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Connectivity as engine for productivity among smallholder peanut farmers in Senegal

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Abstract

Peanut is a major source of income for many farmers in Senegal. However, this sector faces several problems in all the segments of the value chain such as yield decline and serious market disturbances. Agricultural production has to be increased to address these issues. This can be done by reinforcing the connectivity of farmers. This study aims to evaluate connectivity as a catalyst for agricultural productivity. An appropriate measure of connectivity integrating various dimensions is computed and an estimate of multilevel mixed-effects linear regression shows its positive and meaningful effect on the output.

Results show that Information and Communication Technologies should be promoted and social networks should be reinforced in agricultural activities. One option is to help Rural Producer Organizations better develop and to be a gateway as community access points.

Keywords: Agricultural productivity; ICT; social network; connectivity; Senegal

JEL Classifications: O13, Q16, Q13

1. Introduction

Human interaction and connectivity through communication tools and sources of timely information can greatly impact farmers' productivity. Poor performance in the agricultural sector in Senegal mainly driven by a succession of unfavorable rainy seasons and the government neglect with sub-optimal budget allocation[2], signals the need for an increased access to information for farmers, including social networks and Information Communication Technologies (ICTs). These cost-effective means are used by farmers to know the position of the trustworthy traders in their regions, to learn the best farming techniques and good storage techniques, to stay informed on the current agricultural and rural policy debate, to get relevant information on the prices on different markets and on farm gate prices etc.

While we let the impact of very advanced technology for future work given their lower penetration rate, we want to shed a new light on the benefit of traditional ICT tools such as telephones, radio-programs promoting farmers' productivity and the information sharing on input and output markets through simple media. With mobile phones so widely available, many traditional ICTs are within the reach of all farmers; unlike the most advanced and specialized devices, which until now, have only been subject to an experimental phase of adoption in rural areas. In fact, the latest technologies that have a low coverage rate in rural areas are not necessarily more appropriate for farmers' activities than the traditional technologies (telephone, radio-program and market information through media) so far, as they require more skills for handling and are not well fit to farmers' resources. Without a strong shift on complementary factors such as educational skill, it will not be possible to fully introduce the newest technology in an efficient way. However, an improvement of the educational status of farmers might require more time and resources. Therefore, it is important to see whether or not current and predominant kinds of connectivity are already sufficiently driving productivity and provide enough incentive to shift to the more structured ones.

Connection through the above mentioned tools can be cost-effective for agricultural household as a means of knowledge sharing that reduces information asymmetries and lowers transaction costs

[2] The sector's contribution to GDP is much higher than the public effort for the sector. The share of agriculture in the national budget was 9.6% on average over the period 2005-2009. However, the state is barely holding his effort year after year. Although it is small, agriculture occupies relatively a considerable share in total GDP (15.1% on average) (Ministry of Agriculture, 2012).

in environments where road infrastructures and public transportation are not very developed. In a context of very tight government budget dedicated to greatly foster physical connectivity, an alternative can be the promotion of better virtual connectivity through ICT usage and through the integration of farmers relying upon community based organizations. Farmers can glean information on prices in the different input and output markets and increase their knowledge regarding some production techniques without having to move through information exchange. This eliminates additional charges in input provision and enables economies of scale. Social capital has been argued to play an important causal role in various socioeconomic outcomes (Durlauf and Fafchamps, 2005). Concerning the functioning of producers' organization, connectivity can help in the democratization of information and transparency in management.

Various studies have suggested that ICTs could play an essential role in agriculture. Lio and Liu (2006) found positive and significant relationship between the adoption of information and communication technology and agricultural productivity based on data collected in 81 countries for the period 1995–2000. Bayes (2001) found that village phones in Bangladesh allow farmers to obtain better prices through information diffusion.

A number other studies have also explored the potential of ICTs in leading to productivity gains and increasing well-being both at cross-national level and at micro level. (Antle, 1983; Röller and Waverman, 2001; Forestier et al., 2002; Waverman et al., 2005; Jensen, 2007; Aker, 2011; Dedrick et al., 2011; Cole and Fernando, 2012). Particularly, there is some evidence of the positive impact of mobile on access to finance (Jack and Suri, 2013), and market integration (Jensen 2007, Aker 2011). Some studies focused on the role of information transmission in promoting agricultural technology adoption and diffusion.

