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# ESTIMATING THE IMPACT OF INNOVATION SYSTEMS ON MAIZE YIELDS: THE CASE OF IAR4D IN SOUTHERN AFRICA

Shephard Siziba\*, Kefasi Nyikahadzoi\*, Joachim Binam Nyemeck\*\*, Aliou Diagne\*\*\*, Adekunle Adewale\*\*\*\* and Fatunbi Oluwole\*\*\*\*

## ABSTRACT

Markets are known to have a great potential to unlock agricultural growth in developing countries. The conventional agricultural research and development approaches used hitherto have not yielded much success in stimulating farmer participation in markets. New agricultural development approaches, such as the Integrated Agricultural Research for Development (IAR4D), view developmental challenges as multi-dimensional and as such require multi-pronged and integrated initiatives – better known as innovation systems – to overcome. Using data from IAR4D trials in Zimbabwe, Malawi and Mozambique, the study evaluates the efficacy of IAR4D in stimulating market integration and crop intensification. The impact of IAR4D on maize yield, estimated using the local average treatment effect (LATE) is significant in all the countries. Yields improved by margins ranging 107–149 kg ha<sup>-1</sup>, which is quite substantial in a region where yields average around 1000 kg ha<sup>-1</sup>. These findings give credence to the proposition that innovation systems such as IAR4D are more effective in stimulating agricultural growth.

Keywords: Innovation systems, IAR4D, impact, market integration

JEL: Q13, Q16, Q18

## 1 INTRODUCTION

The problems of hunger and poverty, quite widespread in sub-Saharan Africa (SSA), are largely rooted in the low levels of crop productivity (Sanchez *et al.*,

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1997). Improving crop yields demands use of improved technologies to overcome the biophysical constraints of limited rainfall, low soil fertility, pests and diseases, complemented by planting high yielding crop varieties (HYV). Though currently a number of technologies to improve crop yields exist, their usage is very low in SSA. For example, average fertilizer use in many sub-Saharan African countries is still less than 10 kg ha<sup>-1</sup> arable land a year (FAOSTAT, 2012). As a result SSA agriculture has failed to transform from subsistence low productivity to commercial high productivity. Reasons for this failure are multidimensional, and include poverty, poor institutional and policy environment. Efforts with current agricultural research and development (ARD) approaches have yielded disappointingly low returns with crop yields on a continual downward trend for the past 20 years. The low budgetary allocations to ARD by most governments in SSA partly explains these low returns. Some analysts point further to shortcomings in the design of current ARD approaches. Design weaknesses of the current ARD have been located in their linear and narrow approach to agricultural development solutions, particularly the exclusion of the non-research aspects (Hawkins et al., 2009). A new approach called Integrated Agricultural Research for Development (IAR4D) recognises the multifaceted challenges of rural development and invites knowledge and actions of all stakeholders in the agricultural system. Investment from the private actors, which is crucial in connecting farmers to markets, is one of the key recognitions of IAR4D.

## 2 MARKET INTEGRATION AND RURAL DEVELOPMENT

Market development can be a tool for fostering rural development and reducing poverty. As described by Timmer (1988) and Staatz (1994), the agrarian transformation essentially involves farmers moving away from a subsistence production mode to a more market integrated mode. With increased market integration farmers use more purchased inputs, produce more marketed surplus and as well have increased demand for other goods and services. This transformation process is self-reinforcing – as farmer household's disposable income increases, so does demand for variety in goods and services, inducing increased demand-side market participation, which further increases the demand for cash and thus supply side-market participation (Boughton *et al.*, 2007). Despite, the well noted potential benefits of engaging in markets, very low levels of market participation are observed among smallholder farmers throughout most of SSA (Barret *et al.*, 2008). Stimulating market participation by smallholder farmers has been a policy challenge for many SSA governments beginning in the post-independence era. Efforts at this have seen policy swings from strong market interventionism to market liberalism associated with the Structural Adjustment Programmes (SAPs) of the 1980s. According to Barret *et al.* (2008), the difficulty with market

participation is that it is both a cause and consequence of economic development. The theory of market participation at the household level can be rooted in the trade theory of Ricardo, and Coase's theorem of transaction costs. The latter explains the motivation of farmers to engage in trade/markets so that they can enjoy a diverse consumption bundle. They can exploit welfare gains from trading by concentrating in the production of goods they have comparative advantage, and exchange for those they have no comparative advantage, mostly manufactures. The former (Coase) explains how transaction costs can impose barriers to markets and lead to market failures.

