Diversification towards high value export production, farm household productivity and efficiency in Senegal

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Abstract

Crop diversification or product innovation is one alternative put forward in the literature to enhance farmer's agricultural productivity in a context of imperfect or missing factor markets. In this paper we provide empirical evidence of how this alternative - induced in part by the modern agri-food supply chains - is effective in *les Niayes*, Senegal. We analyse agricultural productivity and efficiency at the household level using three rounds of panel data and nonparametric-based methodology. We find that rural farmers involved into high value green bean export production are more productive and efficient than their counterparts that are not involved into this type of crop diversification. This result suggests that productivity and efficiency gains from involvement in high value export production can spread out to the entire farm.

Keywords: Agricultural production, Total factor productivity, efficiency, panel data, Contract farming, Off-farm income
JEL codes: Q12, D24, D13

1. Introduction

Agriculture is potentially a sector that draws more attention in many developing countries and particularly in rural areas where poverty is more pronounced. It is estimated that eighty-two percent of the rural Sub-Saharan population lives in agriculture-based countries where agriculture is a major source of growth, accounting for 32 percent of GDP growth on average (World Development Report, 2008). In many instances, agricultural productivity is often the common denominator of issues such as population growth, agricultural growth lagged, food security and poverty reduction (e.g. Fuglie, 2008; Dercon and Christiaensen, 2011; Cunguara and Darnhofer, 2011)[1]. However in a context of scarce resources and imperfect or missing factor markets that is typical for many developing countries, the way to enhance farmer's agricultural productivity is still an important policy question. Where direct support from the government such as subsidies is very limited, crop diversification or product innovation is one of the most common alternatives put forward in the literature.

In this paper we provide empirical evidence of how that alternative - induced in part by modern agri-food supply chains - is effective in rural Senegal. New transformations in the agri-food sector in developing countries have recently accentuated the importance of this pathway for farmer's agricultural growth. One important aspect of the development of modern agri-food supply chains is the increase of non-traditional high-value exports from developing to developed countries (see e.g. Swinnen, 2007). Our study focuses on *les Niayes*, an area where the development took place. Some farmers cultivate domestic fresh fruit and vegetables and other commodities along with green beans, a high value product mainly intended for the international export market (see e.g. Maertens and Swinnen, 2009).

[1]For a policy perspective for example, it is unlikely to increase agricultural growth and income of farmers without adequately improve farmer's productivity and efficiency. An improvement of farmers' performance might induce high agricultural production and contribute to alleviate food insecurity and poverty through consumption and revenue gain.

Our objective is to analyse how the involvement in the high value export production is related to farm household agricultural productivity and efficiency in the region *les Niayes*. It has been argued that farmer's productivity gain can be achieved by the switching from subsistence production to higher value cash crop (Evans and Ngau, 1991) or by the dynamic processes of change in a farming system characterized by a combination of cash cropping and subsistence food crop production (Coelli and Fleming, 2004). Particularly in such case of modern agri-food supply chains, it is advanced that the involvement in high value export productions - through contract farming - is a way to alleviate constraints small farmers face in terms of access to resource such as credit or input provided by companies. Moreover information on (new) technologies, better farming practices - induced by the stringent requirement in international food market - and better management might be transmitted to contracting farmers and might affect their skill and ability (see e.g. Masakure and Henson, 2005; Schipmann and Qaim, 2010; Arumugam et al., 2010). All these factors are considered as likely to affect farmers' productivity in the export production as well as the productivity of farmers' other production.

Our contribution to the literature is threefold. First, we analyse the effect of the involvement into the export production – through contracting[2] – on productivity and efficiency at the farm household level. We account for the fact that rural farmers in *les Niayes* are much diversified in the farming (crop) activity and also intensively involved in off-farm activities. Most studies focusing on the impact of contract farming on productivity are crop or plot specific. For example some assess the effect of high-value crops contracting on the productivity of local staples such as rice (e.g. Minten et al., 2007). Others test whether the supervision by contracting firms increases the productivity of crops under contract (e.g. Bellemare, 2010) or compare farm productivity or efficiency under contract and non contract

[2]Throughout the paper when not explicitly specified contracting households are defined as those who are involved additionally in green beans export production with an agreement with an exporter agri-food company.

production for a given product (e.g. Key and McBride, 2003; Ramaswami et al., 2005; Hernández et al., 2007; Neven et al. 2009). Some of these studies also restrict the analysis to partial productivity measures such as yield or labor productivity while this may be of limited use (see Coelli et al., 2005)[3]. However others studies (Savadogo et al., 1994; Chavas et al., 2005; Fernandez-Cornejo, 2007; Anríquez and Daidone, 2010; Lovo, 2011) show that a narrow focus on farm activities is inappropriate for productivity and efficiency analysis when market imperfections and technical interdependencies cause jointness between farm and off-farm activities[4]. In this study, we consider the household off-farm income as an additional output in a nonparametric estimation of a multiple input multiple output production function and we derive Färe-Primont-based total factor productivity and its potential sources such as technical and scale mix efficiency.

Second, we take advantage of the panel dimension of our data and address some issues highlighted in the agricultural literature. These are related for example to the potential endogeneity of agricultural decisions such as the involvement into the high value export production. Some previous cross sectional studies deal with the endogeneity problems with econometrics methods but the cross section dimension of the data is still limited to solve the issue of the dynamics of agricultural technologies adoption decisions (see e.g. Doss, 2006). Our three rounds of balanced panel data allow us to account for these dynamics.

Finally, like in many developing countries the emergence of modern agri-food supply chains is increasingly affecting the Senegalese agri-food system. The exports of fresh fruits and vegetables from Senegal have substantially increased and are favoured by the strategy of diversification towards agricultural export products promoted by the government. In a policy perspective, understanding the interplay between such agricultural diversification and the

[3]An exception is the recent study of Rao et al. (2012) that use a meta-frontier approach to estimate total factor productivity effects due to differences in technology as well as gains due to technical and scale efficiency.
[4] This latter point is stressed in the literature on the linkages between farm and off-farm activities.

farm household performance is particularly relevant for the Senegalese government that has devoted substantial effort to promote this strategy as a source of income generation for poor rural households.

The remainder of the paper is structured as follows. In the next two sections, we describe our case-study and the data collection procedure. We describe in section four the first stage of DEA-based methodology along with variables used to compute household productivity and efficiency scores. In section five, we specify different econometric methods and models to identify the differential impact of the involvement in high value export production on these scores, and discuss the estimation results. We draw some final conclusions in section six.

