Technical Efficiency of Cassava's Producers in the Hinterland of Kinshasa, Democratic Republic of Congo

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Abstract

This study aims at identifying the main determinants of efficiency of cassava producers in the hinterland of Kinshasa. Data used were from a sample 202 farm-household survey randomly selected. The Data Envelopment Analysis was applied to compute the efficiency score. The truncated regression model was used to identify factors associated with the efficiency score distribution. The results of estimations revealed that only few farm-households have reached the frontier of best practice and therefore can be viewed as technically efficient. The results of truncated regression showed that landholding property, associations, formal education of household head and farm size are the key drivers of technical efficiency differentials between producers.

Keywords: Productivity, Efficiency, Farm-household, Agriculture

Résumé

Ce papier se propose de mesurer l'efficacité technique des producteurs de manioc dans l'hinterland de Kinshasa d'une part ; et d'autre part, d'identifier ses principaux déterminants. Les données utilisées proviennent d'une enquête administrée auprès de 202 producteurs. La méthode d'enveloppement de données est appliquée pour mesurer les scores d'efficacité technique sous les hypothèses de rendements d'échelle constants (REC) et rendements d'échelle variables (REV). Par ailleurs, le modèle de régression tronquée intervient pour expliquer la variance de scores d'efficacité. Les résultats révèlent un niveau élevé d'inefficacité des producteurs de manioc. En effet, le score moyen d'efficacité est 0.318 et 0.272 respectivement sous REV et REC. Cela suggère que l'efficacité technique des producteurs de manioc de l'hinterland de Kinshasa peut être améliorée de 0.73 sous

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l'hypothèse REC et de 0.68 sous l'hypothèse REV. Le score moyen de l'efficacité d'échelle est largement supérieur au score moyen d'efficacité technique sous REC et REV, soit 0.902. Ce résultat implique que l'inefficacité dans la production de manioc observée dans cette étude est davantage liée à la mauvaise allocation de ressource qu'à la taille de la culture. Les résultats issus du modèle de régression tronquée révèlent que le niveau d'instruction du producteur, la possession de terres arables en propriété et la taille de la ferme affectent positivement la distribution des scores d'efficacité technique.

Mots-clés : Productivité, Efficacité, Ménages, Agriculture

Introduction

With an underdeveloped industrial sector, agricultural activities remain the principal component of economic development in the Democratic Republic of Congo (DRC). Consequently, it is absurd to think of development without adequate agricultural policies and strategies that foster the improvement of agricultural productivity and performance. This assertion is supported and justified by several reasons: (a) agriculture accounts for about 45% of GDP and 20% of export earnings; (b) agricultural activities are the mainstay of livelihoods and a source of income for over 60% of the population; (c) the majority of the Congolese population is affected by food insecurity; and (d) domestic industry is still at a primitive stage and needs a dynamic and productive agriculture to provide essential raw materials.

Despite the adoption of many agricultural reforms and policies, the agricultural sector in the DRC remains dualistic with a dominance of small size traditional family farms. Two farming systems, namely the traditional farming system and the modern farming system, coexist. Technically, the traditional farming system, also called itinerant agriculture, is characterized by relatively long fallow periods, depending on whether the region is under-populated or over-populated. High-yielding varieties to improve production and other inputs for land regeneration are not used in the traditional farming system. This production system continues to resort to shifting cultivation and depends on family labor. In the traditional production system, women play a dominant role as the participation of men is limited to pre-farming tasks (cutting trees, clearing land, incineration, etc.). The possibilities of access to resources, such as loans, improved inputs and modern tools, are very limited.

Before 1960, the colonial authorities tried to promote traditional agriculture by using the so-called paysannat. The goal of paysannat was to replace the extensive farming system, a source of land destruction, with a more intensive farming system, ensuring the sustainability and improvement of land productivity. However, a few years after political independence, the paysannat system, which was still at the experimental stage, went bankrupt. The attempts made to revitalize the traditional agricultural system did not lead to significant progress. Thus, traditional farming remains essentially unchanged: the techniques of traditional production remain rudimentary and many farmers continue to use varieties with poor yields. The modern farming system, introduced during the colonization period, was composed of large farms mainly specializing in export crops and owned by foreign companies. These companies had access to resources and were the principal recipient of the results of agronomic research, which was carried out according to their needs. Most of them went bankrupt after the *Zairianisation* of the 1970s, although those which still survive continue to farm in the same manner.

