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Agricultural commercialization and household food security: The case of smallholders in Great Lakes Region of Central Africa

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Abstract

Rwanda and the Democratic Republic of Congo (DRC) faces the challenge of low food production and high incidences of poverty. Several programs initiated in the region to improve food security and market access have had limited success. Many households mainly grow bananas and legumes as staple crops. Using propensity score matching, this paper evaluates the impact of bananas and legumes commercialization on household food security. Commercial oriented farmers have more diverse diets than non-commercial oriented ones because they can easily purchase other foods to supplement own production. Commercialization has a robust and positive effect on household food security. It significantly increases household dietary diversity and reduces the number of coping strategies adopted during food shortage. Programs that promote commercialization of smallholder agriculture coupled with improved infrastructure in terms of roads and market information systems are continuously needed to facilitate commercialization of farm produce.

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1. Introduction

Like in many parts of the world, Great Lakes region of Central Africa faces the challenge of low food production and high incidences of poverty mainly in the rural areas. Agriculture is important to population live in rural areas and relies on farming for securing their daily livelihood. On average the sector contributes 33% of national income, 70% of full time employment and 40% of total export earnings in Africa (Otsuka *et al*., (2013). In Rwanda and South Kivu province of the Democratic Republic of Congo (DRC) 90%, 78% of the farm households respectively practice subsistence agriculture as their main livelihood strategy (CIALCA, 2009). The governments of the countries grapple with these challenges, yet less improved production and marketing technologies have been adopted. Therefore, commercialization of banana and legumes which are major staple food crops in the region has potential to address these challenges and improve livelihoods of smallholders. However, the region is characterized by poor marketing infrastructure with many smallholder farmers not motivated to participate in markets in fear of high transaction costs (Ouma *et al*, 2010). Goetz (1992), Key *et al*, (2000) and Makhura *et al*, (2002) also alluded that high transaction costs is one of the key reasons for smallholder farmers' failure to participate in the markets.

In Rwanda, 28% of rural population are food insecure, 24% and 25% are highly and moderately vulnerable to food insecurity respectively (WFP, 2009). Besides, 44.9% of the population live below national poverty line earning less than 64000 Rwandan francs per annum in 2010/2011 (GOR, 2013). In the DRC approximately 73% of population are food insecure (UNDP, 2010). This may be because these two countries have just recovered from political and civil wars which subjected smallholders to various production and marketing constraints. Soil degradation is also severe and yields of nearly all subsistence food and also cash crops continue to decline due to production constraints.

World Bank (2008) reported that in Sub-Saharan Africa, imperfect input and output markets continue to persist because of high transaction costs, risks and diseconomies of scale thus delaying achievement of food security goals. Food insecurity has been attributed to factors such as soil infertility and apparent lack of capacity to introduce sustainable production practices such as adoption of production technology, fertilizer use, improved seed and irrigation (Sahley *et al*, 2005). This clearly shows that transforming subsistence to a more commercialized production could improve the household access to diverse types of food due to increased purchasing power. The efficient markets are very important to farmers in determining food distribution from surplus to deficit regions to benefit everyone. Empirical

findings in Eastern DRC indicate that the persistent civil conflict is the main contributor to food insecurity because farm households often abandon agricultural and marketing activities (WFP, 2012). The fighting groups destroy crops and steal the crops and livestock. Besides, in Rwanda, Burundi and South Kivu poor climatic conditions leads to low farm income of 60% of the households (Ekesa *et al*. 2013) thus contributing to regular incidences of food insecurity in the Great Lakes region.

Commercialization of agriculture has long been considered an important means of enhancing food security, nutrition and incomes particularly when market access barriers are reduced (Gabre-Madhin *et al*, 2009). Studies by Lundy et al, (2002) also propose that for smallholder farmers to thrive in competitive global economy, it is necessary to create an entrepreneurial culture in rural communities where "farmers produce for markets rather than trying to market what they produce". One of the suggested ways to achieve commercialization is to support farmer organizations to allow smallholders to realize economies of scale in service access and delivery (Peacock *et al*, 2004). This argument is in favor of market access interventions referred to as "market oriented strategies" comprising collective marketing, participatory market research, product transformation and business plan development promoted by the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA)[2] to increase commercialization of banana and legume products and eventually address food insecurity challenges in Great Lakes region.

We build on the extensive agricultural economics literature about the effect of smallholder commercialization on their livelihoods. Commercialization studies in Africa has mainly focused on horticultural industry with these studies showing that smallholder horticultural commercialization is a means of increasing household incomes and reducing poverty at the household level (e.g. *Maertens et al*., 2012; Michelson, 2013 and Muriithi and Martz, 2014). Despite the fact that most smallholder farmers in Africa grow food crops, there is limited empirical studies focusing on their commercialization. Most common studies touching food crops have been done by Govereh *et al* (1999) in Kenya, Zimbabwe and Mozambique and Strasberg *et al*, (1999) in Kenya and found that commercialization positively influences fertilizer use and food crops productivity among rural households.

[2] CIALCA is a consortium of the International Institute of Tropical Agriculture (IITA), Bioversity International and The International Centre for Tropical Agriculture (CIAT) and their national research and development partners, supported by the Belgian Directorate General for Development Cooperation.

Rios et al. (2009) investigated the linkages between commercialization and productivity farm households in Tanzania, Vietnam and Guatemala and showed a positive and significant correlation between commercialization and productivity in Vietnam and Guatemala but insignificant in Tanzania. Smallholder commercialization of either food crops or horticulture have been done mainly in Eastern, Southern and West Africa with very few studies in Central Africa especially in Rwanda and DRC thus our paper becomes a pioneer in this regard. Still, the implications of smallholder commercialization for household food security are not yet fully understood and the findings not always in consensus (Maertens *et al*., 2012), which is likely to be due to inability to empirically identify the causal relationship. We use propensity score matching (PSM) approach to evaluate the contribution of commercialization of staple crops on household food security of rural households. Our study addresses two research questions: (1) what are the factors influencing commercialization of banana and legumes and (2) what is the impact of commercialization of banana and legumes on household food security among smallholders in Great Lakes Region.