2. Data

Les Niayes is a littoral area of the north-west of Senegal – from Saint Louis to Dakar – and presenting important depression favourable for the market gardening. Eighty percent of the horticultural production of the country stem from this zone (RFAU/AOC- IAGU, 2007). *Les Niayes* is considered as the main horticulture area and is also seen as a good prospect zone for the extent of the horticulture export. The majority of households in this area are smallholder horticulture farmers producing —next to French beans for export— a large variety of vegetables and basic food crops for the local market and for direct consumption (Fall and Fall, 2000). Most of the export companies are based in this area where they source produce and recruit laborers.

The data we use in this study were collected in this horticulture zone around the regions of Dakar and Thiès. Three rounds of large farm-households surveys were conducted in August-September 2005, in July-August 2007 and in July-August 2010 respectively. During the first survey, 300 households were randomly selected in 29 villages. The villages were also randomly selected in three rural communities in the regions Dakar and Thiès—Sangalkam, Diender and Noto. The same sample of the 300 households was surveyed in the subsequent rounds in 2007 and 2010. The attrition between the three rounds was only 5 households or 1.66 percent of the original sample. As our focus is on agriculture, only households that were involved in agricultural production and potentially diversified into off-farm activities are selected. 2.03% of the households took part only in off-farm activities during the three surveys rounds and are then dropped from the sample. Due to methodological issues that arise in the data envelopment analysis with missing values, we retain a total sample of 708 observations which is a balanced panel of 236 households that were involved in the agricultural production throughout the three surveys rounds. For these households, the surveys data provide detailed information on farm household agricultural production and inputs as well as information on off-farm activities that allow an analysis of agricultural productivity at the household level.

3. Diversified household activities in *les Niayes*

It has been argued that earning from off-farm activities can help stimulate farm investment and improve productivity in a country with a poorly functioning factor market. The importance of off-farm activities in that context allows conducting an analysis basing on the non separability hypothesis of farm decisions. In a theoretical model, Chavas et al. (2005) show that under market imperfections, farm production analysis is more appropriate at the household level due to the jointness in the technology underlying farm and off-farm activities. This is more plausible for many developing countries where resources are scarce and where agricultural households are not confined only to farm agricultural production. The figures below show that our case study is not an exception.

Table 1 presents the percentage of the households that were involved in farm and off-farm activities for the three surveys rounds and for the whole sample. Households' activities in *les Niayes* are much diversified. The households in our sample were intensively involved in farm production and off-farm activities as well. 18.36% of the households in the total sample were engaged exclusively in farm production. However the trend shows that the share of those who were confined only to this activity decreases progressively over years (Table 1). More and more households combined then farm and off-farm activities. At least 20% additional farm households became more diversified by involving into off-farm activities in 2010, compared to the level in 2005 that is 71.61%. In fact by 2010 almost all households were looking at another source of revenue other than farm production.

Table 1: Involvement of households in farm and off-farm activities (%)

	2005	2007	2010	All sample
Farm production	100	100	100	100
Vegetable	98.73	93.64	92.37	94.92
Green bean high value export market	28.39	20.76	6.78	18.64
Vegetables domestic/regional market	97.46	88.98	92.37	92.94
Fruit	9.75	32.2	41.1	27.68
Other basic food crop	28.81	28.81	50	35.88
Livestock production	31.36	16.1	26.69	24.72
Off-farm activities	71.61	80.08	93.22	81.64
Number of households	236	236	236	708

Note: All the percentages are calculated with respect to the number of households. Off-farm activities include off-farm wage or self-employment.

Source: Calculated from household survey data.

Farm activity in *les Niayes* is also diversified and is divided into agricultural production and livestock production with more involvement into the former. Along with some fruits and some basic food crops, vegetables took a large proportion in the agricultural production[5]. More than 92% of the households in our sample cultivate at least some types of vegetables.

[5]A large variety of vegetables includes green bean, tomato, cabbage, carrot, aubergine, cucumber, onion, pepper, courgette, etc. Basic food crops are tuber such as potato, cassava, etc. or cereals such as rice, millet, etc. About thirty products were cultivated. Households combined several cultures and the proportion of them who were involved only in fruits or other basic food crops production did not exceed respectively 1.81% and 2.23% of the total sample.

Although being the main cultures, the involvement in the production of vegetables has slightly decreased over the years contrary to fruits and basic food crops production (Table 1). This might be due to the problem of the lack of water often faced by the households in this area (Faye et al., 1995)[6]. While vegetables need more water, fruits and some basic food crops rely mainly on rainfall. Considering the importance of the nutritional value of vegetables for health and the fact that these vegetables are the main components – aside the rice - in the meals in Senegal, the way to improve household agricultural productivity in this area remains an evident policy question.

Along with the traditional agricultural production, some households in *les Niayes* have also differentiated their agricultural production towards high value products. One example in the area under study is the production of green beans. 18.64% of households in the total sample grow green beans mainly for the export market through contracts with agri-food companies. This is promoted by the emergence of the production and trade of high-value agricultural products in international food markets during the last two decades and also by the strategy of diversification of agricultural products of the Senegalese government. Such diversification towards the export market is seen likely to confer several advantages to households, such as additional source of revenue and enhancing agricultural productivity through for example learning spillovers (Foster and Rosenzweig, 1995; Hernández et al., 2007; Minten et al., 2009; Rao et al., 2012)[7]. While this diversification may be a potential advantage, it is interesting to note that households in our sample move in and move out the high value export production throughout the surveys rounds[8]. This is also one example of the

[6] 74.06% of the households in the 2007 sample responded to suffer from the lack of water during the 12 months prior the 2007 survey.
[7] See Maertens and Swinnen (2009) for more details on the area under study.
[8] 61.44% of the 236 households were not involved in high value export production in all the three years while 2.97% (in the three years), 9.32% (in 2005 and 2007), 1.27% (2005 and 2010), 0.85% (2007 and 2010), 14.83% (in 2005), 7.63% (in 2007) and 1.69% (in 2010) were engaged in green beans export production.

dynamic of agricultural technologies adoption decisions that a cross sectional data can hardly deal with (Doss, 2006).

Another important source of revenue for rural households stems from off-farm activities. Their involvement in these activities is not negligible. These are agricultural or non agricultural labor and self-employment. Some households have one or more members working as employees in the export agro-industry or on the fields. Other household's members work for the private such as nurse, attendant, unskilled worker, or the State. Some households 'members are also engaged in self-employment activities such as chauffeur, bricklayer, carpenter, tailor, hairdresser and small businesses, mostly trading activities. The intensity of the interest for off-farm activities is shown in Table 1.