The role of social interactions in driving technology adoption is mixed. Some some researchers have found negative peer effects (Kremer and Miguel, 2007), no effects (Duflo, Kremer, and Robinson, 2008; using randomized controlled trial as impact assessment method) and positive effects (Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006; Conley and Udry 2010; Oster and Thornton, 2012). In a more recent study, Genius et al., 2014, found that both extension services and social learning are strong determinants of technology adoption and diffusion using duration analysis, on a micro-dataset consisting of recall data covering the period 1994–2004 for olive-producing farms in Greece.

Conley and Udry (2010) looked also at the effect of social learning on the use of input among pineapple farmers in Southern Ghana by using data on farmers' communication patterns to define each individual's information neighborhood. They found significant evidence that farmers adjust the amount of fertilizer applied onto their pineapple plots to align with those of their information neighbors who were surprisingly successful in previous periods. The mechanism that drives peer effects are: individuals prefer to behave like their friends, individuals learn about the benefits of the technology from their friends, and individuals learn about how to use a new technology from their friends (Oster and Thornton, 2012).

As far as this paper is concerned, we want to extend this discussion by focusing on the effects on agricultural outputs. We simultaneously take into account the mixed effect of the different kinds of ICT tools as well as the contribution of social networking when orienting the analysis on the output effect. Many studies conducted on the relationship between connectivity and productivity often use one dimension (either telephone or social interaction or agricultural extension services) to assess the connectivity and might miss the crucial point. In fact, considering one single dimension and ignoring the complementarity of the others can lead to measurement effect and introduce bias. Integrating all these dimensions allows distinguishing the specific effects while controlling at the same time the other observable and unobservable effects related to the missing factors that probably also lead to similar outcomes. The approach also makes it possible to quantify the correlation between each dimension and the latent variable. Estimating the role of peers or social interactions in driving technology adoption is made difficult by the problem of correlated unobservables (Manski, 1993). These latter could be linked to every factor affecting information dissemination that might have similar effect on the agricultural output. A shift of the connectivity level of a given farmer cannot be entirely imputed to one given mechanisms but is generally the results of the combination of several factors that enter into consideration.

This study focuses on peanut farmers and contributes to the emerging quantitative literature by developing a framework to get a more accurate and complete measure of farmers' connectivity and by assessing empirically its impact on productivity.

The objective is to show the potential of connectivity as a tool for improving agricultural productivity and raising farmer incomes. Good connectivity is an advantage that allows to increase productivity by giving farmers valuable market updates, by enabling knowledge diffusion across the broader community and by facilitating collaboration between them whether they belong to a producer organization or not. Given that there are a bulk of project that tried to integrate ICT applications and embarked systems in the Africa rural area these last years, this study aims to show that there are potential productivity gains and in turn well-being improvement with the future implementation of more sophisticated and adapted ICT-in-agriculture applications. The results might provide helpful indications and insights for policymakers and private sector so that they can put resource to enhance ICTs and promote complex but adapted ICT applications for farmers such as e-extension, Interactive Voicemail Service (IVR) or audiovisual tools.

The rest of the paper is organized as follows. In the first part we present the groundnut sector in Senegal. In the second part the theoretical framework is presented and the study finishes with the presentation of the results and discussions.

2. Peanut Value Chain in Senegal : Vital Sector in Decline

Peanut occupies a central place in agriculture in Senegal and is an important crop in rural Senegal especially in the Centre. The sector employs 87% of active population in rural areas and taking up half of the cultivated land and generating a large share of farmers' incomes. Peanut accounts for 42 % of revenues in industry, especially in oilseed manufacturing and in paste companies such as SUNEOR, the main groundnuts end-buyer. However, there is a trend towards a decline in peanut output in Senegal due to severe shocks that have adversely affected the supply and upset the whole value chain. For example, the total production of peanut has experienced a big decline of 59% during the 2011-2012 crop year compared to 2010-2011 due to the poor rainy season. The production stood at 527,528 tons against 1,286,855 tons during the 2010-2011 campaign, that is, a difference of 759,327 tons[3]. The yield per hectare has decreased by 43.4%, falling to 609.3 kg per hectare. The cultivated area also decreased by 27.6% with 865,770 hectares against 1,195,573 hectares in the previous agricultural campaign (ANSD, 2011)[4].