Empirical observations of the smallholder farming systems in SSA indicate a picture of poor market integration. The farming systems are characterised by low monetary incomes, relatively thin markets (for agricultural inputs, outputs and finance, consumer goods and services), large number of smallholders in very small volumes of the same commodities (Poulton, Kydd and Dorward, 2006). According to the authors, these conditions normally co-exist with poor communication networks (that is, roads and telecommunications,) poor access to information (commodity prices, agro input prices, new technologies, and on potential contracting partners), difficulties in enforcing impersonal contracts and widespread rent-seeking behaviour. Transactors are often poorly informed. Buyers have limited knowledge about the commodities produced by the smallholder producers, and smallholders lack access to information on the quantity and quality of commodities that buyers want (Coulter and Onumah, 2002). The advent of mobile phones has improved smallholder farmers' access to market information. However, smallholders are often unable to process complex market information when it is available.

Market uncertainty faced by smallholders dampens production incentives and contributes to stagnation in agricultural output and productivity (Coulter and Onumah, 2002). Many authors agree that such conditions pose particular problems for the supply-chain development needed for agricultural intensification, and these are exacerbated by the fact that such development may require significant simultaneous and complementary investment by a number of market participants (Dorward *et al.*, 2004; Poulton, Kydd and Dorward, 2006). Such investments carry high risks of transaction failure and hence high transaction costs incurred in obtaining protection against such risk (Poulton, Kydd and Dorward, 2006).

### 3 LOW CROP YIELDS AND POOR MARKET PARTICIPATION

The yields of most crops in sub-Saharan Africa are considered well below their potential levels. For example, yields average 1–2 tons/ha grain for maize and 0.5–1.0 t/ha for grain legumes (FAOSTAT, 2012). In the past 30 years the crop

yields have persisted on a downward trend. This leaves for much of the continent where most of the population depends on agriculture for a livelihood, little hope for reducing hunger and poverty by 2015. The yield gaps are largely attributed to low utilisation of agricultural technologies by the farmers. Use of basic agricultural technologies, such as chemical fertilizers and improved seeds, which catapulted much of Asia into the Green Revolution in the 1960s, is still scanty in sub-Saharan Africa. The reasons why farmers fail to access and use improved crop production technologies are many and multidimensional, and include poverty, poor institutional and policy environment.

To arrest the decline in crop yields and increase yields requires a transformation of the mode of agricultural production. Two mostly cited transformations are intensification and commercialisation of agriculture. Intensification refers to increased use of inputs on the same land area to achieve more output. Calls for intensification are usually motivated by the increasing scarcity of land due to population pressure. Commercialisation is associated with cash cropping, specialisation and increased productivity. Market integration of farmers is the key feature of these transformations towards higher yields. Markets provide the incentives and means to produce more output and access more purchased inputs (fertilizers, HYV and pesticides), enabling the transformation to a high-input, high-output farming system.

#### 4 IAR4D CONCEPT

Integrated Agricultural Research for Development (IAR4D) initially developed by FARA is a concept that is still evolving (Hawkins *et al.*, 2009). With more experiences learned from its test trials currently taking place in selected sites across sub-Saharan Africa, it is continually being developed. The concept of IAR4D is largely motivated by the failure of the hitherto conventional Agricultural Research and Development systems (ARD) in Africa. The conventional ARD system assumes linear configuration, where research systems observe farmer problems and independently develop possible research products as solutions. The ARD system assumes transformations would be achieved once the research products are extended to farmers and adopted. The system lacks a feedback mechanism among farmers, researchers and extension service arms. Possibly, the greatest weakness of the conventional approach is that it ignores the non-research components in the whole process (Hawkins *et al.*, 2009). The non-research components include policymakers and private players such as traders, retailers, among others. What has come to be apparent is that availing research products or technologies is but just a necessary condition and not sufficient for the transformation of the agricultural system. Farmers fail to access or afford the new technologies due to a plethora of challenges and many of these are located in the