4. Farm household total factor productivity and efficiency measurement

4.1. The Data Envelopment Analysis-based methodology

In a previous section we have shown that the hypothesis of joint household decisions between farm and off-farm activities is likely to hold in our case study. Therefore considering off-farm income as an additional output for rural farmers, we estimate multiple-output production technologies at the household level using the data envelopment analysis (DEA) method.

DEA and stochastic frontier analysis are two principal techniques widely used in productivity and efficiency literature (see Coelli et al., 2005). While the first one is a non parametric approach, the latter involves econometric methods that account for random noise. Both methods have their advantages and their drawbacks. Although DEA is a deterministic method confounding the effects of data noise with inefficiencies – the main disadvantage –, our choice for DEA is based on the fact that this method is less computationally demanding than the stochastic frontier analysis for which more assumption are needed concerning the functional form of the production function and the distribution of the errors terms[9]. Moreover DEA is primarily adaptable for multiple inputs and multiple outputs case because of inputs and outputs that can be quantified using different units of measurement and also because of the presence of zero-valued inputs and outputs as it is in our case (See e.g. Lovo, 2011).

In the multiple inputs and outputs DEA setting, we use the distance function approach to compute aggregate levels of output and input with which total factor productivity and efficiency levels are derived. Among several aggregator functions, the Malmquist-based aggregator function is widely used in the literature, due in part to its capability to not require information about input or output prices (as in our case) and also to its ability to decompose productivity growth into mutually exclusive and exhaustive components such as efficiency measures (see e.g. Fare et al., 1994; Coelli and Rao, 2005)[10]. However O'Donnell (2012) shows that between measures or indexes that can be estimated without information on prices, the Lowe and the Färe-Primont-based measures or indexes are economically-ideal in the sense that they satisfy all economically-relevant axioms and tests from index number theory[11]. In this paper we follow the methodology in O'Donnell (2010; 2012) and estimate the production technology and levels of total factor productivity and efficiency based on Fare-Primont aggregator functions using the DPIN 3.0 computer program. The methodology is summarized as follows.

[9] Stochastic frontier analysis assumes a given functional form for the production function. Some studies use the Cobb-Douglas or the Translog functional form that involves several testing hypothesis. This is applied also to the distribution of the errors terms. The DEA considers the best performing households in the sample as forming the frontier by constructing a non-parametric piece-wise frontier over the data such that all observed points lie on or below the production frontier. Productivity and efficiency measures are then derived relatively to this surface. Thiam et al. (2001) performed a meta-analysis to review empirical estimates of technical efficiency in developing country agriculture and found that factors such as stochastic versus deterministic frontiers, the number of variables in the model, crop type and sample size do not seem to significantly affect estimates of technical efficiency across studies.

[10] This has been seen as an advantage in the context of African agriculture, where input market prices are either nonexistent or insufficiently reported to provide any meaningful information for land, labor, and livestock (Yu and Nin-Pratt, 2011).

[11] For example it is demonstrated that in the case of a panel of more than two data points, Malmquist-based measures fails the transitivity test. It is also shown that Malmquist-based measures do not preserve its properties in the presence of variable returns to scale (Grifell-Tatjé and Lovell, 1995; Kerstens et al., 2010).

Given a set of input quantity, $x_{it} = (x_{1it}, \dots, x_{Kit})$ and output quantity, $q_{it} = (q_{1it}, \dots, q_{Jit})$ for the household *i* in the year *t*, the DEA linear programs computes an aggregate input, $X_{it} = X(x_{it})$ and an aggregate output, $Q_{it} = Q(q_{it})$, where $X(.)$ and $Q(.)$ are non-negative, non-decreasing and linearly homogenous Fare-Primont aggregator functions. Total factor productivity of the household*i* in the year *t* is then calculated as: $TFP_{it} = Q_{it}/X_{it}$. Furthermore, the maximum *TFP* that is possible using the technology available in the year *t*, is derived as: $TFP_t^* = Q_t^*/X_t^*$, where Q_t^* and X_t^* are aggregates of the output and input vectors that maximize *TFP*.

The program also decomposes total factor productivity into different measures of efficiency. In this study we focus on two measures that are generally used in the literature (see e.g. Fare et al., 1994; Rao et al., 2012). The first measure of efficiency is the output-oriented technical efficiency defined as :$\mathrm{TE_{it}} = \mathrm{Q_{it}}/\overline{\mathrm{Q}}_{\mathrm{it}} \leq 1$, where $\overline{\mathrm{Q}}_{\mathrm{it}}$ is the maximum aggregate output that can be produced by the household *i* in the year *t*, if it holds its input vector and output mix fixed[12]. The *TE* is a measure of the productivity shortfall associated with operating below the production frontier. The second measure of efficiency we consider is the output-oriented scale-mix efficiency; a measure of the productivity shortfall associated with diseconomies of scale and scope. It is defined as: $\mathrm{SME_{it}} = {}^{\overline{\mathrm{Q}}_{\mathrm{it}}/\mathrm{X_{it}}}\big/_{\mathrm{TFP_t^*}} \leq 1.$

As multiplicatively-complete measures, the total factor productivity and the two measures of efficiency are related by the following relation:

$$TFP_{it} = TFP_t^* \times TE_{it} \times SME_{it}. \tag{2}$$

[12]An output-oriented analysis considers a maximal proportional expansion of the output vector, given an input vector. We choose this orientation contrary to the input-oriented analysis as it is more reasonable in our case that agricultural households would maximize output from a given set of inputs (see Coelli et al., 2005; Coelli and Rao, 2005).

Three points about the production technology we estimate need to be noted. First, contrary to the stochastic frontier analysis, the DEA constructs a unique production frontier in the year *t*. In this regards we assume that all households have access to the same technology in a given year but the degree of access (level of efficiency) to using this technology may differ. This assumption might be strong at first sight. Indeed it can be argued that compared to contracting farmers, non-contracting smallholder households are more affected by credit and information constraints for example, making it much more difficult for them to access modern production technology (see Rao et al., 2012). However, it is also likely that contracting farmers that have access to a given technology in a given year may still use somewhat this technology in the subsequent year even if they exit into contracting in that year. Moreover of 236 agricultural farmers in our sample, 58.47% have cultivated at least once the high value product green beans by 2005, 62.71% by 2007 and 63.14% by 2010[13].