[4] National Agency of Statistics and Demography

The decline over the decade can be explained by factors like lower international prices, droughts and successions of bad rainy seasons, suppression of preferential tariffs with the French market (1972), exchange rate devaluation (1994), low intensity of use of improved inputs, and internal factors related to political reforms and actions at various level of the value chain. The recent liberalization of peanut sales has upset the value chain. During the 2011/2012 marketing campaign, foreign buyers such as Indians and Chinese offered higher prices which diverted peanuts from local processors with whom they used to deal with. This created shortage of peanuts for the three main peanut processing companies SUNEOAR, NOVASEN and CAIT[5] that no longer hold the export monopoly. While many others farmers at the mercy of private traders were obliged to sell in unofficial and uncontrolled market channels at lower prices. Output prices as well as input prices might affect productivity. Risk on past prices can also have effect on farmers' production decisions and reduce the resources allocated to farming activities (Schultz, 1979; Mundlak et al., 1989; Fulginiti and Perrin, 1993). The adoption and the intensity of use of fertilizer by groundnut farmers has been declining over time and groundnut productivity is today lagging behind its potential level. There is a need to revitalize this sector to improve aspects such as farmers' income and effective functioning of the agricultural export sector.

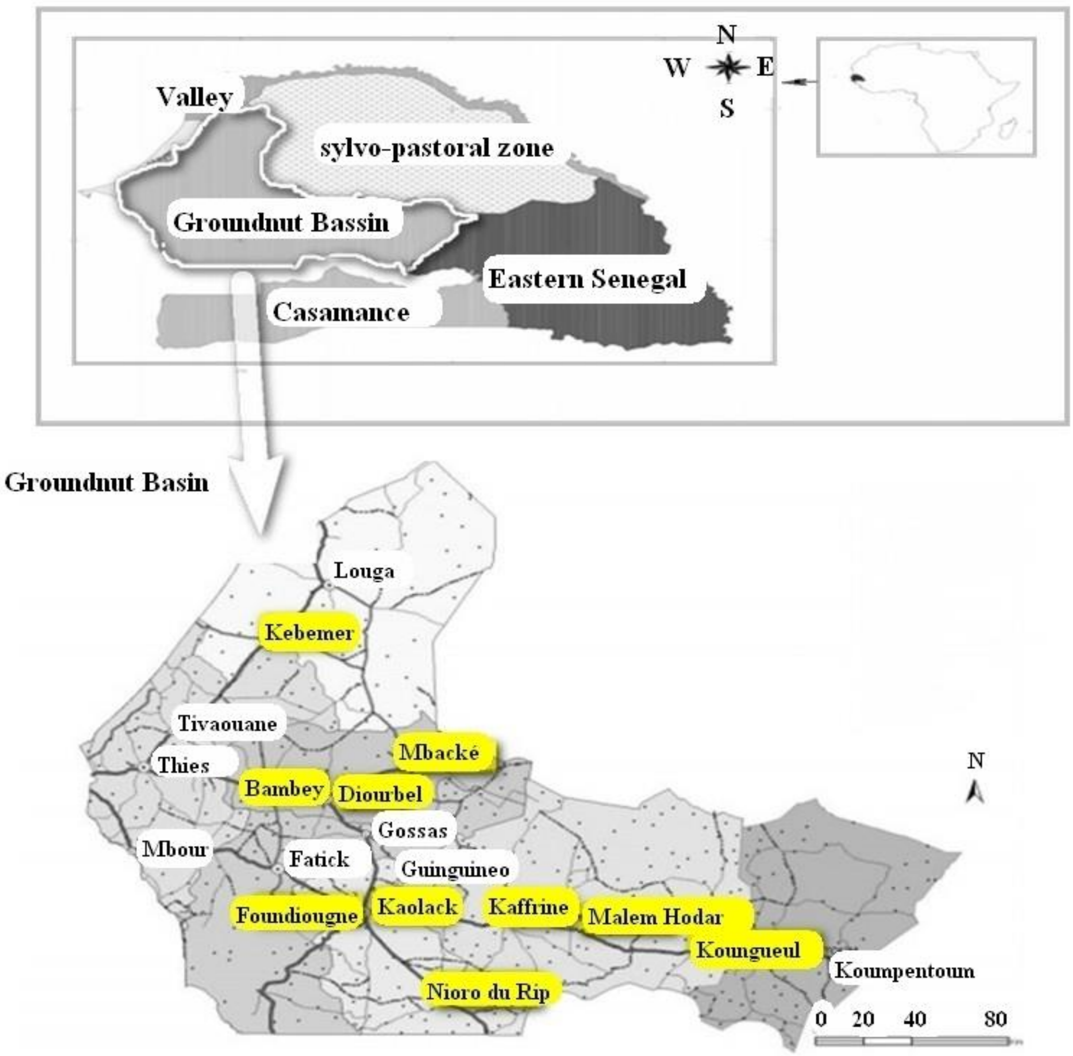
Initiatives such as Rural Producer Organizations (RPO) can help to spread farmers' network by linking them to the different value chains, by creating a platform for information dissemination and by acting as intermediates for access to inputs. These RPOs can also serve as relys and gateways of modern ICTs just like the traditional ones in the rural world. Although, their functioning must be improved to better meet economic needs and address social farmers' constraints. Promoting the establishment of RPOs is a good initiative to improve rural service delivery and poverty reduction, but these organizations work slowly to reach their full potentials because all members do not benefit equitably.