Providing enough food for a growing population remains the main challenge of the Congolese agricultural sector. The DRC is one of the Sub-Saharan African countries where agricultural production has been trailing population growth for many years. The food production index has been largely unstable and has shown a steady decline since 1969. The DRC, which achieved food self-sufficiency during the first years of political independence, has become a net food importer and depends on food aid. Thus, this study aims at understanding the factors of inefficiency of DRC's agriculture, using evidence of cassava's producers of hinterland of Kinshasa.

Materials and Methods

This study was conducted in the hinterland of Kinshasa, which consists of all the neighborhoods of Kinshasa. This area is dominated by agriculture and its related activities. The hinterland is a vast area of Kinshasa located in the Commune of Maluku and on the Batékés Plateau, which has an area bordering on 7000 km^2. The Commune of Maluku is limited to the north by the Congo River, Congo-Brazzaville and the territory of Kwamouth (the Province of Bandundu); in the east by the territory of Bagata and Kenge (the Province of Bandundu); in the south by the territories of Kasangulu, Kisantu and Kimvula (the Province of Bas-Congo); and in the west by the Commune of N'sele (Pauwels, 1993; De Saint Moulain and Kalombo, 2005). The vegetation of Kinshasa consists of savanna strewn with shrubs and forest galleries. Following urban pressure, Kinshasa has localized on hills and the Kwango Plateau (Lubini, 1988). The land of the Batéké Plateau is characterized by a tropical climate and low soil fertility (Crabbe, 1980). The hydrographic network of Kinshasa is made up of rivers (Kalamu, Gombe, Makelele, Funa, N'djili, Nsele, Mayi-Ndombe and Bombo-Lumene) taking their sources from hills. These rivers run from south to north and join the Congo River at the level of the Malebo Pool. Following the Köppen classification, the climate of the Batéké Plateau is type AW4 (Wet Tropical Climate Soudanien) and characterized by two seasons, a dry season, which extends from mid-May to mid-September and a wet season starting in mid-September, and ending in mid-May (Bultot, 1950).

The attribution of the arable land in the Plateau of Batéké occurs according to both traditional land tenure and Congolese legislation. Nsombo (2005) underlines the communal nature of the land in the Téké community and culture. However, population growth and the development of the commercial economy have created a problem of land tenure in the hinterland of Kinshasa. Among the population living in this area, the Téké people represent the oldest group and form the majority. They are concentrated in the south and upstream of the Malebo Pool (Mutamba, 1989). Three other ethnic groups, the Suku, Yaka and Yansi, are also located in this zone.

The data used in this study were collected from households and MFI surveys. The household survey was conducted in villages located in the area between Menkao, Dumi and Mbankana and where Téké represent the main share of the population. These villages include Menkao, Bita, Kingankadi, Dumi, Mutiene, Inzolo, Mbankana, Quatrième Cité/CADIM and Kinzono. Taking into account the lack of reliable demographic data at the communal level, the first step in the survey consisted of counting the households per village among the selected villages. The sample was made by quota with a rate of 15%. This resulted in a sample of 202 households randomly selected from each of the designated villages.

The household data was collected from a cross-sectional survey of the three groups of selected villages. A household was defined as a social unit sharing the same residence, resources and income. A structured questionnaire was used to obtain data at the household level. The questionnaire consisted of a wide range of questions regarding the household's characteristics, including age, gender and education of the head of the household as well as social capital, etc. The questionnaire also consisted of data directly related to cassava production, such as land use, labor (family and hired), cassava-planting materials and cassava output. The questionnaire was pre-tested in order to correct mistakes eliminate irrelevant and adding relevant information. The household survey was conducted by investigators selected on the basis of communication skills, all of whom had masters' degrees in agricultural sciences or economics and knowledge of cultural and social traditions of the study area. The data collection procedure was supervised and questionnaires were examined to ensure complete responses. Thus, uncompleted questionnaires were detected and omissions rectified by revisiting the respondents. The descriptive statistics of variables used in this study are reported in App. Table I.