Second, we assume a variable returns to scale technology concerning the structure of technology. Assuming constant returns to scale technology implies that smallholder households are operating at optimal scale. This hypothesis may be inappropriate in our case where households are involved in several activities in a context of imperfect competition and constraints on finance that may cause an agricultural farmer not to be operating at optimal scale (see Coelli et al., 2005).

Finally, we do not impose any restriction concerning the nature of technical change. We allow shifts in technology over time i.e. either technological progress or technological regress. Technological regress has been the most reported result from studies concerning less developed countries (see Coelli and Rao, 2005). As in agriculture where weather and climate for example have obviously an influence on the production and also in the dynamic context of

[13] It is possible to estimate different production technologies using the framework of meta-frontier model developed by Battese et al. (2004) and O'Donnell et al. (2008). However this methodology is hardly technically applicable in our case of multiple output-input due to the size of the sample of contracting farmers.

our case study, we follow O'Donnell (2010) and account for omitted environmental variables as well as changes in the stock of knowledge by allowing the production possibilities set to expand or contract over time.

4.2. Input and output variables

We consider six outputs and five inputs. The output is divided into three categories, crop production, livestock production and off-farm income. Crop production is further disaggregated into four categories. This (dis) aggregation is kept as minimal as possible to avoid the problem of degrees of freedom but also as reasonable level to account for quantity and quality differences between products (Coelli et al., 2005, Chavas et al., 2005; Lovo, 2011)[14]. Table 2 presents statistics on the inputs and the outputs used to estimate the production technology.

Table 2: Inputs and outputs used in the DEA

	Overall	2005	2007	2010
Outputs				
Green bean (kg)	894.75	1368.09	595.71	720.44
Vegetables (real aggregate valuesin 1000 FCFA)	7.75	10.27	5.00	7.97
Fruits (real aggregate valuesin 1000 FCFA)	0.84	0.57	0.56	1.41
Other commodities (real aggregate valuesin 1000 FCFA)	1.35	1.38	1.13	1.54
Livestock earnings (in 1000 FCFA)	51.49	77.49	29.09	47.91
Off-farm income (in 1000 FCFA)	992.76	847.37	494.74	1636.16
Inputs				
Adult male members	5.09	3.56	5.12	6.58
Adult female members	4.83	3.53	4.80	6.15
Children members	3.17	1.09	3.36	5.05
Hired labor (in 1000 FCFA)	190.19	164.19	158.48	247.90
Land (hectares)	4.96	5.77	5.73	3.37
Livestock (livestock unit)	2.47	2.64	2.41	2.35
Cost of inputs (in 1000 FCFA)	509.31	440.50	421.29	666.12

[14]For example as households in *les Niayes*are involved in several cultures, ignoring aggregation into types of commodities in this case may lead to technical problems in the linear programming of the DEA.

Note: the number of observations in each year is 236. Statistics displayed in this table are mean values.

Source: Calculated from household surveys data.

Vegetables production, fruits production and other commodities production are measured as an output index for all vegetables crops, all fruits and all other commodities, respectively. These indexes are real aggregate values of all composite commodities obtained after deflating the nominal aggregate values using a Laspeyres price index to make an adjustment for difference in the level of prices[15]. The nominal aggregate value is the sum of the total revenue derived from the sale of each commodity belonging to the group. The prices indexes are Laspeyre's weighted average farm level prices for each commodity. The weights are respective proportions of each commodity in the total (nominal value) output for the commodity bundle considered. The farm level prices were recorded during the surveys and when unavailable for some (very few) commodities, median prices or village level prices are used. Although considered as a vegetable production, green bean production is set apart as output measured in kilogram sold. This is to account for the quality difference between the other vegetables and this commodity that is mainly intended for the export production with high added value. The second category of output used in the DEA is the livestock earnings that consist of the revenues from the sale of animals, meat or animal products. The third category of output off-farm income, are the earnings from any off-farm activity such as wage, self-employment and unearned incomes. Fish farming is not considered in this study due to missing data recorded in the 2005 sample. However this is a negligible activity as it concerns only few households who live along the side sea[16].

In the input side we consider as inputs family and hired labor, the area cultivated during the twelve months prior the surveys, variable inputs and the livestock unit. Family labor is

[15] This adjustment is made in other studies (e.g. Croppenstedt and Miller, 2000).

[16] Less than 1% of households are involved in fish farming both in the 2007 and 2010 samples.

disaggregated into child labor (the number of children less than fifteen years old), male labor and female labor as the number of males and females adults more than fifteen years old. This disaggregation of family labor takes into account the labor allocation within the household (see Chavas et al., 2005). Hired labor is measured in terms of cost as the amount paid to non-family workers. Variable inputs are measured as the cost of agricultural inputs (fertilizer, pesticide, seeds, transports, tractor service, maintenance, etc…).

4.3. Descriptive statistics for estimates of total factor productivity and efficiency

Three observations are derived from the estimates. First, the maximum total factor productivity (*TFP**) possible using the technology available are on average 1.27 in 2005, 0.44 in 2007 and 0.56 in 2010. Rural households in *les Niayes* seem experienced thus technical regress in 2007. This decline might be related in part to unfavourable climatic conditions, notably the water scarcity. Indeed 74.15% of farmers in the 2007 sample declared undergone a lack of irrigation water in that year and 72.57% of that percentage, a fall of agricultural output.

Second, descriptive statistics in Table 3 indicate that irrespective of the status of households, total factor productivity on average is much less compared to the maximum productivity that is possible using the same technology available in each year. These figures are consistent with the relatively low level of productivity in developing countries often reported in the literature. The statistics in Table 3 suggest that the entire productivity shortfall is likely to be attributed more to scale mix inefficiencies. Indeed about half of the households on average could be able to reach the maximum level of productivity through only economies of scale and scope, as they appeared already to be technically efficient.

