The results of a Tukey post-hoc test in SPSS is shown in table 5. The post-hoc test identified six groups of farm deciles with significant differences in efficiency at 95% confidence interval. The four highest deciles (7 264 - 20 902 m^2 of land) had little differences in mean efficiency scores. Also the two lowest deciles (1171-2191 m^2) seem not to differ much in terms of efficiency scores. Yet, deciles of smaller farms had a higher mean efficiency score than the mean of the deciles of the larger farms.

Land deciles	Area cultivated (m^2)	Homogenous groups (mean efficiency scores)					
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
X	20 902	0.41					
IX	12 228	0.43	0.43				
VIII	9 143	0.43	0.43	0.43			
VII	7 264	0.46	0.46	0.46			
VI	5 924		0.48	0.48	0.48		
V	4 847		0.48	0.48	0.48		
IV	3 925			0.50	0.50		
III	2 954				0.54	0.54	
II	2 191					0.57	0.57
I	1 171						0.63

Table 5: Tukey range test in efficiency scores by land decile.

Household poverty levels

The poverty head count index in the sample is 0.75. This result is in line with the International Monetary Funds' estimates that 80% of the farming population lives below the poverty line [49]. This suggests that only 25% of the farming population had income levels that succeeded to meet household food and non-food needs. The poverty gap and severity were on average estimated at 0.40 and 0.26 respectively, but, vary from 0.57 to 0.20 for the poverty gap and 0.42 to 0.10 for the poverty severity from the lowest to highest land decile (Table 6). The group of farms with the smallest size were worse off in terms of income.

Land deciles (m^2)	Share of agricultural income	Standard Efficiency scores	Corrected Efficiency scores	Poverty indicators		
				Poverty Incidence	Poverty gap	Poverty severity
1 171	0.45	0.62	0.63	0.86	0.57	0.42
2 191	0.62	0.60	0.57	0.84	0.56	0.41
2 954	0.66	0.56	0.54	0.80	0.47	0.33
3 925	0.71	0.54	0.50	0.75	0.42	0.27
4 847	0.74	0.53	0.48	0.80	0.44	0.29
5 924	0.74	0.50	0.48	0.74	0.38	0.23
7 264	0.77	0.51	0.46	0.72	0.36	0.22
9 143	0.78	0.47	0.43	0.71	0.34	0.20
12 228	0.80	0.47	0.43	0.66	0.29	0.16
20 902	0.84	0.46	0.41	0.58	0.20	0.10
7 055	**0.70**	**0.53**	**0.49**	**0.75**	**0.40**	**0.26**

Table 6: Farm efficiency and household poverty.

Farm productivity and household welfare

This section compares the farm productivity and household welfare indicators. Table 3 suggest that land ownership had a positive impact on household welfare while affecting the efficiency negatively. Off-farm income was important for the smallest farms and its importance decreased as landholding size increased. This is confirmed for other low income African countries [14]. The land-constrained households have little choice but to practice unsustainable farming methods, and this is undermining current and future land productivity. They are more likely to engage in off-farm work but their labour productivity is typically lower than that of large farms. While non-farm employment is believed to be a potential avenue to overcome land constraints among households, the underemployed workforce is typically engaged in the country's large informal sector where the level of payment is very low. Hence, the majority of the more diversified households are poor with the highest rate of household under the poverty line. It is hard then to appreciate how the inverse relationship between farm size and land productivity can strengthen nearly landless households under these conditions or how livelihoods can be sustained and allow them to cross the poverty line.

Factors Influencing the Household Welfare

The results presented in table 7 give an indication that landholding has a positive impact on household welfare while being negatively correlated with the farm efficiency. Yet, what happens if efficiency increases for a given land area? Will it increase welfare? An econometric model including other household and farm characteristics as explanatory variables is necessary to gauge the causality between farm efficiency and household's welfare. The variables included are: efficiency, age and gender of the household head, education, active people in the household, participation in producer cooperatives, access to credit, farm size and land fragmentation indicator (Simmons index), and agricultural expenditures. Variables like age and gender of the household head, education, participation in producer cooperatives, and access to credit did not yield a significant effect on the household welfare and were not included in the final model.

Variables	Coefficient estimate	t-test	VIF
Intercept	6.61e+04	3.22**	
Agricultural expenditures	3.16 e-01	5.74***	1.12
Efficiency scores	2.49 e+05	7.89***	1.06
Simmons index	-2.17 e+05	-6.12***	1.04
Land available	7.62 e+00	8.43***	1.17

Residual standard error	226488.304	
Root MSE	226488.304	
Multiple R-squared	0.067	
Adjusted R-squared	0.065	

Symbols indicate significant differences at ***: p-value ≤ 0.01, **: p-value ≤0.05, *: p-value ≤ 0.10

Table 7: 2SLS estimates for explaining household welfare (dependant variable: income per adult equivalent).