For empirical analysis, we used two analytical approaches. Firstly, we ran technical efficiency (TE) and scale efficiency (SE) scores of cassava farmers using Data Envelopment Analysis (DEA). Following Coelli (1996), we estimated the TE in cassava production by using the following DEA linear program under a Constant Return to Scale (CRS), that is:

$$TE_j = Min_{\theta_j^{crs},\lambda} \theta_J^{CRS}$$

Subject to

$$P_j \leq P\lambda; \theta_J^{CRS} F_J \geq F\lambda; \lambda \geq 0$$

Where (J^{th}) is a farmer drawn from (n) farmers of the sample; (P) is cassava produced (kg); (θ_J^{CRS}) is TE (J) of the farmer under CRS and (λ) is a vector of weights $(nx1)$ and (F) is a set of input variables used for cassava production, including planting material (kg), labor (man-days) and land(ha). Land is the total land area used for cassava production, including land owned, rented and obtained through gift. Labor is composed of the family labor force and external labor supply. Plant materials include those obtained from self-production, bought or received from other external sources. Modern inputs such as manures, pesticides, fertilizers are not used in cassava production in the hinterland of Kinshasa. An extremely limited number of cassava farmers use tractors; therefore, any farmer using a tractor was not randomly drawn in the sample. In addition, small agricultural tools such as the hoe and the spade are used in cassava production and other tools are depreciated in full (they did not have an accountable value), and therefore were not considered as inputs for the empirical estimation of DEA efficiency scores.

The DEA CRS specification is based on the assumption that all DMUs are operating at the frontier of efficiency. However, given agricultural input market imperfections, environmental constraints and several other constraints faced by the cassava producers from the hinterland of Kinshasa, it is probable that this assumption is unrealistic. Thus the Variable Returns to Scale (VRS) assumption needs to be specified and is more appropriate and better fits the data than the CRS hypothesis. However, we estimate and discuss the efficiency scores obtained from both assumptions. The TE of cassava producers under

VRS is run by adding the convexity constraint $(\lambda_J = 1)$ to the CRS DEA linear program (Coelli, 1996).

The efficiency scores under VRS may be equal or greater than those obtained under the CRS assumption. Moreover, the scale efficiency (SE) can be obtained by calculating the ratio $(\theta_J^{CRS} / \theta_J^{VRS})$. The SE can be either Increasing Returns to Scale (IRS) or Decreasing Returns to Scale (DRS). Efficiency scores range from 0 to 1. Thus, $0 \le \theta_j \le 1$ and $0 \le SE \le 1$. The farmer is technically efficient if $\theta_j = 1$ and scale efficient if $SE = 1$.

The efficiency scores are computed under output-orientation. This choice is explained by the fact that the cassava producers from the hinterland of Kinshasa do not have control over productive forces because of market imperfections and the dependence of agriculture on the environment and natural conditions. The efficiency scores are computed using the DEAP software developed by Coelli (1996).

Secondly, we explored the key drivers of TE differences among cassava producers by estimating a truncated regression (TR) model. The TE is used as a dependent variable, while household and institutional characteristics are used as explanatory variables. The choice of a TR model is dictated by the nature of the TE measure, which is truncated at 1, and by the findings of the academic literature (Battese and Coelli, 1995; Simar and Wilson, 2007). The TR model used to identify covariates associated with TE score is given by:

$$TE_i = \psi + \sum_{k=1}^{N} \psi_i X_i + \mu_i$$

Where TE_i is technical efficiency score obtained from DEA, X is a set of potential determinants of TE differentials, ψ is a set of unknown parameters to be estimated that captures the effect of covariates on TE, and μ is an error term that independently follows normal distribution with $(0, \sigma^2)$.