Table 3: Mean total factor productivity and efficiency estimates from the DEA

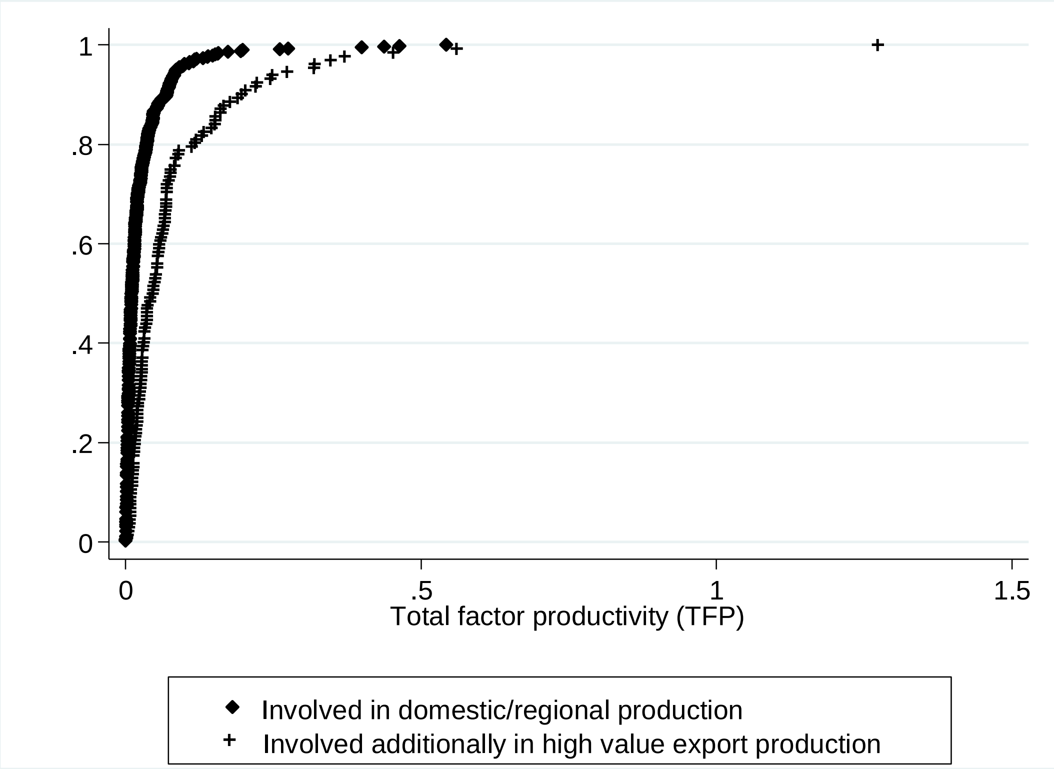
	All households	Involved additionally in the high value export production	Not involved additionally in the high value export production
Total factor productivity *(TFP)*	0.04	0.08	0.03
Maximum Total factor productivity *(TFP*)*	0.76	0.88	0.73
Technical efficiency *(TE)*	0.74	0.80	0.72
% Efficient	50.56	59.09	48.61
Scale mix efficiency *(SME)*	0.07	0.12	0.05
% Efficient	0.42	1.52	0.17
Number of households	708	132	576

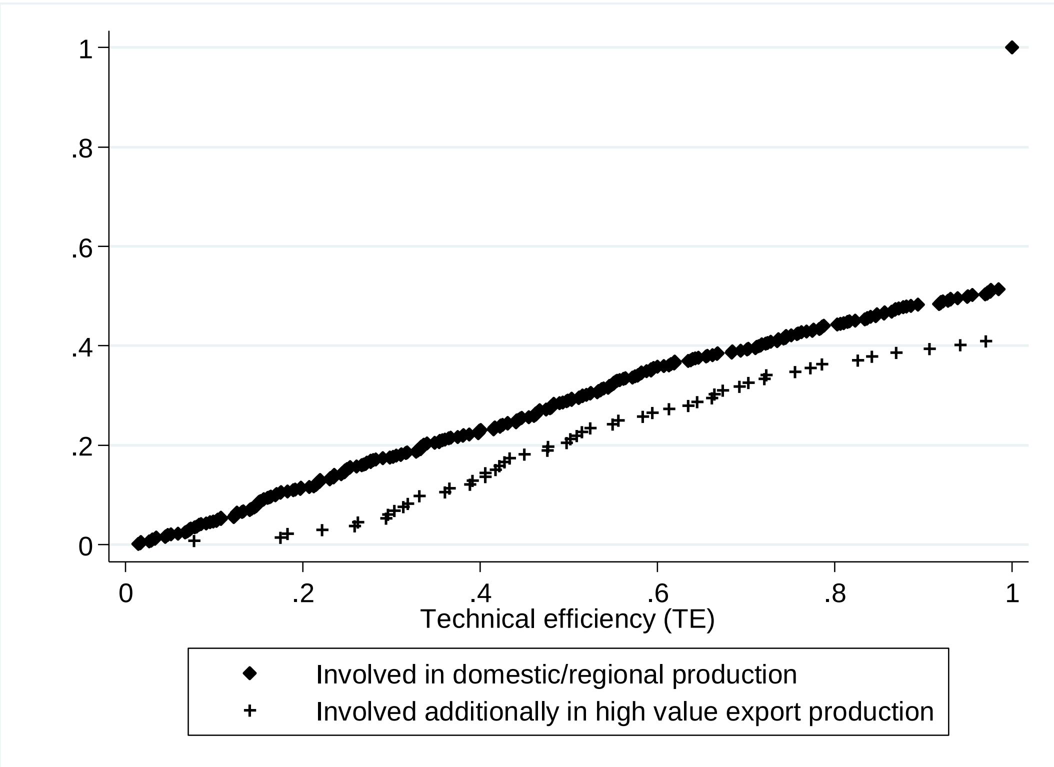
Note: The trend over the years 2005, 2007 and 2010 are displayed in Table A1 in Annex.