The Groundnut basin is presented in figure 1. Its covers the western center of the country and concentrates 65% of the rural population (Kelly et al., 1996). As its name indicates, the groundnut basin is the agricultural area where groundnut cultivation dominates. The Groundnut basin provides the essential part of groundnut production in the country and accounts for around

[5] Novasen : Nouvelles Valorisation d'Arachide du Senegal. CAIT : Complexe Agro-Industriel de Touba

30% of the nation's land area. The districts highlighted in yellow are the areas where groundnut farmers are surveyed (Kébémer, Bambey, Diourbel, Mbacké, Foundiougne, Kaolack, Kaffrine, Malem Hadar, Kounghel, Nioro du Rip). The groundnut basin is characterized by a Sahelian climate with an average annual rainfall between 200 and 900 millimeters but with a steady decline throughout the region due to the movement of the isohyet lines.

Figure 1: Senegal groundnut basin



Source: Author adapted from Fond/DTGC

3. Research Methodology

3.1. Data Set and Study Area

The results in this study are based on a survey conducted by IFPRI among peanut farmers in Senegal in 2012/2013. Farmers were interviewed about their socio-demographic characteristics and their agricultural activities. Organizational-level data were also collected for the different surveyed groundnut RPOs. Data on the use of ICTs and farmer networks were obtained in addition to some attitudinal measures such as altruism derived from lab-like field experiment. These data on peanut form a sample of 29 village-level RPOs consisting of 334 farmers for whom we acquired information. This sample was drawn from a dataset of 204 Senegalese RPOs collected in 2009 from which we selected all organizations involved in the groundnut value chain and that stated collective commercialization as one of their main purposes. In each group we have one to fourteen individuals randomly selected. Apart from the survey conducted by IFPRI on these selected individuals, a training on group functioning and collective action has involved some of these individuals (ranging from 0 to 4 leaders and members) drawn randomly in each group and in collaboration with two national cooperative federations[6]. But here, we are interested on the potential linkage between connectivity and farming activities.

3.2. Summary Statistics

Summary statistics for household-level variables are presented in Table A1 in the Appendix. In the first group, the variables are those used to measure connectivity and the second group is formed by the variables related to agricultural activities.

While almost 67% of the farmers are informed on prices of agriculture related products over the last 12 months, only 15% of the farmers are informed through basic ICT tools such as telephone and radio. This is low when considering the high mobile phone penetration rate with 82% of the individuals having a cellphone and almost 83% of the sample having a radio or a television in the study area. Connectivity is not only a matter of using ICT tools but also includes social interaction with other farmers and agricultural extension agents as explained earlier. Around 22% received at least once agricultural extension advices from NGOs or state agencies.