The variable efficiency could potentially be considered as endogenous because the dependent variable income is indirectly used to calculate the efficiency levels. Hence three instrumental variables are selected for a 2-stage least squares approach. The variables land, agricultural expenditures and active people can serve as instruments for the efficiency. Both agricultural investments and land can be considered as perfectly suitable instrumental variables but enter also in the main equation of the linear regression model. This is not the case for the number of active people because we assume that the redundant availability of labour does have a direct link with income or welfare.

Table 7 presents the outcomes of the explanatory variables for a farmer's welfare, taking into account the endogeneity for variable efficiency and using number of active people as an instrument. The dependent variable is income per adult equivalent (BIF/adult equivalent) as an indicator of the household welfare. These results demonstrate how efficiency positively impacts farmers' welfare. Hence, keeping all other variables (including for example land) constant, a farmer can increase household welfare by improving productivity. Investment and landownership positively impact a farmer's welfare. Land concentration seems to negatively impact welfare. This can be due to the fact that wealthy farmers buy more land which increases their number of plots. Note however that also for these variables some endogeneity or simultaneity problems might arise.

Table 7 gives also the Variable Inflation Factor (VIF) which is used to test for potential multicollinearity. The VIF provides an indication of how much the variance of the estimated coefficients is inflated when multicollinearity exists. Values exceeding 4 warrant further investigation, while values above 10 indicate serious multicollinearity requiring correction[10]. In our model all VIFs calculated fall below the cut-off values.

Conclusions and Policy Implications

This study analysed the efficiency and poverty levels of small-scale farms of Burundi. Despite the significant efficiency in

smallholder agriculture, findings raise concerns about the viability of these very small-scale farms in the densely populated areas of the country. Given the rapid population growth, shrinking farm sizes, and declining soil fertility, it has become very difficult to ensure household food security. Most households have such small landholdings that agriculture may not be a realistic possibility for earning a living even if efficiency is high.

This situation is expected to worsen with the continuing land subdivision due to the inheritance system. As a consequence, poorest household mainly depend on casual labour income in order to survive. Both consumption and income appear as increasing functions of landholdings. Yet the scope for expanding agricultural land is very limited in Burundi, putting limits on the ability to generate sufficient economic livelihood among households.

Under the current farm practices, smaller farms are more efficient but given their small size, this efficiency level is insufficient to raise them above the poverty line. Without fundamental changes in agricultural policies and farming systems, Burundi has little scope for sustainable smallholder-led agricultural intensification. In the absence of non-farm income, the source of rising local incomes would come from supporting agricultural growth among the small but sustainable farmers (especially farms able to invest in soil fertility restoration) and thereby catalysing a more successful economic transformation. This highlights a great need for policies that stimulate agricultural investment such as credit access, improved markets for agricultural products and more effective extension services. Moreover, land markets could allow households to buy and sell land. This would facilitate to free lands for other farmers.

Sustainable rural employment is critical to encourage the nearly landless farmers leave farming activities (or to free labour from the farms) which may benefit those who might remain on farm operations as well. The transfer of the workforce to other sectors would make agriculture more viable for at least three reasons: first, it would free up agricultural land. Second, it would allow more investment in agriculture via transfer of investment or remittances. Finally, it would improve the market for those farmers who stay in agriculture. This could boost the potential for agriculture to play its role. It would create possibilities to generate scale economies and have positive spill-over effects on the growth of other sectors. This paper does not suggest abandoning policies directed to very small farms in agriculture, but cautions that policy in the field of rural development should be rethought for designing successful poverty reduction strategies.

Notes:

[1]A partial checking of the database was done. As result one part of the data was removed as we could not manage to correct all the errors.

[2]Previous studies highlighted that 72% of food production were consumed by the household while 28% were either sold to the market or exchanged through social network.

[3]Information on average price is found at the national statistics Bureau (Annuairestatistique 2013).

[4]Proximate composition of foods http://www.fao.org/docrep/W0078E/w0078e11.htm#P9840_707166 (last accessed on 20 May 2016)

[5]The food poverty line was defined based on a food basket of 2500 kcal/day

[6]The exchange rate from the Interbank Burundi (s.a) of 1238 at the time of the survey was used : www.interbankbdi.com

[7]http://data.worldbank.org/indicator/AG.CON.FERT.ZS (last accessed on 13 June 2016)

[8]Information from the regional agricultural office (Karuzi) on prices (in 2012) of fertilisers before the subsidy programme which is currently applied on fertiliser sector in Burundi (since august 2012).