2. Analytical framework and estimation techniques

(a) Modelling of impact of commercialization of food crops

We adopt average treatment effect (ATE) framework as originally proposed by Rosenbaum and Rubin (1983) to estimate the impact of commercialization on household food security. The ATE parameter measures the effect or impact of a "treatment" on a person randomly selected in the population (Wooldridge, 2002) and corrects the selection biased suffered by logits, probit and tobit models. In our study context, "treatment" corresponds to being commercial oriented. Following Rosenbaum and Rubin's counterfactual framework, ATE (ψ_i) is regarded as the difference between the outcomes in this case household food security (Y_i) of farmer $\boldsymbol{i}$ who is commercial oriented $\boldsymbol{M} = 1$ and the one who is subsistence oriented $\boldsymbol{M} = 0$.

$$\psi_i = Y_i(1) - Y_i(0) \tag{1}$$

In estimating the impact of commercialization from equation 1, is often impossible when using non experimental data (cross-sectional data) due to the fact that either $Y_i(1)$ or $Y_i(0)$ cannot be observed at the same time for each farmer $\boldsymbol{i}$. The average treatment effect is therefore specified as:

$$E(\psi_i) = P[E(Y^1|M=1) - E(Y^0|M=1] + (1 - P[E(Y^1|M=0) - E(Y^0|M=0)] \tag{2}$$

where P is the probability of observing a farmer being commercial oriented. Equation 2.7 indicates that the ATE for the entire sample is the weighted average of the effect of commercialization (treatment) and subsistence oriented (controls) each being weighted by its relative frequency. The counterfactual problem arises because unobserved counterfactuals, $E(Y^1|M=0)$ and $E(Y^0|M=1)$ cannot be estimated (Smith & Todd, 2005).

In situation where there is no information on the counterfactual situation then estimating the direct impact of commercialization from the variation in outcomes across the farm households using statistical matching method is appropriate (Blundell & Costa-Dias, 2000). In order to obtain comparison group to the treatment group that prevents selection bias, experimental approach is normally appropriate. However, our study uses quasi-experimental approach where it is not possible to observe both outcomes for a given farmer simultaneously. In order to address this problem, we use Propensity Score Matching (PSM) approach proposed by Rosenbaum & Rubin (1983). PSM prevents selection bias that occurs if unobservable factors that influence both the error terms of the outcome and

choice equations are not considered. The PSM summarizes the pre-treatment characteristics of each subject into a single index variable, and then uses the "propensity score" to match similar individuals.

The propensity score is probability of a farmer moving from subsistence to commercial oriented production conditional on covariates (X). This conditional probability is the propensity score which allows identification of farmers with similar characteristics. Estimating the treatment effects by PSM requires two assumptions to be satisfied. The first is conditional independence assumption (CIA) which states that given a series of observable covariates Xs, commercialization is independent of the potential outcomes (food security) with $\coprod$ representing independence while Y^0, Y^1 denotes potential outcomes with and without the commercialization and M commercialization variable.

$$Y^0, Y^1 \coprod M \left| X, \theta X \right. \tag{3}$$

Holding the observable covariates Xs constant, the subsistence oriented farmers' outcome has the same distribution that commercial oriented would have experienced had they not become commercial oriented.

The second assumption is common support or overlap condition which rules out the predictability of M given Xs, such that $0 < P(M = 1 \left| X \right.) < 1$. It guarantees that the farmers with the same X values have a positive probability of being both commercial and subsistence oriented thus farmers falling outside common support region are not included in the estimation of ATE. If this assumption holds then the matching quality is improved by excluding farmers at the tails of the propensity score distribution and ensures that characteristics observed in the market oriented group can also be observed among the non-commercial oriented group (Bryson *et al*, 2002). The disadvantage of this assumption is that it reduces the sample size and if the number lost is too large; then the remaining sample may not be sufficiently representative raising doubts on the ATE estimates (Caliendo and Kopeinig, 2008). Considering the above assumptions, the propensity score matching estimator for average treatment effect on treated (ATT) is specified as follows:

$$\psi_{ATT}^{PSM} = E_{P(X)|T=1}\{[E(Y(1) \left| M = 1), P(X)\right] - E(Y(0) \left| M = 0, P(X)\right]\} \tag{4}$$

It indicates that the ATT is the mean difference in food security between commercial oriented and non-commercial oriented farm households. PSM is a conditional probability estimator therefore Rosenbaum and Rubin (1983) proposed probit or logit model to be used to estimate propensity score followed by

matching algorithm. Estimation of propensity score is first accomplished using probit model following (Johnston and DiNardo, 2007) as shown in equation 4.10:

$$\Pr ob[y_i = j] = \frac{\exp(\beta_j x_i)}{s(j = 0 - j)\exp(\beta_j x_i)}, j = 0,1.....,J \quad (5)$$

where the left side represent the probability of being commercial oriented for *j*th household and 'x_i' variables are characteristics of the observed household, which are the same across all outcomes. Thereafter, given population of units and propensity score then the average effect of commercialization (AEM) can be estimated using various matching approaches.