[6] a French NGO (GRET) and a Senegalese NGO (PINORD)

In order to evaluate respondent generosity, we have performed an experimental investigation during the survey using the dictator game framework where individuals are given the opportunity to give money or not (Kahneman et al, 1986). We set a hypothetical scenario where the first player receives a donation of 100 000 CFA[7] and will determine an allocation/split of this endowment to share with a second player randomly selected and entirely passive who doesn't know the identity of the proposer. The responder makes the decision regarding the amount of money to keep and to give. When the individual was only concerned with their own interest the entire endowment was allocated to himself and nothing to the second player. Altruism is evaluated by the amount of initial endowment shared by the responder. Generosity through strengthened reciprocity might influence the impact of goods and services received by the individual in their neighborhood. Individuals are repaid in the future according to the favor they did in the past. Current and future network interaction can be captured through this reciprocal incentive as the individual wishes to treat generously those who have treated or will treat them kindly.

The involvement in the RPOs is captured by an indicator variable telling whether the members have given their last financial contributions or not and are attending the group meetings. It has been observed that 66% of the respondents attended at least half of their group meetings but only 41% paid their financial contribution to the RPO. Being an active member of producers' organization group can allow information dissemination thus giving a great opportunity to benefit from many kinds of external capacity building, facilitating the peer effect through improved input use, filling technological knowledge gaps and generating output commercialization strategies. Besides, we also include the individual's position in the group (leader and only ordinary member).

Network for emergency monetary assistance is obtained from this question: *If urgent could you get a loan of 50,000 CFA?* 64% of the respondent might be able to get a loan in this situation. In 30% of household, one member has a saving account. This variable gives a rough estimate of how farmers have access to formal banking schemes.

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[7] On 23 May 2014, 479.576 FCFA = US $1 (OANDA, 2014).

The production function is measured using the estimated value of agricultural output. The agricultural inputs are: labor proxied by family labor, land measured in hectare metric, capital measured by the value of the machinery and fertilizer measured by sum of chemical and organic fertilizers consumed. The average groundnut production is estimated to 3 082 kg. Regarding trends of output commercialization in average households in the sample have sold 247.74 kg of peanuts during the campaign prior to the year when we have collected data.

3.3. Productivity and Connectivity

The production takes the form of a Cobb-Douglas function where the intercept depends on the degree of interconnection of households so that variation in the production will not be related only to variation in the used inputs but also to the degree of connectivity of households.

Assuming different implemented technologies as a result of differentiated level of connectivity of households, the augmented production function can be expressed as follows

$$ln\, Y_{hk} = \Phi\,(C) + \beta(X_h) + \varepsilon_h \qquad (1)$$

$$\Phi(\mathrm{C}) = \varsigma + \sum_{s=1}^{S} c_s + \mu_{hk} \qquad (2)$$

Where ε_h is a random disturbance, Φ(C) is the effect of the farmer's connectivity on the output, X_h represents the traditional production inputs, Y_{hk} the production function of household h living in location k and c_s the manifest variables that are determined by the unobservable multidimensional latent variable C capturing the household multidimensional connectivity, μ_{hk} is the random intercept. $\Phi(\mathrm{C})$ is estimated using a confirmatory factor analysis.

Unlike many previous studies, we did not use one-dimensional variable to capture connectivity but opted to use simultaneously all the relevant proxies. Individual connectivity is a multidimensional concept that cannot be directly observed and has to be measured as latent and determined through multiple observable proxies.

In consideration of a possible measurement error, a confirmatory factor analysis is performed to estimate the relationship between a set of observable measures and the connectivity variable. This relationship is described as follows:

$$C_s = \xi\ \Phi(\mathrm{C}) + \ \varepsilon \qquad (3)$$

Observed variables (c_s) are linked to the latent variable C through the matrix parameter ξ. This matrix of loadings ξ determines the relationship between the latent variable and the observable measures. The estimated connectivity measure will be an aggregate of indicators highlighting the different dimensions that enter into consideration.