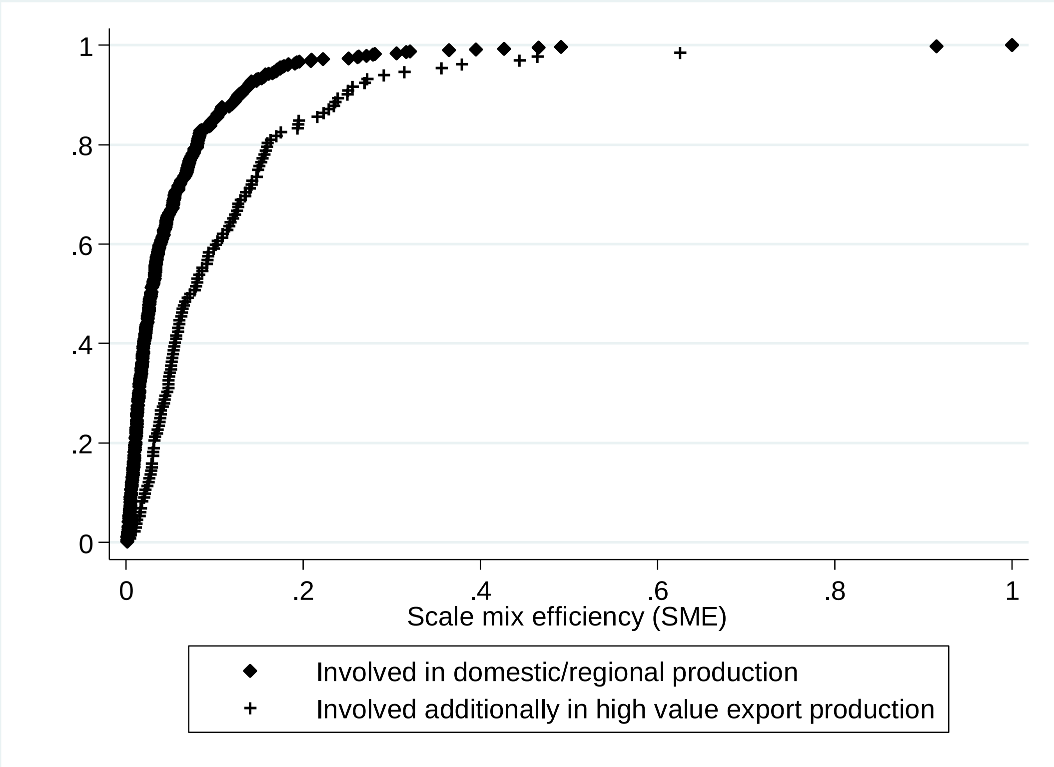
Source: Calculated from household surveys data.

Third, we examine in a descriptive view whether there is any difference in productivity and efficiency between households involved only in the domestic/regional production and households involved additionally in the high value export production i.e. contracting households. Table 3 shows that on average, total factor productivity and efficiency for those cultivating additionally green beans for the export are higher than their counterparts. Even though low as highlighted above, Figure 1 shows that total factor productivity and efficiency cumulative distribution functions for contracting households significantly dominates those of non-contracting farmers. Note however that the percentage of technically efficient contracting households is slightly equal as the percentage of technically efficient non-contracting households. We examine thus in the next section whether the difference in productivity and efficiency observed holds when accounting for some observable covariates and unobserved heterogeneity.

Figure 1: Cumulative distribution of total factor productivity and efficiency by type of households







Source: Calculated from household surveys data.

5. Total factor productivity and efficiency: econometric analysis

We examine in this section the differential effect in terms of total productivity and efficiency between households who diversify towards high value export production and those who are not. We employ the widely used two-stage DEA-based approach that consists in regressing the non-parametric productivity and efficiency estimates on some covariates[17].

5.1. Models and estimation methods

We consider three models. In the first model farm household total factor productivity (*TFP*) is regressed on some explanatory variables that are found in the literature likely to impact on productivity. In order to distinguish the channel through which these variables

[17] Some critics advance the serial correlation of the DEA efficiency that might make inconsistent the estimates in the second stage of the two-stage DEA-based approach (e.g. Simar and Wilson, 2007). However Banker and Natarajan (2008) provide a formal statistical basis of this approach.

impact on farm household productivity, we estimate two additional models in which the dependent variables are the two components of productivity previously identified i.e. technical efficiency (*TE*) and scale mix efficiency (*SME*). The models are the following:

$$TFP_{ht} = \alpha_1 + \beta_1 contract_{ht} + \sum_j \gamma_j X_{j,ht} + u_h + \varepsilon_{ht} \qquad (3)$$

$$TE_{ht} = \alpha_2 + \beta_2 contract_{ht} + \sum_j \gamma_j X_{j,ht} + u_h + \varepsilon_{ht} \qquad (4)$$

$$SME_{ht} = \alpha_3 + \beta_3 contract_{ht} + \sum_j \gamma_j X_{j,ht} + u_h + \varepsilon_{ht}, \qquad (5)$$

where *h* and *t* represent respectively the household and the year. u_h is the household random effect and ε_{ht}, the error term. β, γ and α, are coefficients to be estimated with a particular focus on the first. Table A2 in Annex gives the definition of the variables.

contract is a dummy variable taking the value 1 if the household diversified his production toward an high value export production i.e. when it produces, contrary to other households, additionally green beans in a given year *t* through an agreement with an exporter company. Productivity and efficiency may be enhanced through contracting and we hypothesize that $\beta \geq 0$.

Control variables included in *X* are non-negligible possible sources of productivity or efficiency considered in the literature. These variables reflect managerial capabilities, market or households characteristics. For example, factors like human capital endowments (age and education of the household head) and social capital (belonging to an organization) or idiosyncratic factors (the gender of the household head, the ethnicity of the household, whether the household head is born in the village) might affect the household decision making (Conley and Udry, 2010; Foster and Rosenzweig, 1995). Other variables such as the ratio of female adults to male adults and the dependency ratio of children to adults control for relative labor endowments or labor allocation among family members (Chavas et al., 2005; Lovo, 2011). Additional factors market controls (household access to resource) are whether the household has not owned any land and has not access to a communal land, and value of agricultural equipment and machinery. Rural community dummies and time dummies are also included in *X* to account for environmental, geographic or macroeconomic conditions that is difficult to control for in the first stage DEA.

In a baseline regression, we ignore the panel dimension of the data and we estimate the model (3) by ordinary least square (OLS) and the models (4) and (5) using tobit regression analysis. While by definition there is no *a priori* restriction on the distribution of the total factor productivity estimates (*TFP*), the technical efficiency (*TE*) and the scale mix efficiency (*SME*) scores are censored values bounded between 0 and 1. Thus a limited dependent regression analysis seems more appropriate for these cases[18]. However in either case, although all regressions control for many observables variables, results from the pooled regressions might suffer from unobserved household heterogeneity or endogeneity problem. For example, difference in productivity or efficiency may be due to unobserved time invariant factors specific to households such as their managerial abilities. Particularly for the variable of interest, participation in green bean export production as contract farming is likely to be non-random. For example some unobserved household characteristics such as household heads' entrepreneurial ability can influence both agricultural decisions and productivity (Key and McBride, 2003; Pfeiffer et al., 2009). Also households can decide — based on their access to resources and their preferences — to participate and self-select into contract

[18] There is no consensus in the literature concerning the use of OLS or tobit in the second stage of DEA analysis (see e.g. Hoff, 2007). Some studies (McDonald, 2009; Banker and Natarajan, 2008) argue that the efficiency scores are not generated by a censoring process but are fractional data and conclude of the inadequacy of tobit estimation over OLS, contrary to others (Simar and Wilson, 2007).

farming. A farmer who has grew green beans, and finds it useful, may be more likely to have a favourable attitude toward the technology than one who has not yet adopted it (Barham et al., 2004). In such cases, the coefficients β may be biased in the pooled regressions that ignore unobserved household heterogeneities and potential endogeneity of the *contract* variable.