We used nearest neighbor matching (NNM), caliper matching (CM) and kernel-based matching (KBM) that have been proposed by Smith and Todd (2005) to match commercial oriented and subsistence oriented farm households. The NNM matches each treated farmer with the control group that has the closest propensity score. However, NNM is likely to yield poor matches especially if the closest neighbor is far away. This problem can be reduced by applying caliper matching algorithm, by imposing a maximum tolerance on the difference in propensity scores. It can also be overcome by allowing replacement, which reduces the number of distinct subsistence oriented used to construct the counterfactual outcome, and thereby increases the variance of the estimator (Smith and Todd, 2005). Caliper matching is a variant of nearest neighbor matching that attempts to avoid ''bad'' matches by imposing a restriction that allows for maximum distance between the commercial and subsistence oriented farmer. Treated farm households for whom no matches can be found within the caliper are excluded from the analysis. Caliper matching is one way of imposing a common support condition and its major disadvantage is that it is difficult to know a priori what choice for the tolerance level is reasonable (Smith and Todd, 2005). In KBM algorithm, all treated farmers are matched with a weighted average of all controls that are inversely proportional to the distance between propensity scores of treated and control groups. One major advantage of this approach is that it yields ATE estimates with lower variance because it utilizes more information (Heckman *et al*, 1998).

We then assessed the overlap and common support match quality through analysis of density distribution of the propensity scores and estimating the percentage means between the groups after matching. In addition, standard errors were calculated using bootstrapping methodology to reduce estimation bias as suggested by Lechner (2002). Imbens, (2004) argue that although bootstrapping has been applied widely but there is little formal evidence to justify it. Nevertheless it was performed to check if the matching procedure balanced the distribution of the relevant variables in both the control

and treatment group. It simply compares the situation before and after matching and check if there is any difference after conditioning on the propensity score, and if there are differences then remedial measures such as inclusion of interaction terms in the estimation of the propensity score may be done (Caliendro and Kopeinig, 2008). In order to test for the robustness of results, Rosenbaum bounds approach was used (Rosenbaum, 2010). Sensitivity analysis is important because PSM assumes that the selection process is accounted for by observable characteristics. Rosenbaum's approach helps to assess how robust the results are to hidden bias due to unobserved characteristics. The high sensitivity to hidden bias exists when conclusions change for critical values of gamma (Γ) is just slightly above one while low sensitivity if conclusions change at large values of Γ (Rosenbaum, 2005).

(b) Measuring agricultural commercialization

We measured agricultural commercialization in terms of scale adapted from von Braun (1994) and Strasberg *et al*, (1999) and Bekele *et al*, (2010). It is an index measured as proportion of total amount sold to total output produced at farm level as given in equation (6):

$$\delta_k = \frac{\sum_{i=1}^{n} S_{ki}}{\sum_{i=1}^{n} Q_{ki}} * 100 = \; where \rightarrow Q_{ki} \geq S_{ki} \; and \; 0 \leq \delta_k \leq 10 \qquad (6)$$

Where δ_k is commercialization index of farm household growing k crops, S_{ki} is value of crop sold in monetary terms of crop k and Q_{ki} is the monetary value of total crop k where k ranges from $1,2 \ldots k$. The crops considered are bananas and legumes (dry beans, soya beans and groundnuts) grown as staple food crops in Rwanda and the DRC. The index measures the extent to which a farm household crop production is oriented towards the market. The larger the index the higher the degree of commercialization and a value of zero showing a totally subsistence-oriented household. Following the works by Strasberg *et al*, (1999) and Bekele *et al*, (2010) the farm households involved in greater sales of crop output with index value of fifty or more ($\delta_k \geq 50$) are commercial oriented while those with lesser or no sales ($\delta_k < 50$) are subsistence oriented.

(c) Measurement of household food security

We used household dietary diversity and indices of coping strategies during food scarcity to measure household food security in Rwanda and DRC. These methods complement each other such that

information not captured by one tool is captured by another. To accurately capture dietary diversity, evaluation was done in terms of the variety of food groups consumed. Dietary diversity is appropriate measure because it is normally highly correlated with calorie and protein intake and household income procedures that are normally considered to be more accurate (Swindale and Ohri-Vachaspati, 2005). Dietary diversity is a simple arithmetic sum of the number of different food groups consumed or a weighted sum where additional weight is given to the frequency by which different foods are consumed (Hoddinott, 1999). We calculated dietary diversity using the frequency of consumption of different food items by a household during the 30 days before the survey. The study emphasized on the foods that were important to the population in Rwanda and DRC and created ten food groupings: cereals, legumes, oil, sugar, tubers and bananas, fruits, vegetables and other leaves, meat and fish, eggs, and milk products. Determining which food items to appear in the lists was based on the recommendations from key informants such as project staff members, government officials, academics, prominent community members or other knowledgeable individuals (Coates *et al*, 2007). The household head was asked about different items that they have consumed in the last 30 days. If household head was male, the woman was asked for food consumption questions because she is knowledgeable on issues related to preparation and serving of food to the household members.

The index of coping strategies is an index based on how households adapt to the presence or threat of food shortages (Hoddinnot, 1999). The households who use more severe strategies are prone to poverty and more vulnerable to be destitutes (Hoddinott, 1999). Based on the strategies adopted by a particular household coping strategy index was then computed to measure the household food security status (Maxwell, 1996). Food insecure households employ the following strategies: change their diet, switch food consumption preferences, eat less preferred food, reduce the portion of meals and some may reduce the number of people that they have to feed by sending them to eat somewhere else, others ration the available food while others skipping whole day without eating (Maxwell and Caldwell, 2008). The seven strategies carry weights that reflect how frequently the household uses the strategy in a given period (Hoddinnot, 1999). Therefore, coping strategies index calculates the frequency of these coping household behaviors and their severity into one score. The method is straightforward and correlates well with more complex measures of food security such as calorie and protein intake (Maxwell and Caldwell, 2008). The questions were adapted from Hoddinott (1999) and Coates *et al*, (2007). We assigned wiights to household food insecurity access scale following the previous works done by Hoddinott (1999). The labels “often” was counted as four (more than 10 times in the past 30

days); "sometimes" counted as three (three to ten times in the past 30 days); "rarely" is counted as two (once or twice in the past 30 days); "never" is counted as one. A weighted sum of all the coping strategies used by the household was generated. The higher the weighted sum, the more food insecure the household is.