4. Results and discussions

The results of the estimates are presented in Table 1 which shows in its lower part the model linking household agriculture production to the level of connectivity estimated with household that effectively have produced during the 2011/2012 campaign. In the upper part are presented the relationships between observable variables and the latent variable of connectivity. Connectivity is not directly measurable but is rather inferred from other variables that are observed, as explained earlier. The parameter for the variable measuring media utilization is fixed to one (1) in order to calibrate and set the connectivity measure equal to this variable in the absence of measurement errors. Changing this for some other variables doesn't change the significant effect of connectivity.

The results indicate that all the manifest variables are significantly related to the latent variable of connectivity, hence the relevance of using several indicators rather than unidirectional ones. The variables used to build an accurate measure of farmer connectivity include those related to farmers' social network and their faculty to interact with others and those related to farmer's use of quite basic ICT tools as shown in Table 1. Connectivity is also expressed by the number of visits of an agricultural extension agent (from NGOs, Government branches) received by the household over the last 12 months. The results indicate the beneficial role of extension services on increasing crop yields for groundnut farmers. Agricultural extension services generally assist the farmers in the adoption of improved technology, decision making and in their general agricultural problems. The role ICTs have to play in information on agricultural prices received a particular interest and is included in the measurement model as stated earlier

All the indicators are significantly correlated to connectivity and Table A2 in the appendix allows an efficient comparison and interpretation of the correlation between the indicators and the latent variable of connectivity (using the standardized factor loadings). Accessibility to information on prices, Network for emergency monetary assistance, Generosity, Telephone, Involvement in the RPO and Financial inclusion have the large factors loading and are the manifest variables the most correlated with the latent variable of connectivity. They are likely to be the strongest channels for connectivity.

We performed a multilevel mixed-effects linear regression allowing random intercept combined with a two-stage residual inclusion (2SRI)[8] to correct for endogeneity. Fertilizer is instrumented as: the village price index for fertilizer (computed as the mean of the prices faced by individuals in the village) and the source of purchase while labor is proxied by family size that is exogenous. The instruments are good predictors and the Kleibergen-Paap rank Wald F-statistic[9] as well as the Hansen J test reveal appropriateness of the instruments Table A3 in Appendix.

Standard errors are clustered at village level to account for possible spatial correlation and better estimate the variance-covariance matrix. In fact, two households from the same village will be more alike than those from different villages. However, this cluster effect might be limited regarding some location specific characteristics as all villages are located in the Senegal groundnut basin and are likely to have approximately the same physical commercial market opportunities for inputs and to quite equally benefit from government investments in presence of spillover effects. Taking into account measurement issues in the assessment of our connectivity variable, endogeneity of traditional production inputs as well as potential heterogeneity in the production function allow dealing with inherent causal identification problems in this kind of analysis. Estimated production functions show a positive impact of connectivity on the output, meaning that social network and ICT matter explain the differences in agricultural productivity among farmers. All the inputs are logged value and the corresponding parameters are elasticities. The results show that the input elasticities are significant across all the models with a higher elasticity found for land (around 0.6). The value of land elasticity is consistent with the proposition that agricultural growth in sub-Saharan Africa has been driven primarily by land expansion (Dethier and Effenberger, 2011).

[8] For more details see Garen, 1984; Vella, 1993; Terza et al., 2008; Wooldridge, 2010
[9] See Stock and Yogo, 2005 ; Baum et al., 2003; Kleibergen, F. and R. Paap., 2006

Table 1: Productivity and Connectivity

Measurement model for Connectivity $\boldsymbol{\Phi}(\mathbf{C})$ $\boldsymbol{c_s}$		Intercept Cons_c_s	σ(c_s)
# Radio/Television	1	1.468***	1.546***
	(0)	(0.080)	(0.142)
Informed on prices	0.841**	0.794***	0.116***
	(0.367)	(0.025)	(0.015)
Informed on prices through ICTs	0.370*	0.179***	0.137***
	(0.195)	(0.024)	(0.013)
Telephone	0.260**	0.952***	0.0408***
	(0.118)	(0.013)	(0.003)
Network Agricultural extension advice visits	1.347**	0.639***	1.940***
	(0.656)	(0.090)	(0.182)
RPO meeting attendance	0.530**	0.706***	0.188***
	(0.257)	(0.028)	(0.018)
Network for emergency monetary assistance	0.639**	0.762***	0.154***
	(0.280)	(0.026)	(0.016)
Generosity/sharing	24,292**	37,024***	2.32e+08***
	(11,540)	(1,040)	(2.42e+07)
Saving-Financial Inclusion	0.661**	0.349***	0.198***
	(0.292)	(0.030)	(0.019)
Position in the RPO (ordinary member =0)	1.122**	0.508***	0.767***
	(0.544)	(0.058)	(0.0753)
Involvement in the RPO	0.679**	0.516***	0.218***
	(0.327)	(0.031)	(0.022)