[9]Farmers could not remember all the food items bought during the survey year.

[10]https://onlinecourses.science.psu.edu/stat501/node/347 (last accessed on 10th November, 2016)

References

1. Hedden-Dunkhorst B, Mollel NM (1999) Small scale farming and extension in south africa's northern province. South African Journal of Agricultural Extension 28: 93-107.

2. Mellor JW (2014) High rural population density Africa - What are the growth requirements and who participates?. Food Policy 48: 66-75.

3. Wiggins S, Kirsten J, Llambí L (2010) The Future of Small Farms. World Development 38: 1341-1348.

4. Verschelde M, D'Haese M, Rayp G, Vandamme E (2012) Challenging small scale farming: A non-parametric analysis of the (inverse) relationship between farm productivity and farm size in Burundi. Journal of Agricultural Economics 11: 261-287.

5. Lipton M (2010) From Policy Aims and Small-farm Characteristics to Farm Science Needs. World Development 38: 1399-1412.

6. Hazell PBR (2005) Is there a future for small farms?. Agricultural Economics 32: 93-101.

7. Rosset PM (1999) The Multiple Functions and Benefits of Small Farm Agriculture. Policy brief 4 Institute for Food and Development Policy, Oakland, CA USA.

8. Bravo-ureta BE, Pinheiro AE (1997) Technical, economic, and allocative efficiency in peasant farming: evidence from the dominican republic. The Developing Economies 35: 48-67.

9. Mellor JW (1976) The New Economics of Growth: A Strategy for India

and the Development World. Cornell University Press, Ithaca, NY.

10. Robbins P, Ferris RSA (2003) The impact of globalisation on the agricultural sector of East and Central African countries. International Institute of Tropical agriculture, Ibadan, Nigeria.

11. World Bank T (2007) World Development Report 2008: Agriculture for Development. The World Bank, Washington.

12. Kirsten J, Sartorius K (2002) Linking agribusiness and small-scale farmers in developing countries: Is there a new role for contract farming?. Development Southern Africa 19: 503-529.

13. Narayanam S, Gulati A (2002) Globalization and the Smallholders: A review of the Issues, Approaches and Tentative Conclusion. MSSD Discussion Paper No. 50 Food Policy Research Institute, Washington DC.

14. Jayne TS, Yamano T, Weber MT, Tschirley D, Benfica R, et al. (2003) Smallholder income and land distribution in Africa: implications for poverty reduction strategies. Food Policy 28: 253-275.

15. Glover D, Kusterer K (1990) Small farmers Big business: Contract Farming and Rural Development. The MacMillan Press LTD, Great Britain.

16. Oketch JS, Polzer T (2002) Conflict and Coffee in Burundi. In: Lind J, Sturman K (ed.), Scarcity and Surfeit, The Ecology of Africa's Conflicts. Institute for Security Studies South Africa.

17. MINAGRIE (2011) Agriculture et Development du monde rural. République du Burundi, Bujumbura.

18. Verschelde M, D'Haese M, Rayp G, Vandamme E (2013) Challenging Small-Scale Farming: A Non-Parametric Analysis of the (Inverse) Relationship Between Farm Productivity and Farm Size in Burundi. Journal of AGricultural Economics 64: 319-342.

19. Valdés A, Foster W (2010) Reflections on the Role of Agriculture in Pro-Poor Growth. World Development 38: 1362-1374.

20. Pedro PS (2011) Investing in Agriculture in Burundi: Improving food security and conditions for women farmers. Oxfam, Bujumbura.

21. Ricker-Gilbert J, Jumbe C, Chamberlin J (2014) How does population density influence agricultural intensification and productivity? Evidence from Malawi. Food Policy 48: 114-128.

22. Buse RC, Salathe LE (1978) Adult Equivalent Scales: An Alternative Approach. American Journal of Agricultural Economics 60: 460-468.

23. Weisell R, Dop MC (2012) The Adult Male Equivalent concept and its application to Household Consumption and Expenditures Surveys (HCES). Food and Nutrition Bulletin 33: 157-162.

24. Niragira S, D'Haese M, D'Haese L, Ndimubandi J, Desiere S, et al. (2015) Food for Survival: Diagnosing Crop Patterns to Secure Lower Threshold Food Security Levels in Farm Households of Burundi. Food and nutrition bulletin 36: 196-210.

25. Demetriou D (2014) The Development of an Integrated Planning and Decision Support System (IPDSS) for Land Consolidation. Springer, Switzerland.