(d) Data collection methods and sampling technique

CIALCA project worked from 2006 to 2012 in 10 mandate areas[3] across the Economic Community of the Great Lakes Countries (CEPGL) region comprising Rwanda, Burundi and the DRC. The mandate areas were selected through spatial analysis based on human population density, access to markets and agro-ecology. The projects' ultimate goal was to improve agriculture-based livelihoods in Central Africa through increasing farm productivity, household incomes and improving food security and nutrition (CIALCA, 2007). However, we chose Rwanda and South Kivu of Democratic Republic of Congo because majority of smallholders had participated in market access improvement component of the larger project. We conducted survey in three mandate areas: Kigali-Kibungo and Umutara in Rwanda and South Kivu in the DRC. The sampling design followed a multi-stage procedure and in the first stage, seven action sites were purposively selected from the mandate areas. Action site is defined by CIALCA as geographical zones, covering a group of communities comprising between 500 and 5,000 farm households (Ouma *et al*, 2012). CIALCA operates directly in Action sites where technologies are developed, evaluated and promoted through on-farm experiments and participatory research approaches.

Five and two action sites in Rwanda and the Eastern DRC respectively were chosen from the mandate areas based on the main crops (bananas and legumes) promoted by CIALCA, varying access levels to local and regional markets and the presence of active agricultural development networks. The action sites visited were Kabare, and Walungu territoires (in French) in South Kivu, DRC while Kirehe, Gatsibo (Umutara), Kayonza, Ngoma, and Bugesera in Eastern province of Rwanda. Secondly, 30 farmer groups in CIALCA program were selected in all the seven action sites. Farmer groups selected were 21 and 9 from South Kivu, the DRC and Rwanda respectively. The list of farmer groups was obtained from the CIALCA offices. Final stage, farmer group leaders provided a list of members and

[3]Mandate areas are defined as areas with similar agro-ecological conditions and poverty profiles. The number of people living in each mandate area can vary between 300,000 and 1,200,000. They correspond to set of Districts in Rwanda and Territoires (in French) in North and South Kivu mandate areas in the DRC. Action Sites correspond to different administrative units in each of the countries {'Secteurs' (in French) in Rwanda, and 'Localités' (in French) in South-Kivu}.

based on it, farmers were randomly selected proportionate to the size of the group. The sampling design generated a total of 480 banana and legume farming household heads.

We collected from farm households using a structured questionnaire to obtain information about the household's agricultural production and marketing activities and household food security. Two different agro-ecological regions in Rwanda and DRC were covered in the sample to ensure that food security is well captured as some parts of the regions experience transitory food insecurity while others experience chronic food insecurity due to different socio-economic conditions and agro-ecological potential. Key informant interviews were performed with government extension officials from the Rwanda Agricultural Board (RAB), CIALCA staff, Institut pour l'Etude et la recherché Agronomiques (INERA), Bukavu and farmer groups to provide information about the food groups included in the food consumption survey. The questionnaire was prepared based on the information derived from measurements that have also been applied by other researchers and their perceptions of production, commercialization and food security relationships. Before collecting data; pre-testing was carried out by well-trained research assistants to assess the appropriateness of the data collection instruments in order to increase the reliability and validity of the instruments. The pre-testing exercise pinpointed feasibility problems that helped in making necessary adjustments on the questionnaire before being used to collect data.

3 Results and discussion

3.1 Socio-economic characteristics of farm households

The unconditional statistics presented in Table 1 suggest that crop commercialization may have a role in affecting household food security. However, commercialization is endogenous and a simple comparison of food security indicators between commercial oriented and non-commercial oriented households has no causal interpretation. This is because the differences in outcome variables (dietary diversity score and coping strategy index) could be attributed to other factors including household and resource endowment factors. Farm households can achieve food security without being commercial oriented. Hence, a detailed multivariate analysis can test the impact of commercialization on household food security better.

[Insert Table 1 here]

3.2 Indices of household coping strategies and dietary diversity

We asked a total of seven questions regarding how the households respond to food shortage. The strategies were given weights in order to calculate the severity of using them. Based on the recommendation by Hoddinott (1999), the strategies such as reducing the types of food eaten, consuming less preferred foods was assigned weight one while reducing quantity eaten and skipping meals in a day got two. A weight of three was given to going to sleep hungry and skipping meals the whole day. The higher the weighted sum of coping strategies, the more the food insecure the household is. The severity of strategies used by households was significantly higher ($p<0.01$) among the subsistence oriented farmers and in the Democratic Republic of Congo (DRC) (Table 2). This means that more farm households in Rwanda were food secure since they had lower means for strategies used and incidences where households skip meals and go to sleep hungry hardly occurred.

The households in the DRC were likely to face food insecure periods because in most cases they adopted more severe strategies like skipping meals in a day or whole day, sleep without food. This is attributed to lower crop yields, lower off-farm opportunities and lower household assets endowment compared to Rwanda. The majority of community members in the DRC hardly take breakfast and lunch while dinner remains the most important meal to them (Ekesa, 2008); a situation similar to some households. CIALCA baseline survey showed that 38% and 61% of farm households in their mandate areas in Rwanda and the DRC respectively often have too little to eat and more than 80% consume a maximum of two meals per day (Ouma *et al*, 2012). The farm households in Eastern DRC consume a maximum of two meals per day because of lack of enough food due to poverty, war and insecurity, insufficient harvest and lack of money (Ekesa, 2008)

Dietary diversity involved a number of foods consumed over a given period of time since consumption of a more diverse diet has positive nutritional outcomes. In Rwanda, Burundi and the DRC, household consider itself food secure if it has enough staples such as cassava, cooking banana, beans, maize and sweet potatoes (Ekesa *et al*, 2013). From the key informant interviews and survey, the food consumed in the rural areas of Central Africa include cereals, legumes, roots and tubers , bananas, vegetables, fruits, meat and milk products. Cereals mainly consist of sorghum, rice and maize while legumes include beans, soya and groundnuts. Roots and tubers such as cassava, Irish and sweet potatoes were consumed with cassava being the most important food security crop because it is drought resistant and both root and leaves are consumed. Traditional vegetables consumed included *sombe* (cassava leaves), *amaranthus* while other vegetables were cabbages, onions, tomatoes and cucumber.