Production function	OLS	MMEL	MMEL 2SRI	MMEL Augmented	MMEL 2SRI Augmented
Land	0.599***	0.592***	0.593***	0.596***	0.597***
	(0.040)	(0.040)	(0.037)	(0.038)	(0.035)
Fertilizer	0.0255***	0.017**	0.061***	0.0138*	0.056**
	(0.008)	(0.008)	(0.016)	(0.007)	(0.016)
Capital	0.0437***	0.0417***	0.0432***	0.0367***	0.0384***
	(0.009)	(0.008)	(0.008)	(0.0086)	(0.008)
Labor	0.295***	0.292***	0.284***	0.241***	0.239***
	(0.090)	(0.092)	(0.091)	(0.084)	(0.081)
Residual_fertilizer			-0.049**		-0.0459*
			(0.019)		(0.021)
$\boldsymbol{\Phi}(\mathbf{C})$				0.454**	0.419*
				(0.221)	(0.218)
Constant	10.71***	10.78***	10.62***	11.00***	10.83***
	(0.253)	(0.260)	(0.272)	(0.218)	(0.232)
Observations	257	257	257	257	257
R-squared/Log pseudo likelihood	0.546	-250.32	-247.45	-247.37	-244.861

Robust and clustered standard errors in parentheses;***P<0.01,**P<0.05,*P<0.1. MMEL: Multilevel mixed-effects linear regression. 2SRI: two-stage residual inclusion.

In addition, we also found a meaningful correlation[10] (0.171 significant at the 1% level) between the computed index of connectivity and the quantity of groundnut previously sold by the individuals. This might reflect the association between efficiency in output commercialization and connectivity. Favorable agricultural commercialization could lead to greater productivity level among groundnuts farmers.

The results highlight the benefit of building relationship with others and disseminating information through communication technology facilities. Connectivity is another means that can help farmers to maximize their outputs and their profits. It can allow them to discover new production systems, to surpass geographical limitations by extending their business; and they have the possibility to stay informed on input and output price movements without additional high costs. Social network and ICTs led to the same effect, that is, to strengthen farmers' capacities and reduce their social isolation.

RPOs should be supported and accompanied by the promotion of individual ICTs or group level devices usage in order to increase their efficiency and improve their functioning regarding transparency, input and output price bargaining, and in order to foster information sharing on agricultural technics. In fact, RPOs currently provide only limited services, despite their great potential to solve problems faced by farmers. Figure A1 in the appendix shows that more than 34% of farmers mention lack of assistance as the major problem that their group is facing in achieving its goals.

5. Conclusion

Social network, knowledge and information sharing are essential in famers' business today. This study was done in order to understand the relationship between smallholder groundnut farmers' connectivity that includes the level of ICTs and social network usage and their agricultural productivity. This research was carried out in Senegal among farmers in groundnut RPOs and clearly highlights that connectivity can help to boost agricultural productivity. It has shown evidence of positive returns for productivity by using a multidimensional measure of connectivity and by estimating a multilevel mixed-effects linear regression to better account for heterogeneity in the production technology.

[10] This is a simple correlation calculation and does not comes from the econometric model.

Concerning ICTs the analysis is based on quite basic devices and gives the hope that oriented applications developed on these underlying technologies might reinforce the important role of connectivity as a productivity-enhancing factor. These applications must be easily manageable for people with limited formal education. Mobile phones and media could help to increase income, improve the efficiency of markets, reduce transaction costs, and can be a factor of convergence between poor and rich farmers.