26. Simar L, Wilson PW (2000) A general Methodology for bootstrapping in non-parametric frontier models. Journal of Applied Statistics 27: 779-802.

27. Bundervoet T (2006) Estimating Poverty in Burundi. Households in Conflict Network; Working Paper 20, The Institute of Development Studies - at the University of Sussex - Falmer - Brighton - BN1 9RE.

28. Greenland S (2000) An introduction to instrumental variables for epidemiologists. International Journal of Epidemiology 29: 722-729.

29. Angrist JD, Imbens WG, Rubin BD (1996) Identification of Causal Effects Using Instrumental Variables. Journal of American Statistical Association 91: 444-455.

30. Abdulai A, Huffman W (2000) Structural Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana. Economic Development and Cultural Change 48: 503-520.

31. Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. European Journal of Operational Research 2: 429-444.

32. Banker RD, Charnes A, Cooper WW (1984) Some Models for estimating technical and scale efficiencies in data envelopmet analysis. Management Sciences 30: 1078-1092.

33. Murillo-Zamorano LR (2004) Economic Efficiency and Frontier Techniques. Journal of Economic surveys 18: 33-77.

34. Simar L, Wilson PW (2008) Statistical Inference in Nonparametric Frontier Models: Recent Developments and Perspectives.

35. Cochet H (2001) Crises et Révolutions Agricoles au Burundi. Karthala, Paris.

36. Cazals C, Florens JP, Simar L (2002) Nonparametric frontier estimation: a robust approach. Journal of Econometrics 106: 1-25.

37. Veettil PC, Speelman S, van Huylenbroeck G (2012) Estimating the Impact of Water Pricing on Water Use Efficiency in Semi-arid Cropping System: An Application of Probabilistically Constrained Nonparametric Efficiency Analysis. Water Resources Management 27: 55-73.

38. Simar L, Wilson PW (1998) Sensitivity Analysis of Efficiency Scores: How to Bootstrap in Nonparametric Frontier Models. Management Science 44: 49-61.

39. Wu D, Olson DL (2008) A comparison of stochastic dominance and stochastic DEA for vendor evaluation. International Journal of Production Research 46: 2313-2327.

40. Bruni ME, Conforti D, Beraldi P, Tundis E (2009) Probabilistically constrained models for efficiency and dominance in DEA. International Journal of Production Economics 117: 219-228.

41. Wu D, Lee CG (2010) Stochastic DEA with ordinal data applied to a multi-attribute pricing problem. European Journal of Operational Research 207: 1679-1688.

42. Gharakhani M, Kazemi I, Alizadeh Haji H (2011) A robust DEA model for measuring the relative efficiency of Iranian high schools. Management Science Letters 1: 389-404.

43. Mugera A, Ojede A (2011) Agricultural Productivity Growth in Africa: Is Efficiency Catching-up or Lagging Behind?. 2011 Conference (55th), Melbourne, Australian Agricultural and Resource Economics ociety.

44. Foster J, Greer J, Thorbecke E (1984) A class of decomposable poverty measures. Econometrica 52: 761-766.

45. Foster J, Greer J, Thorbecke E (2010) The Foster-Greer-Thorbecke (FGT) poverty measure: 25 years later. Journal of Economic Inéquality 8: 491-524.

46. Asogwa BC, Umeh JC, Okwoche VA (2012) Poverty and Efficiency among the farming Households in Nigeria: A Guide for Poverty Reduction Policy. Current Research Journal of Economic Theory 4: 6-10.

47. FAO (2015) Country fact sheet on food and agriculture policy trends. Bujumbura.

48. Tizikara C, Wilcock D, Habyarimana PC (2007) Needs Assessment and Action plan for Improving Agricultural Research and Technology Transfer. World Bank, Rwanda.

49. IMF (2014) Country reports 14/293. In: 2014 Article IV Consultation, Bujumbura.

50. Baghdadli I, Harborne B, Rajadel T (2008) Breaking the cycle: A strategy for conflict- sensitive rural growth in Burundi. The World Bank, Washington.

51. Niragira S (2011) Optimizing land use among small scale farms through agricultural specialization in the north of Burundi Ghent University, Ghent.

52. Benjamin D (1994) Can unobserved land quality explain the inverse productivity relationship?. Journal of Development Economics 46: 51-84.

53. Sen AK (1975) Employment, Technology, and Development. Oxford University Press.

54. Lamb R (2003) Inverse productivity: Land quality, labor markets, and measurement error. Journal of Development Economics 71: 71-95.

55. Barrett C, Bellemare M, Hou J (2010) Reconsidering conventional explanations of the inverse productivity-size relationship. World Development 38: 88-97.