The dietary diversity was significantly ($p<0.01$) different between commercial oriented and subsistence oriented farm households. The commercial oriented households had more diverse diets because they could easily purchase other foods to supplement their own production. Ruel, (2002) also observed that lack of dietary diversity is one of the severe problems among poor households who often rely on starchy staples, monotonous diets with little or no animal products, few fresh fruits and vegetables. The dietary diversity was insignificantly different between Rwanda and the DRC while the households in the later reported frequent consumption of fish due to proximity to Lake Kivu.

[*Insert Table 2 here]*

Malnutrition in the region is mainly caused by poor quality diets, mainly comprising high intake of staple crops (cassava, banana, maize) but fewer intakes of meat and fish products, fruits and vegetables. It is estimated that 70% of farm households consume vegetable protein daily but over 80% consume animal protein once a week or less often (Ouma *et al*, 2012). The most malnourished individuals came from subsistence oriented households because they could not afford to purchase highly nutritious foods or even produce enough for the household. A nutritional survey conducted in February 2013 in South Kivu reveals that global acute malnutrition rates are higher than the minimum acceptable rate[4] of 10% and Walungu and Kabare have 12.4% cases of malnutrition among the children (UNICEF, 2013).

3.3 Estimating the impact of commercialization on household food security

In this section, we present results from propensity score matching approach. The approach determines the factors influencing commercialization of banana and legumes crops and evaluates the causal effect of commercialization on household food security. We interpreted the results using different matching approaches, namely nearest neighbour, caliper and kernel matching.

3.3.1 Determinants of commercialization of farm households

Considering the conditional independence assumption (CIA) in PSM, explanatory variables expected to significantly influence household food security and commercialization were included in the probit model. A variable should only be excluded if there is consensus among the researchers that it is unrelated or if it is considered an improper covariate (Rubin and Thomas, 1996). However, Caliendro and Kopeinig (2008) indicated that the inclusion of non-significant variables in the PSM probit does

[4] Generally, it is accepted that a situation that has a global acute malnutrition rates above 10% need nutritional support. This categorisation is based on the World Health Organisation (WHO) decision tree for selective feeding programmes (UNICEF, 2013).

not create bias or make them inconsistent estimates. Therefore, the probit model has been used to predict the probability of commercialization status of farm households (Table 3).

The probit model has a McFadden pseudo-R^2 value of 0.096[5] and a log likelihood value of −299.03. Gender, education of the household head, ownership of transport equipment, farm size, and distance to the market, market information, access to all-weather roads and CIALCA market orientation strategies significantly correlated with commercialization, all with the expected signs. Male headed household had higher likelihood to become commercial oriented than female headed ones. The banana production and marketing decisions in the region were mainly dominated by men because male often control major production resources such as land, finances and labor.

[Insert Table 3 here]

Education of the household head is associated with a higher level of banana and legumes sales. The likelihood to become commercial oriented, increases by 5% for every additional year of education attained by the household head. As education level increases many household heads becomes more commercial oriented and focus on commercial production to make profits. Education influences household's ability to understand market dynamics and make them commercially motivated thus help to improve decisions about the quantity of output to sell (Makhura *et al*, 2002; Ochieng *et al*, 2013).

Consistent with other studies elsewhere, households owning transport equipment had more likelihood to become commercial oriented than those who do not own any transport equipment (Rios *et al*, 2009; Gebremathin and Jaleta, 2010). Transport equipment and proximity to all weather roads encourage commercialization because of their effect on reducing marketing costs such as time and transport costs. The transport equipment used by smallholders in the study area were bicycles, motorbikes, carts and few motor vehicles. The distance to markets often influence marketable volumes as well as local market pricing conditions. A unit decrease in distance to the market increased the probability of household being commercial oriented by 1%.The households located far away in remote villages experienced higher marketing costs than those closer to the markets.

[5] The McFadden pseudo-R^2 has been reported because Hoetker, (2007) argues that many authors often simply report the value of pseudo-R^2 without identifying which pseudo-R^2 they are reporting. This means that the reader can neither interpret the meaning of the measure nor compare it to similar models in other papers. Note that interpretation of this R^2 does not correspond to R^2 in OLS.

The farm households accessing market information were likely to be market oriented than those who did not. Market information is very important in farming since it informs the farmers about the market prices and potential buyers, thereby facilitating decisions on the quantity to sell. The farmers who are well informed can get higher prices for their produce. In addition, market information helps to increase utilization of yield enhancing farm inputs such as fertilizers and improved varieties which eventually increases commercialization levels. As expected farm size had a positive significant influence on commercialization. Large farms enjoy economies of scale and often produce surplus and easily become market oriented compared to small farms. This means that land plays a key role in promoting market oriented production in smallholder agriculture. Similar findings have been reported among smallholders in maize sector in South Africa (Mukhura *et al,* 2002) and cassava and maize in Ghana (Martey *et al*, 2012).

The adoption of CIALCA market orientation strategies had positive and significant influence on commercialization. The market orientation strategies disseminated to farmers through groups are business plans, collective marketing, product transformation and participatory market research. Capacity building and subsequent adoption of these strategies enabled farmers to bulk their produce, store, wait for better prices and earn higher incomes. They increased the households' likelihood to be commercial oriented by 5%. In the DRC farmers managed to raise their sales revenues by 50% through storage facilitated by credit schemes (*warrantage* in French) since they do not have to sell immediately after harvest but store the produce for sale at better market prices (Vanlauwe *et al*, 2013). To improve smallholders' commercialization, intensive participatory market research for outlets with potential to enter into contractual arrangements with buyers such as supermarkets, NGOs, schools, colleges or universities is important.