non-research domain. For example, farmers are poor, they lack cash and have no access to credit, there are thin and fragmented markets, and policy environment may be adverse. Unsurprisingly, the returns to ARD have been very low in sub-Saharan Africa. Integrated Agricultural Research for Development incorporates non-research components in an innovation systems framework (Hawkins *et al.*, 2009). The ultimate aim of IAR4D is to generate innovations rather than mere research products or technologies. Interactions and feedback processes are encouraged through networks, to work around technical, social and institutional constraints. Integrated Agricultural Research for Development engenders changes in institutional and policy environment. For practical implementation the IAR4D uses Innovation Platforms (IPs) as action points. Innovation Platforms are networks of multiple organisations or actors along a commodity value chain. For details on the IAR4D concept refer to Hawkins *et al.* (2009).

## 5 PATHWAY IAR4D IMPROVES MARKET PARTICIPATION AND YIELDS

IAR4D is largely expected to stimulate yields via intensification. It removes barriers to market access for farmers, setting forth the agrarian transformation of increased input use and hence productivity. The IAR4D concept largely attempts to improve market participation via strategies that reduce the transaction cost and ultimately seeks to improve the competitiveness of smallholders in the market. Most of the reductions in transaction costs emanate from the establishment of Innovation Platforms that increase information flows between farmers and other actors in the value chains. For example, the search costs for market information and the associated hidden costs of imperfect knowledge such as risk and uncertainty is reduced as farmers are in constant contact with input- and output-side actors in the chain. Furthermore, IPs may potentially increase trust among the actors and therefore reduce costs associated with price/contract negotiation, monitoring and enforcement. There are also actions of IAR4D that are aimed directly at influencing markets. For example, IAR4D promotes institutional innovations such as collective marketing that reduces transaction costs of dealing with several uncoordinated production units. It promotes the identification and development of potential business opportunities for smallholders and private sector (see Hawkins *et al.*, 2009).

## 6 LINKING FARMERS TO MARKETS IN ZMM

Starting in 2008, the Sub Saharan Africa Challenge Program (SSACP), led by FARA, has been running test trials of the IAR4D concept across sub-Saharan Africa. Three widely differing agro-ecologies in western, eastern and southern

Africa were selected for implementation of IAR4D. In southern Africa, a corridor running from north-eastern Zimbabwe through central Mozambique and southern Malawi (ZMM) was selected.

Innovation Platforms were set up at various levels within the IAR4D sites, from the lower tiers at villages to higher up at district levels. At district level 12 innovation platforms were operationalised, four in each country. The IPs mobilised farmers and other stakeholders such as agribusiness actors, policy makers, and local government, extension and research agents to create networks for collective actions towards agricultural development problems. The process involved brainstorming, identification and prioritisation of constraints, and then crafting of solutions. Some of the solutions demand changes in the institutional structures of market arrangement, credit access, or simple exchange of knowledge and information on production technologies. Examples of implemented solutions in ZMM are: collective marketing, contract farming of horticultural crops, securing maize grain buyers at better prices establishment of learning alliances for natural resource management technologies, among others. Lack of a remunerative market outlet was an issue commonly identified and acted upon across the IPs in ZMM. The poor market access was caused by a combination of poor roads, high transport costs and price risks among others.

This paper aims to identify determinants of market participation by farmers and subsequently estimates the impact market participation induced by IAR4D has on crop yields. The case of maize, the staple and most widely grown crop with an acreage share of more than 40% of smallholder farmers' total cultivated area in southern Africa, is used.