The selected covariates used for estimation are household head age, household's head years of schooling, household size, gender of the household head, landholding property, farm size, household participation in social and economic organizations, and villages located in the area of Mbankana and villages located close to Dumi. The household head age is used as a proxy of experience and is expected to increase efficiency. The household head's education is measured by the number of years of schooling, and this is also expected to increase TE by affecting managerial skills, which would result in efficiency score variations among farmers. Nevertheless, several empirical studies have reported mixed effects (Ali and Flinn, 1989; Bravo-Ureta and Pinheiro, 1993; Battese et al., 1996). Family labor is an important source of labor supply in the hinterland of Kinshasa, as in many developing nations. In the context of labor markets imperfections and credit constraints, as with the case of study area, farm-households with inadequate family labor will face farm labor limits. Thus, we expected that the size of household will be positively associated with TE, and that household dependency ratio will be negatively correlated with production efficiency.

The relationship between farm size and productivity has been much debated among researchers in developing nations. The studies carried out on this topic showed mixed results. A significant number of studies have reported a positive relationship between farm size and productivity (Deolalikar, 1981; Fan and Chan-Kang, 2005; Bhandari, 2006). Several other studies found an inverse relationship, explained by the relative advantage of using more family labor by small farms, which reduces the monitoring and supervision costs of hired labor (Sen, 1962; Berry and Cline, 1979; Barrett, 1996). Thus, farm size is expected to be positively or negatively associated with TE in cassava production. It is expected that landholding property will have a positive effect on TE distribution as this may be a source of motivation for producers. It is also expected that network participation will be positively associated with TE scores. The villages of residence are expected to be either positively or negatively correlated with TE distributions.

Results of estimations

Table1 presents the computed technical and SE scores of the cassava farmers. The results reveal that TE scores in cassava production are very low and many farmers are working in the inefficiency zone. Indeed, under the CRS assumption, the mean TE score of the farmers from the sample is estimated at 0.272 (SD=0.186). Moreover, 45% of farmers have TE scores ranging from 0.20 to 0.40 and about 36% of households have a TE score in the interval of 0.41 and 0.60. Only 3% of households from the sample might be viewed as technically efficient.

Table 1 Distribution of TE and SE in cassava production

	TE (CRS)		TE (VRS)		SE	
Interval	Frequency	%	Frequency	%	Frequency	%
0.00-0.20	92	45.5	81	40.1	0	0
0.21-0.40	73	36.1	70	34.7	3	1.5
0.41-0.60	24	11.1	27	13.4	4	2

0.61-0.80	7	3.5	10	5	27	13.4
0.81-1.00	6	3	14	6.9	168	83.2
Average	0.272		0.318		0.902	
Maximum	1		1		1	
Minimum	0.03		0.032		0.254	
S.D	0.185		0.231		0.13	

A similar feature is observed for VRS TE scores. The results from the VRS assumption show that the average TE score is estimated at 0.318. About 40% of the farmers from the sample are in the zone of TE with scores ranging from 0.00 to 0.20; and 37% of farmers range from 0.21 to 0.40. Only 7% of the sampled farm-households are technically efficient. The findings report that the majority of farmers (92% under CRS and 88% under VRS) have TE scores less than or equal to 0.60. The estimated SE shows that 83% of cassava producers are close to the SE line. The average SE score is very high and estimated at 0.90.

Table 2 presents the results of TR model applied to identify key factors affecting TE scores differences among farm-households.

Table 2 Determinants of TE in cassava production

	CRS model		VRS model	
Variables	Coefficients	Z-statistic	Coefficients	Z-statistic
Education	0.0060**	1.94	0.0094***	2.55
Household head male	-0.0348	-0.83	-0.0307	-0.62
Household head age	0.0004	0.37	0.0007	0.54
Household size	-0.0096	-1.57	-0.0056	-0.78
Land property holding	0.0673***	3.01	0.0632***	2.40
Farm size	0.0098	1.03	0.0192*	1.71
Associations	0.0698***	2.84	0.0645***	2.25
Mbankana group	0.0095	0.36	0.0227	0.73
Dumi group	-0.0032	-0.12	-0.0104	-0.32
Constant	0.1621***	2.19	0.1126	1.28
	Prob.$>\chi^2 = 0.004$		Prob.$>\chi^2 = 0.009$	
	Log likelihood = 90.80		Log likelihood = 59.7	
	Wald $\chi^2 = 23.70$		Wald $\chi^2 = 21.86$	