3.3.2 Propensity score matching results

The probit model results calculated individual propensity scores that were used to match the commercial oriented and non-commercial oriented farm households. The procedure revealed the underlying causal effects of commercialization on household food security. The indicators for household food security used in the analysis were dietary diversity index and index for coping strategies during food shortage. PSM controls for all confounding factors that correlate with both the household food security and the commercialization. The simple mean comparisons of the outcome variables between the two groups do not control for the effect of other covariates (see Table 1). Before assessing the impacts of commercialization, the quality of matches were tested in order to check for the

fulfilment of common support condition and ensure that the distribution of the variables between the commercial oriented and non-commercial oriented households is balanced.The density distribution of estimated propensity scores for the two groups of farmers is presented in Figure 1. The graph demonstrates that the condition for common support is fulfilled because of substantial overlap in the propensity score distributions for the two groups. In addition it also indicates a good comparability between the commercial oriented and non-commercial oriented households.

[Insert Figure 1 here]

The overlap shows that commercial oriented farm households can also be food insecure as well. Therefore, random selection into treatment is necessary such that households with similar characteristics can be observed in treatment as well as non-treatment groups (Heckman *et al*., 1998) which would help in estimating the impact of commercialization on household food security. Furthermore, the main purpose of the propensity score estimation is not to predict selection into treatment as good as possible but to balance distribution of all covariates (Augurzky and Schmidt, 2001). Hence, we did balancing tests before and after matching for all the covariates. Although, in caliper matching it's often difficult to know the reasonable caliper but this study used 0.005 and 0.05 calipers, which are reasonable to prevent bad matches. Bootstrapped standard errors based on 50 replications and sensitivity analyses shown by critical level of hidden bias (Γ) are reported in Table 5.

The results of covariate balancing test before and after matching using different matching algorithms: NNM, Caliper and Kernel matching is presented in Table 4. The average standardized bias difference for all covariates of 17.11 before matching is reduced to about 9.51 for NNM, 4.49 for caliper (0.005) and 2.28 for caliper (0.050) and 2.72 for Kernel after matching. Similarly, the Pseudo- R^2 also dropped significantly from 0.096 before matching to as low as 0.005 for Kernel after matching. The standardized mean difference for all covariates used in the propensity score of 17.11 per cent before matching is reduced to as low as 2.28 per cent after matching. The p-values of the likelihood tests show that the joint significance tests of covariates could not be rejected before matching but after matching. The low mean standardized bias and insignificant p-values of the likelihood test after matching implies that the proposed specification of the propensity score is successful in balancing the distribution of covariates between the commercial and subsistence oriented households.

Our results also showed that pseudo-R^2 values for the caliper and the kernel approach were considerably lower after matching than before. This implies that the covariates used in the propensity

score are randomly distributed in the commercial oriented and the non-commercial oriented groups. The caliper method had the best matching quality despite a high sample loss during matching while kernel approach has a lower sample loss and a better matching quality.

[Insert Table 4 here]

Using different matching algorithms the impact of commercialization on household food security index ranged from 24.220 to 32.580 in terms of increasing the dietary diversity within the household while it reduced coping strategies during food shortage by 0.163 to 1.986 (Table 5). These results indicate that commercialization had a significantly positive impact on household dietary diversity, although there was no significant impact on reducing coping strategies used by households during food shortage. The estimated gain in increasing household dietary diversity was statistically significant for NNM, Caliper matching and Kernel matching.

[Insert Table 5]

The impact increases the dietary diversity of treated households (commercial oriented) on average by 24.220 for NNM, 31.647 for caliper matching and 32.580 for kernel matching. On the other hand, it reduces the number of coping strategies used by the commercial oriented households during food shortage but it is not statistically significant. This could be because both commercial oriented and non commercial households predominantly use similar coping stragegies. The results show that commercilization reduces the number of strategies on average by 1.986 for NNM, 0.404 for caliper and 0.646 for kernel matching. The matching algorithms produced different quantitative results, but similar qualitative findings. According to Backer and Ichino (2002), a combination of any three of the matching approaches (Nearest Neighbour, Caliper and Kernel) is adequate to reach a reliable conclusion on the relative effect of intervention. Based on this, the results confirm the postulated hypothesis of a positive impact of commercialization on household food security among banana and legume producers in Central Africa. However, the smallholders in this region face major marketing challenges such as poor road infrastructure, reducing farm sizes, inability to adopt market orientation strategies and small markets that reduces ability to sell more produce at profitable prices. These challenges prohibit the achievement of sustainable household food security in the region.

The Rosenbaum bounds[6] sensitivity analysis on hidden bias show the critical values of gamma (Γ) at which the conclusion of the impact of commercialization on household food security may be questioned. The robustness to hidden bias varies across different outcomes and the value of gamma Γ vary from 1.10 for NNM to 1.65 for Kernel matching. This imply that if the farmers with the same characteristics differ in their odds of participation by 10 to 65%, the significance of commercialization effect on household food security may be questionable. It also suggests that the unobserved characteristics would have to increase the odds ratio of participation in commercial oriented production by 10 to 65% before it creates bias in the estimated impact. The 1.10 critical value of Γ indicates that the result is highly vulnerable to unobserved bias. However, the results conform to other studies such as Clement, (2011), Becerril and Abdulai, (2010), Kiiza *et al* (2011) and Ochieng *et al*, (2014) that have reported low values of Γ. The matching procedures have Γ of above 1.35 which is acceptable. Nevertheless, the estimated impact of commercialization remains robust even in the presence of unobserved characteristics and that the important variables influencing commercialization and household food security were included in estimation[7].