## 7 METHODOLOGY

### 7.1 Data

The study utilises survey data collected by the sub-Saharan Africa Challenge Programme (SSACP) in 2008 and 2010 in the ZMM pilot site (See Fig. 1). A sub-sample of 1 138 farmer households from Zimbabwe (293), Malawi (473) and Mozambique (372) was available for this study. As mentioned earlier, these households are part of the ZMM pilot learning site of the SSACP being run under the auspices of FARA. The SSACP cast the IAR4D trial in a quasi-experimental design. The design involved an experimental district, which received the treatment, and a control district, which did not receive treatment. The districts were stratified on the basis of infrastructural development and agro-climatic potential. Under infrastructural development, factors such as road network, availability of government extension services and number of town centres were considered. The

aim being to ensure that the intervention districts were very closely comparable to the control district. Five villages and 10 villages were selected within the IAR4D and control districts, respectively, for participation. An important feature of this design is that assignment of IAR4D to villages was random. Within the selected villages participating households were also randomly selected. Though in the SSACP design, two types of control farmers were distinguished, the “clean” and “conventional”, in this paper these have been pooled to make one control group. As indicated by FARA (2009), conventional refers to those districts where “conventional” ARD is implemented and “clean”, those districts where there is hardly any ARD implementation. Table 1 summarizes the sample size and distribution by country. For details about the SSACP, refer to FARA (2009).

Table 1: Sample size and distribution

Country	Control	IAR4D	Total
Malawi	295	178	473
Mozambique	231	141	372
Zimbabwe	199	94	293
ZMM	725	413	1,138

**LOCATION OF THE ZIMBABWE/MALAWI/MOZAMBIQUE CORRIDOR PILOT LEARNING SITE**

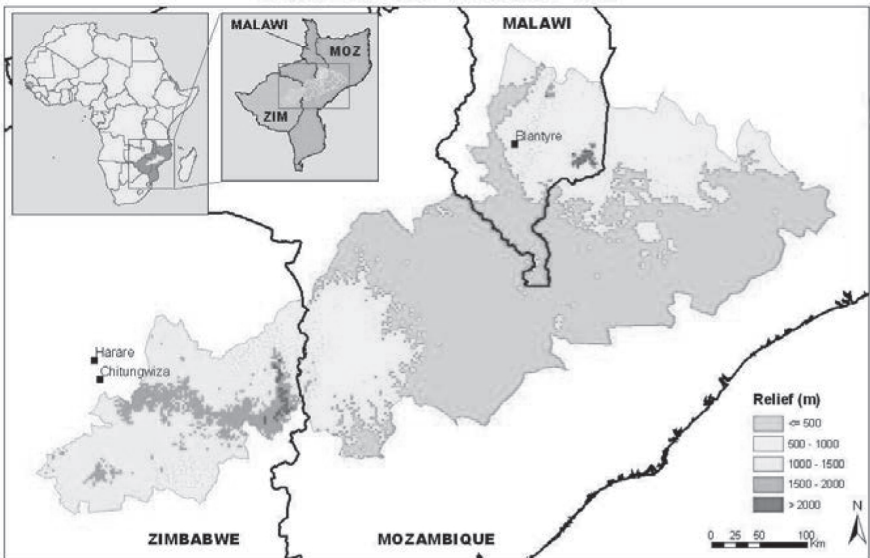


Fig. 1: A map showing the ZMM corridor

## 7.2 Estimating the market participation model

The study adopts a probit model to estimate factors affecting the probability of farmers to participate in maize market as sellers. The variables used in the model are informed by theory and empirical literature (Boughton *et al.*, 2007; Barret *et al.*, 2008). The dependant variable for market participation was binary, designating one for farmers who sold maize, and zero for not selling maize. A dummy variable for IAR4D, with one indicating farmers in IAR4D villages and zero for the control villages, was included among the covariates to verify influence of IAR4D on market participation. Other explanatory variables used include household demographics, household asset endowment and country dummies.