Key: * p<.1; ** p<.05; ***p<.01

The likelihood ratio tests indicate that all variables in both TR models specified (VRS and CRS), taken together, have statistically and significant effects on TE scores. The results of the VRS model reveal four covariates likely to be significantly and positively associated with TE scores. Landholding property, the household head's number of years of formal schooling and associations are significant at 1%, while farm size is significant at 10%. Under the CRS assumption, farm size is not statistically significant. The effects of household head age, household head male and villages of residence are not found to be statistically and significantly associated with TE scores. In other words, this means that TE is distributed independently of them.

Discussion of results

The results of DEA-estimated TE and SE scores suggest some relevant and important findings. A few farm-households have reached the frontier of best practice and therefore can be viewed as efficient. This means that these efficient farmers apply their resources relatively better than the other share of farmers from the sample with similar inputs. These efficient farmers have a higher ability to use resources in producing cassava than their counterparts, given the available technology represented by the best practice frontier. The mean values of the TE scores (VRS and CRS) in the sample are very low and the majority of farmers are operating in the region of inefficiency, and thus may be viewed as not using resources in an optimal way compared to the efficient farmers from the sample. In other words, the results reveal a high level of technical inefficiency among farm-households from the sample, which needs to be reduced in order to produce at the best possible TE level. Given the high level of inefficiency in cassava production, there are significant possibilities for improving efficiency in the hinterland of Kinshasa. The average TE scores (27% under CRS and 32% under VRS) indicates that farm-households from the sample would substantially improve their production with the same inputs. On average, TE scores may be increased by 73% under CRS and by 68% under VRS assumptions. Although TE is a relative concept, our findings are not consistent with empirical studies from Nigeria, which reported high levels of average technical efficiency scores and small variance between cassava farmers (Ogboma et al., 2007; Ogundari and Ojo, 2007; Iheke, 2008; Edeh and Awoke, 2009; Onu and Edon, 2009; Adeyemo et al., 2010).By comparing technical and SE scores, it is clear that the SE scores are higher than the TE scores under both CRS and VRS assumptions. The mean value of the SE score is greater than that of the TE score, suggesting that technical inefficiency scores make a greater impact on cassava production inefficiency rather than scale inefficiency. In other words this finding suggests that the inefficiency in cassava production results more from the use of inadequate farm management practices than from farm size. This finding implies that the improvement of farm management practices of inefficient farmers will increase the cassava production efficiency and will allow a high level of output with the same inputs. From an agricultural policy viewpoint, the diffusion of optimal farm management practices in cassava production through the extension services will assist in improving the efficiency scores of farm-households. Moreover, this finding calls for research aiming at understanding the management practices of efficient farm-households to assist the formulation of agricultural policy and extension programs.

Since TE is a relative concept and the wide variations in TE scores are unconditional, many lessons may be learned by conditioning them on a set of relevant household and institutional characteristics. The results of TR models show that landholding property, associations, formal education of household head and farm size are the key drivers of TE differentials between farm-households. The positive coefficient of landholding property means that households with landholding property are more technically efficient than their counterparts without landholding property. It should be noted that in the hinterland of Kinshasa, farmland conflicts are greater than in the rest of the country. The attribution of land property rights involve both traditional authorities and the State, actors which are often in permanent conflict. In many cases, these conflicts are resolved to the detriment of small landholders. This in turn results in an increased rural population without land, who are then obliged to grow their crops on the same plot for consecutive larger number of seasons. Land conflicts are more likely to limit farmers' efforts to maximize outcome and to affect their risk aversion, leading to low efficiency. This finding supports previous studies that have suggested land tenure reform to promote agricultural intensification and productivity growth in sub-Saharan African (Besley, 1995; Gavian and Fafchamps, 1996; Feder and Nishio, 1999; Jacoby and Minten, 2007). The result calls for government intervention in land administration to overcome land tenure insecurity and increase household access to arable land.