4. Conclusions and policy recommendations

Our analysis show that commercial oriented households have significantly higher food security status than subsistence oriented ones. Farm households with large farm sizes, adopters of CIALCA market orientation strategies, received market information, closer to the market and close proximity to all-weather roads are more likely to be market oriented than those who do not. Besides, farmers with higher levels of education, access extension services and apply fertilizers on their farms have higher yields than those who do not access such services. According to World Bank, input markets in Africa are often small and underdeveloped but it can successfully be improved because they have been developed in other regions with smallholders or rain fed agriculture. This is because of the production and marketing constraints are caused by market failures in Africa. We also performed the sensitivity test proposed by Ichino *et al* (2008). The baseline ATT point estimates proved very stable, never approaching zero even if the potential confounding factor is associated with large selection and outcome effects. Given the stability of our benchmark ATT result with respect to potential selection on

[6] We calculated Rosenbaum bounds using the command *rbounds* in Stata 12. Rosenbaum bound addresses hidden bias which consists of both positive and negative selection into treatment status (commercialization). However, our study restricts to positive selection (upper bounds).

unobservable and comparable endogeneity issues, we conclude that our estimated results are robust with respect to unobserved heterogeneity.

To enhance the benefits of commercialization, the governments need to improve the socio-economic conditions surrounding smallholder farmers, particularly, establishing functioning market centers, provision of market information and education are priority for policy attention. Investments in these services will help to increase access to inputs and facilitate higher understanding of disseminated production and marketing technologies in the region. The CIALCA market orientation strategies and market information play a key role in increasing sales of banana and legumes. Therefore, delivering production technologies and market information is crucial in order to increase smallholders' commercialization levels and improving crop production and eventually food security. The public and private sector can do this by strengthening and utilizing the existing linkages between them and farmer groups. They can use the readily available communication channels in rural areas such as radios and mobile phones to provide information on prices, produce buyers and input suppliers etc.

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Table 1: Characteristics of commercial oriented and non-commercial oriented farm households

Variables	Commercial oriented farmers (N=262)		Non-commercial oriented farmers (N=218)	
	Mean	*Std deviation*	*Mean*	*Std deviation*
Outcome Variables				
Dietary diversity score	303.89	123.94	270.87	92.89
Coping strategy index	27.89	9.63	31.13	10.22
Independent variables				
Active family members (persons)	2.95	1.64	2.68	1.39
Female headed (1=yes)	0.16	0.37	0.25	0.43
Dependants (numbers)	3.38	2.44	3.28	2.49
Age of household head (years)	48.29	13.24	47.33	13.16
Education of the head (years)	10.45	3.35	9.95	3.97
Transport equipment (1=yes)	0.40	0.49	0.20	0.40
Farm size (hectares)	1.89	8.30	0.78	2.30
Distance to the market (km)	3.25	3.26	4.26	5.14
Credit Access (1=yes)	0.26	0.44	0.28	0.45
Extension contacts (numbers)	7.15	8.74	6.34	10.41
Market information (1=yes)	0.76	0.43	0.61	0.49
Access to all weather roads (1=yes)	0.32	0.47	0.20	0.40
Pay market fee (1=yes)	0.54	0.50	0.61	0.49
Tropical Livestock Unit (TLU)	1.45	1.85	1.22	5.48
Off-farm income access (USD)	225.87	445.00	128.30	314.52
Mobile phones (numbers)	0.90	0.90	0.72	0.97
Receipt of remittance (1=yes)	0.15	0.35	0.11	0.31
Adopt CIALCA market orientation strategies (1=yes)	0.65	0.48	0.55	0.49
Country(1=Rwanda; DRC=0)	0.48	0.50	0.34	0.48

Source: Authors' results

Table 2: Indices of household coping strategies during food insecurity and dietary diversity index by commercialization and region

	Commercialization status			Region		
Coping strategies	**Subsistence (N=218)**	**Market (N=262)**	**t-test**	**DRC (N=280)**	**Rwanda (N=200)**	**t-test**
Insufficient food in the house	2.68 (1.00)	2.29 (0.94)	4.40***	2.90 (0.81)	1.88 (0.89)	13.05***
Reduce types of food consumed	2.82 (0.93)	2.52 (0.97)	3.51***	2.89 (0.74)	2.33 (1.12)	6.51***
Consume less preferred food	2.97 (0.89)	2.84 (0.88)	1.54	2.98 (0.76)	2.79 (1.04)	2.32**
Reduce quantity served	2.68 (0.98)	2.41 (0.95)	3.00***	2.96 (0.76)	1.94 (0.93)	13.24***
Skipped meals in a day	2.62 (1.00)	2.36 (1.03)	2.74***	2.99 (0.75)	1.77 (0.94)	15.89***
Sleep without food	1.80 (0.94)	1.65 (0.87)	1.81*	1.94 (0.96)	1.42 (0.72)	6.52***
Skipped meals whole day	2.21 (1.09)	1.90 (1.06)	3.10***	2.53 (1.00)	1.36 (0.68)	13.74***
Coping strategies Score	31.13 (10.22)	27.86 (9.63)	3.60***	34.08 (8.36)	22.72 (8.26)	14.74***
Dietary diversity Index	270.87 (92.89)	303.89 (123.94)	-3.24***	286.58 (83.85)	292.15 (142.59)	-0.537

Notes: ***, **, * level of significance at 1%, 5% and 10% respectively.
Standard deviation in parentheses
Source: Author's results