To reduce these biases, we take advantage of the panel dimension of the data and we estimate the three models using a random-effects or a fixed-effects regression that accounts for the correlation between the household random effect, u_h and the observables explanatory variables. We additionally estimate the models (4) and (5) using a random-effects tobit regression to account for the censored nature of the dependent variables. However using a fixed effects regression has the disadvantage to drop the effect of the time invariant variables included in *X*. And using a random-effects or a random-effects tobit regression assumes that there is no correlation between u_h and the explanatory variables; an hypothesis that is highly difficult to hold at least for the variable of interest for the reasons outlined above. Thus in a final regression, we account for this endogeneity and the time invariant variables by using for the three models the Hausman-Taylor estimation that is a panel data random-effects models in which we allow the variables *contract* to be correlated with u_h.

5.2. Results and discussion

The main estimation results are reported in Table 4. The results from tobit, random-effects and random-effects tobit are reported in Table A3 in Annex, for comparison. Considering results from the fixed-effects and the random-effects, the Hausman test performed at 5% level indicates that coefficients are not systematically different between the two methods for the *TFP* model. Endogeneity seems thus unlikely in this model than in the *TE* and *SME* models. Another observation is that the coefficients of the tobit-based regression results in the *TE* model are higher compared to the OLS and the random-effects results while there are similar in the *SME* model. We recall that the tobit-based methods are used to account for the censored nature of the dependent variables in both models. These results confirm the conclusion of Hoff (2007) concerning the discussion of using either OLS or tobit in the second stage of DEA: The difference observed with the *TE* model might be explained by the real nature of the dependent variable where 358 households in the total sample are technically efficient i.e. these observations are actually right-censored. In the same vein the similarity between the tobit-based results and the OLS and the random-effects results in the *SME* model can be explained by the fact that only three observations are right-censored. The efficiency scores in that case can really then considered as fractional data as argued by McDonald (2009) and by Banker and Natarajan (2008). However in overall the sign and the significance of the variable of interest are robust to change of the estimation methods.

Correcting for the unobserved heterogeneity and the potential endogeneity of the variable of *contract* reduces slightly its coefficient in the *TFP* and *SME* models (Table 4). This means that failing to account for time invariant unobserved heterogeneity and endogeneity overstates the effect of *contract* in the OLS regressions. As stressed above, some unobserved household characteristics such as household' entrepreneurial ability for example might influence both agricultural decisions and productivity and efficiency, causing an upwards bias in the OLS estimation. The direction of the bias seems not clear however in the *TE* model as indicated by the fixed-effects and the Hausman-Taylor results.

Table 4: Differential effect of the involvement of high value export production

Dependent variable	Total factor productivity (*TFP*)			Technical efficiency (*TE*)			Scale mix efficiency (*SME*)		
	OLS regression	Fixed-effects	Hausman-Taylor	OLS regression	Fixed-effects	Hausman-Taylor	OLS regression	Fixed-effects	Hausman-Taylor
Contract	0.052***	0.036***	0.039***	0.125***	0.142***	0.115***	0.067***	0.040***	0.048***
Age head	-0.001**		-0.001**	0.000		0.000	-0.001***		-0.001**
Female head	-0.012*		-0.016	-0.088		-0.045	-0.024**		-0.034
Education head	-0.003		-0.002	0.038		0.028	-0.005		-0.002
Ratio female/male adult	0.010*	0.015**	0.011***	0.038***	0.059**	0.045***	0.011*	0.017**	0.012**
Dep_ratio children/adult	0.000	-0.002	-0.001	-0.000	-0.103**	-0.028	0.009	0.015	0.009
Organisation	0.005	0.004	0.006	-0.058**	-0.008	-0.042	0.012**	0.006	0.011
Ethnic wolof	0.005		0.004	-0.008		-0.012	0.013*		0.013
Head born in village	0.002		0.001	-0.025		-0.024	0.011		0.009
Landless	0.010	-0.005	0.008	0.028	-0.053	0.004	0.015	0.015	0.016
farm_liv	0.030***	0.035***	0.031***	0.095***	0.114***	0.103***	0.034***	0.039***	0.036***
Log (agri equipment)	0.004***	0.001	0.004***	-0.004	0.012*	0.001	0.006***	-0.001	0.004**
Year (2=2007)	-0.016***	-0.017**	-0.017**	0.210***	0.235***	0.216***	0.015*	0.012	0.014*
Year (3=2010)	-0.005	-0.008	-0.007	0.201***	0.214***	0.200***	0.024**	0.020**	0.022**
Constant	-0.010	-0.004	-0.004	0.601***	0.373***	0.540***	-0.034	0.019	-0.012
R-squared	0.164	0.126		0.118	0.174		0.157	0.084	
F test (all u_h=0)		0.0064			0.000			0.000	
Hausman test (Prob>chi2)		0.3984			0.0047			0.017	

Rural community dummies are included in the regressions. The number of observations is 708. Significant effects are indicated with *** p<0.01, ** p<0.05, * p<0.1.

Source: Estimated from household surveys data.

The results show that being involved in green bean export production has a significant and positive effect on productivity, technical and scale mix efficiencies. Diversifying towards the export production increases additionally household total factor productivity by 0.036 to 0.039 units. The positive differential effect is ranged between 0.04 and 0.048 units for scale mix efficiency and between 0.115 and 0.142 units for technical efficiency. Although the average impacts on total factor productivity and scale mix efficiency are less than the impact on technical efficiency, they are nevertheless non negligible. Total factor productivity is lower than 0.036 for about 80% of households not involved in green bean export production. Likewise 61% of households not involved in green bean export production have a level of scale mix efficiency lower than 0.04.

The results suggest that household agricultural productivity may increase through the involvement in the high value export production. Our results are in line with the findings of some previous farm-based studies i.e. the use of production contracts is associated with an increase in factor productivity, and represents a technological improvement over independent production (Key and McBride, 2003). The positive impact of contracting on farm household productivity in our case may stem from spillovers effect as it is found in some studies.