Connectivity might help farmers and producers' organizations to reduce their transaction charges, improve their market access - especially for input and credit provisions - and facilitate fast adoption of technical innovation. Improving farmers' connectivity can reduce informational asymmetries and lower the market power of local private collectors and reselling traders (commonly called *bana-banas*) that travel throughout villages and often offer cash payments. This hinders inputs provision through the RPOs and collective marketing and often does not benefit producers especially the less patient or those who are less informed on the current price levels. Small farmers are often at the mercy of these intermediate traders because they have no sufficient bargaining power.

However, despite the potential contribution we found, ICTs and social network have to be used and explored appropriately to improve productivity and rural development. ICTs and RPOs financial contribution must not have impoverishing effect on farmers by pushing them to neglect other basic needs or to reduce the time spent on productive agricultural activity at the expense of meetings or other non-productive community activities.

Government and international organizations in collaboration with private partners such as mobile network operators can help farmers to overcome information failure especially on input and output prices by promoting more equitable access to ICTs, and must provide assistance to RPOs for efficient technology adoption and wide agricultural knowledge dissemination.

Social network - as well as basic ICTs - is important in giving opportunities to rural farmers to stay informed on agricultural technologies and on input prices. The forecasted break-through of sophisticated ICT tools such as internet-based applications must not be a substitute but a complement of the existing methods that are more affordable with the expansion in mobile phone coverage and must rely less on farmers' educational skills.

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Appendix

Table A1: Descriptive statistics

Variables	Observations	Mean	Std error	Minimum	Maximum
# Radio/Television	257	1.48	1.27	0	8
Informed on prices	257	0.80	0.40	0	1
Informed on prices through ICTs	257	0.18	0.39	0	1
Telephone	257	0.95	0.21	0	1
Network Agricultural extension advice visits	257	0.61	1.40	0	10
RPO meeting attendance	257	0.70	0.46	0	1
Network for emergency monetary assistance	257	0.76	0.43	0	1
Generosity/sharing (FCFA)	255	37176.47	16597.01	0	60000
Saving-Financial Inclusion	257	0.35	0.48	0	1
Position in the RPO	257	0.50	0.92	0	3
Involvement in the RPO/Contribution	257	0.52	0.50	0	1
Production (FCFA)	257	747595.30	1069709.00	30000	8000000
Land (ha)	257	7.20	6.67	0	52
Fertilizer (FCFA)	257	17880.35	33968.26	0	276000

Capital (FCFA)	257	149110.90	446031.50	0	7000000
Labor (persons)	257	17.53	8.00	3	49
Output commercialization (kg)	257	251.60	894.85	0	11200

Table A2: Standardized factor loadings

Indicators	standardized loadings	R^2
# Radio/Television	0.205**	0.042
	(0.080)	
Informed on prices	0.542***	0.294
	(0.076)	
Informed on prices through ICTs	0.252***	0.064
	(0.083)	
Telephone	0.318***	0.101
	(0.078)	
Network Agricultural extension advice visits	0.245***	0.060
	(0.082)	
RPO meeting attendance	0.304***	0.092
	(0.083)	
Network for emergency monetary assistance	0.391***	0.153
	(0.079)	
Generosity/sharing	0.384***	0.148
	(0.080)	
Saving-Financial Inclusion	0.362***	0.131
	(0.078)	
Position in the RPO (ordinary member =0)	0.317***	0.101
	(0.081)	
Involvement in the RPO	0.355***	0.126
	(0.080)	

Note: Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The standardized loadings equals $\xi. \sigma(\Phi(C)) / \sigma(c_s)$, where ξ is the unstandardized fators presented in Table 1.

Table A3: Instrument for Fertilizer

Variables	fertilizer
Village level Price	-0.003*
	(0.002)
Source RPO	5.036***
	(0.599)
Source traders	0.034***
	(0. 465)
Cons_	-1.81
	(4.83)
R^2	0.17
Hansen J-statistic (P-value)	0.900
Kleibergen-Paap Wald rk F statistic	25.097
Kleibergen-Paap rk LM statistic (P-value)	0.000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, regional fixed effect added

Residuals of this regression are included in the MMEL to control for endogeneity.

Figure A1: Major Problems in Peanut RPOs