Household head education appears to be among the key drivers positively affecting TE scores obtained both under CRS and VRS assumptions. This indicates that TE increases with the formal schooling of the farm-household head. Farm-households led by more educated heads are more technically efficient than those led by the less educated. Several empirical studies have come to a similar conclusion (Bravo-Ureta and Pinheiro, 1993; Ali and Flinn, 1989; Battese et al., 1996). The positive sign associated with household head education could possibly be due to the fact that education is more likely to improve the quality of decision-making. In addition, education is an important determinant in adopting good farming practices. This finding implies that public policy aiming at investing in education and information will reduce cassava production inefficiency.

Farm size tends to be significantly associated with TE of cassava farmers in the hinterland of Kinshasa. The results suggest that there is a positive effect of farm size on TE. This means that TE increases with farm size. The results suggest that the public policy aiming at increasing the farm size will reduce cassava production inefficiency. The positive sign related to farm size is consistent with other empirical studies, which have reported a positive relationship between farm size and productivity (Deolalikar, 1981; Fan and Chan-Kang, 2005; Bhandari, 2006).

Household participation in associations is found to be an important determinant of TE. The results suggest that households participating in associations are more efficient compared to their non-participating counterparts. This could be due to the fact that membership in associations plays an important role in the adoption and the sharing of farm practices. It generates information on new technologies and reduces input constraints, such as labor and planting-materials. It also facilitates the cooperation, the sharing of tactics and information among participants. This finding calls for public policy to support farm associations and work for the increased participation of farm-households in social organizations such as cooperatives.

Conclusion and implications

This paper aims at evaluating the TE and SE of cassava farmers of hinterland in the Kinshasa. The study also explores the main drivers of differences in TE scores among farm-households producing cassava. DEA was applied to compute efficiency scores estimate TE and SE scores of cassava-producing farm-households. TR was applied to determine key factors associated with TE of farm-households.

The results reveal high levels of technical inefficiency in cassava production: the average TE is estimated at about 0.318 under VRS and 0.272 under CRS, indicating the possibility of increasing the current level of cassava output. The TE scores of sample farm-households may be increased by about 0.73 under CRS and by about 0.68 under VRS. The average SE (0.902) is markedly higher in comparison to the average TE score, implying that the resource misallocation makes a greater impact on the cassava production inefficiency than farm size.

The results of TR models reveal that household participation in associations is one of the key factors positively affecting TE as farmers participating in associations are technically more efficient than their counterparts from the sample. Households led by a head with more years of formal education tended to be more technically efficient than those led by less well-educated household heads. Landholding property is found to be positively correlated with TE scores, indicating that households with landholding property are more technically efficient than their counterparts. Farm size is another covariate positively associated with TE, indicating that farms of relatively big size are more technically efficient than small farms. The findings from TR support the hypothesis that capital endowments have an increasing effect on the TE of farm-households.

The implication is that public policy to improve education and information will enhance cassava production by increasing TE. Moreover, the results call for public policy to improve farm-households access to sufficient credit and landholding property in order to reduce the inefficiency in cassava production. In addition, there is a policy need to improve household participation in the social economy, such as farm organizations and cooperatives, to improve TE in cassava production.

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App. Table 1: Statistical description of variables

Variable	Mean	SD	Min.	Max.
Education	9.43	3.85	0	18
Household head male	0.91	0.28	0	1
Household head age	45.04	9.80	22	66
Dependency ratio	0.50	0.24	0	0.9
Household size	4.95	1.84	1	11
Landholding property	0.55	0.49	0	1
Farm size	13.34	11.45	2.5	100
Credit constraints conditions	0.71	0.45	0	1
Remittances	0.42	0.49	0	1
Associations	0.69	0.69	0	1
Mbankana group	0.34	0.47	0	1
Dumi group	0.32	0.46	0	1
Menkao village	0.33	0.47	0	1
Cassava production	20,074.80	14,964.09	2,000	81,400
Cassava materials	761.62	722.60	74.07	5,541.66

Labor	278.51	231.29	29.411	1,544.11
Land used for cassava production	1.67	1.02	0.20	8.14