Table 3: Determinants of banana and legumes commercialization: *Probit model*

Dependent variable	Commercialization				
Independent variables	Coef.	Rob. Std. Err.	Z	P>z	dy/dx[8]
Female headed (1=yes)	-0.290	0.162	-1.80	**0.075**	-0.115
Active family member (persons)	0.012	0.045	0.29	0.774	0.005
Dependants (persons)	-0.005	0.028	-0.20	0.842	-0.002
Age of household head (years)	0.001	0.026	0.05	0.958	0.001
Age Squared (years)	0.000	0.000	0.14	0.888	0.000
Education of the head (years)	0.124	0.072	1.72	**0.086**	0.049
Education Squared (years)	-0.006	0.004	-1.56	0.119	-0.002
Transport equipment (1=yes)	0.483	0.161	3.00	**0.003**	0.186
Farm size (hectares)	0.033	0.020	1.65	**0.097**	0.012
Distance to the market (km)	-0.035	0.014	-2.49	**0.013**	-0.014
Credit Access (1=yes)	-0.155	0.145	-1.07	0.286	-0.061
Extension contacts (numbers)	-0.003	0.006	-0.48	0.568	-0.001
Market information (1=yes)	0.308	0.142	2.16	**0.030**	0.122
Access all weather roads (1=yes)	0.393	0.144	2.74	**0.006**	0.152
Pay market fee (1=yes)	0.111	0.168	0.66	0.510	0.044
Tropical Livestock Unit (TLU)	-0.010	0.015	-0.63	0.528	-0.004
Off-farm income access (USD)	0.002	0.000	0.83	0.405	0.000
Mobile phones (numbers)	-0.079	0.073	-1.09	0.277	-0.031
Receipt of transfers (1=yes)	0.075	0.193	0.39	0.697	0.030
CIALCA market orientation strategies adoption (1=yes)	0.146	0.071	2.07	**0.046**	0.057
Country (1=Rwanda; DRC=0)	0.183	0.198	0.92	0.357	0.072
Constant	-0.961	0.678	-1.42	0.157	-
N	480				
McFadden Pseudo-R^2	0.096				
LR $\chi^2(21)$	62.69				
Log Likelihood	-299.03				

Source: Authors' results

[8] dy/dx is the marginal effects after probit obtained by *mfx* command in Stata 12.

Table 4: Matching quality indicators before and after matching for commercialization

	Pseudo-R^2 before matching	Pseudo-R^2 after matching	$P>\chi^2$ before matching	$P>\chi^2$ after matching	Mean standardized bias before matching	Mean standardized bias after matching
NNM	0.096	0.045	63.31(0.00)	27.48(0.16)	17.11	9.51
Caliper Matching						
Caliper =0.005	0.096	0.012	63.31(0.00)	7.97 (0.99)	17.11	4.49
Caliper =0.050	0.096	0.006	63.31(0.00)	4.21(1.00)	17.11	2.28
Kernel	0.096	0.005	63.31(0.00)	3.63 (1.00)	17.11	2.72

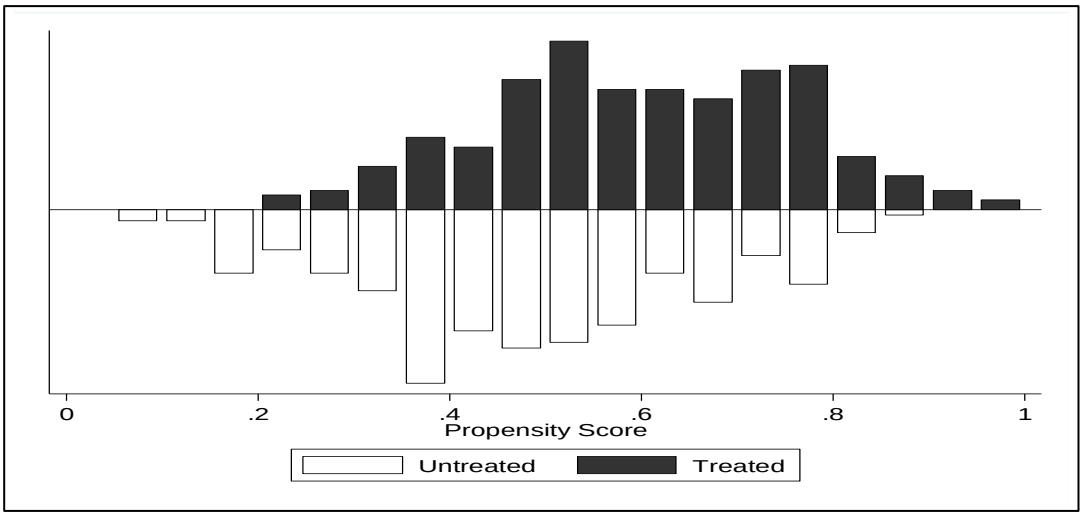
Notes: The values 0.005 and 0.05 are tolerance levels (caliper)
Figures in parenthesis are p-values
NNM=Nearest Neighbour Matching;
Source: Author's results

Table 5: Impact of commercialization on household food security

Matching algorithm method	Outcome variables	Outcome mean				
		Commercial oriented farms	*Non-commercial oriented farms*	*ATT*	*Bootstrap standard error*[a]	*Critical level of hidden bias (Γ)*
NNM	Dietary diversity score	295.092	270.872	24.220	14.238 (2.04)**	1.10
	Coping strategy index	29.142	31.128	-1.986	1.530 (-0.59)	1.35
Caliper Matching						
Caliper= 0.005	Dietary diversity score	304.035	275.713	28.321	13.692 (2.12)**	1.35
	Coping strategy index	28.500	28.904	-0.404	1.148 (-0.78)	1.45
Caliper= 0.050	Dietary diversity score	303.915	272.268	31.647	13.657 (2.13)**	1.45
	Coping strategy index	27.823	28.986	-0.163	1.283 (-0.70)	1.55
Kernel	Dietary diversity score	302.376	269.796	32.580	16.125 (2.41)**	1.55
	Coping strategy index	27.973	28.619	-0.646	1.189 (-0.76)	1.65

Notes: NNM=Nearest Neighbour Matching; ** Denotes significance at the 5%.
[a]Standard errors are bootstrapped with 50 replications of the sample and figures in parenthesis are z-values
Source: Authors' results

Figure 1: Propensity score distribution and common support for propensity score estimation



Source: Authors' results