The more plausible explanation from our results is that the compliance in standards requirements in international food market might enforce or induce contracting households to adopt best agricultural practices that are beneficial for the farm household production (see e.g. Foster and Rosenzweig, 1995; Conley and Udry, 2010). In Table 4, difference in total factor productivity observed between contracting households and non-contracting households results from difference in terms of technical efficiency as well as of scale mix efficiency. Thus it is likely that the standards requirements and the related factors such as information on technologies, and better management might be transmitted to contracting households and might affect their skill and ability that enable them to manage more efficiently the farm household production.

Beside the effect of *contract*, few other covariates are found to be statistically significant in the regression results. For example households who belong to an organization or who belong to the ethnic Wolof group – the main ethnic group, including about 40% of the population in Senegal – are technically efficient as equal as those who are not belong to any group. Also household access to resource plays an important role in productivity and efficiency enhancing as show by the positive effect of agricultural equipment variable.

6. Conclusion

We have analysed how farm household agricultural productivity and efficiency are related to one type of crop diversification i.e. the involvement into the high value export production in the region *les Niayes*, Senegal. The results from the DEA-based methodology have shown that rural farmers involved into the green bean export production were more productive and efficient than their counterpart that were not diversified towards the high value export production. Contrarily to their counterparts who were confined only in the domestic/regional production, households are more likely to benefit in terms of agricultural productivity and efficiency gains when they additionally diversified towards the high value export production. This result suggests that this type of diversification is not only crop-beneficial in terms of productivity, as previous studies have shown. Our study has shown that the productivity and efficiency gain can be spread out to the entire farming production as well. This result also suggests that the involvement in the production intended to international food markets – that is subject to standards requirement -, may be enforce households to enable them to manage more efficiently the entire farm household production. The results from the first stage DEA-based methodology have also shown that, irrespective of the involvement in the high value export production, the majority of rural households have a low level of total factor productivity. The entire productivity shortfall is likely to be attributed to technical and more to scale mix inefficiencies. Thus agricultural households in the whole still have opportunities of productivity gain by removing technical and scale mix inefficiencies.

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Annex

Table A1: Mean total factor productivity and efficiency estimates from the DEA: trend over 2005, 2007 and 2010

		All households	Involved additionally in the high value export production	Not involved additionally in the high value export production
2005				
Total factor productivity *(TFP)*		0.05	0.11	0.03
Maximum Total factor productivity *(TFP*)*		1.27	1.27	1.27
Technical efficiency *(TE)*		0.63	0.76	0.58
	% Efficient	41.53	55.22	36.09
Scale mix efficiency *(SME)*		0.06	0.12	0.04
	% Efficient	0.42	1.49	0.00
Number of households		236	67	169
2007				
Total factor productivity *(TFP)*		0.03	0.04	0.02
Maximum Total factor productivity *(TFP*)*		0.44	0.44	0.44
Technical efficiency *(TE)*		0.80	0.87	0.79
	% Efficient	56.36	67.35	53.48
Scale mix efficiency *(SME)*		0.07	0.11	0.06
	% Efficient	0.42	0.00	0.53
Number of households		236	49	187
2010				
Total factor productivity *(TFP)*		0.03	0.09	0.03
Maximum Total factor productivity *(TFP*)*		0.56	0.56	0.56
Technical efficiency *(TE)*		0.78	0.78	0.78
	% Efficient	53.81	50.00	54.09
Scale mix efficiency *(SME)*		0.07	0.17	0.06
	% Efficient	0.42	6.25	0.00
Number of households		236	16	220

Source: Calculated from household surveys data.

Table A2 : Definition of the variables used in the econometric analysis

Variables of interest	
Contract	Dummy if household diversified his production toward an high value export production=1; 0 otherwise
Human capital endowments	
Age head	Age of household head
Education head	Dummy if household head has at least primary education=1; 0 otherwise
Relative labor endowments	
Ratio female/male adult	Ratio of female adults to male adults
Dep_ratio children/adult	Dependency ratio of children to adults
Social capital	
Organisation	Dummy if a member of household belongs to an organization=1; 0 otherwise
Ethnic wolof	Dummy if household belongs Wolof ethnic=1; 0 otherwise
Idiosyncratic factors	
Female head	Gender of household head
Head born in village	Dummy if household head is born in the village=1; 0 otherwise
Factors market access	
Landless	Dummy if household has not owned any land and has not access to a communal land=1; 0 otherwise
farm_liv	Dummy if household has livestock=1; 0 otherwise
Log (agri equipment)	value (log) of agricultural equipment

Table A3: Differential effect of the involvement in high value export production using alternatives estimation methods

	Total factor productivity (*TFP*)	Technical efficiency (*TE*)			Scale mix efficiency (*SME*)		
	Random-effects	Tobit	Random-effects	Random-effects tobit	Tobit	Random-effects	Random-effects tobit
Contract	0.050***	0.235***	0.125***	0.235***	0.067***	0.060***	0.060***
Age head	-0.001**	0.001	0.000	0.001	-0.001***	-0.001**	-0.001**
Female head	-0.014	-0.202*	-0.063	-0.163	-0.024**	-0.030	-0.030
Education head	-0.003	0.080	0.033	0.064	-0.005	-0.003	-0.003
Ratio female/male adult	0.011***	0.092***	0.042**	0.100***	0.011*	0.012**	0.012**
Dep_ratio children/adult	-0.000	0.020	-0.016	-0.010	0.009	0.009	0.009
Organisation	0.005	-0.109**	-0.050*	-0.089*	0.012**	0.011	0.011
Ethnic wolof	0.005	-0.035	-0.010	-0.048	0.013*	0.013	0.013
Head born in village	0.002	-0.003	-0.024	0.003	0.011	0.010	0.010
Landless	0.009	0.031	0.015	0.017	0.016	0.016	0.016
farm_liv	0.031***	0.171***	0.100***	0.174***	0.034***	0.035***	0.035***
Log (agri equipment)	0.004***	-0.010	-0.001	-0.004	0.006***	0.004**	0.004**
Year (2=2007)	-0.016**	0.341***	0.214***	0.347***	0.015*	0.015*	0.015*
Year (2=2010)	-0.005	0.323***	0.202***	0.323***	0.024**	0.024***	0.024***
Constant	-0.007	0.681***	0.564***	0.618***	-0.035	-0.018	-0.019
Right-censored observations		358		358	3		3
Uncensored observations		350		350	705		705
R-squared							
Log likelihood		-523.485		-518.462	658.48		669.747

Rural community dummies are included in the regression. Significant effects are indicated with *** p<0.01, ** p<0.05, * p<0.1.

Source: Estimated from household surveys data.