## 7.3 IMPACT ESTIMATION

Any assessment of impact, which requires attribution of specific effects to specific interventions, faces formidable challenges (Ravallion, 2001). Meyer (2002) contends that measurement and attribution of impact on individuals is the most difficult and controversial aspect in the field of social science. One major problem is the impossibility to observe the counterfactual corresponding to any change induced by a treatment or intervention (Cameron and Trivedi, 2005; Imbens and Wooldridge, 2009). This problem makes attribution of the effects difficult because it is necessary to observe the counterfactual in order to assess the impact of the change on any individual population unit. Many disciplines have spawned literature concerned with estimating the causal effects (or impact) of treatments, interventions or programmes (see Heckman and Vytlačil, 2007; Imbens and Wooldridge, 2009). The methods used to assess the impact of an intervention range from simple approaches that naively equate impact with the mean differences in the observed outcomes of treated and untreated individuals to rigorous econometric and statistical approaches, such as the structural econometric modelling approach and the potential outcomes approach.

The potential outcomes approach pioneered by Rubin (1974; 1977) is used in this paper. In contrast to the other approaches, the potential outcome approach pioneered by Rubin is less ambitious in the sense that it focuses on identifying and estimating the causal effects of the primary interventions or treatments of interest. There are usually only a very few limited number of interventions of primary interest in any given impact assessment study, and in most cases there is only one. This narrow focus of the potential outcome approach allows the identification of causal effect of a given intervention without having to identify and estimate the full structural functional relationship and with minimal, credible and more easily defensible statistical independence assumptions between the intervention or treatment variable and the finite number of potential outcomes that obtain for each

value of the treatment variable (Angrist and Imbens, 1991; Abadie, 2003). The potential outcomes approach is the conceptual framework that underlies standard methods for establishing the causal effects of treatments in the experimental sciences. In particular, it underlies the design of agricultural experiments and justifies the statistical procedures used to analyze the data from such experiments.

Suppose that we are interested in the effect of some treatment, in our case, market participation induced by the incentive created by IAR4D, which is represented by the binary variable  $D$ , on its subsequent outcome  $Y$ , such as maize yield, it is of interest how maize yield is affected by market participation. In this case, one would like to know how  $D$  causally affects  $Y$ , that is, how an exogenous variation in  $D$  would change the variable  $Y$ . Since market participation ( $D$ ) is endogenous, a regression of  $Y$  on  $D$  does not uncover a causal (structural) relationship (Markus, 2002).

If we consider a variable  $Z$  – a vector (strengthening of farmer organisations, networking with other partners along the commodity value chain, collective marketing, access to market information.) of incentives created by IAR4D, that affect only  $D$  but not  $Y$ , then an exogenous variation in  $Z$  induces an exogenous variation in  $D$  and thus overcomes the endogeneity of  $D$ . Such a variable  $Z$  is called an instrumental variable and has been exploited in numerous studies to identify the effect of  $D$  on  $Y$  (Angrist and Imbens, 1991; Imbens and Angrist, 1994; Abadie, 2003).

The main advantage of this approach is that it allows the researcher to construct estimators that can be interpreted as the parameters of a well-defined approximation to a treatment response function under functional form misspecification (Abadie, 2003). On the other hand, if required, functional form restrictions and distributional assumptions can be accommodated in the analysis. As in the IV model of Imbens and Angrist (1994) and Angrist *et al.* (1996), identification comes from a binary instrument that induces exogenous selection into treatment for some subset of the population.

Although the focus has been on using instrumental variables for identification of average treatment effects – which in this case is the Local Average Treatment (LATE) – in a population, the conditions required to non-parametrically identify the parameters can be restrictive and the derived identification results fragile (Heckman, 1990). Nevertheless, the estimation of LATE requires imposition of mild restrictions that are satisfied by a wide range of models and circumstances in economic research (Angrist and Imbens, 1991). We do not need to make assumptions about the distribution of response variables, nor do we assume that the treatment effect is constant. As such, in the event that there is no group available for whom the probability of treatment is zero, we can still identify the average treatment effect of interest (LATE). Following the Angrist and Imbens

(1994) approach, we define an instrumental variable  $Z$  to be a variable unrelated to the responses  $Y_0$  and  $Y_1$ , and correlated with the treatment  $D$ . Informally, the role of an instrument is to induce a change in the behaviour of the treated in a way that it will have an effect on the outcome variable. In this article, we use the incentive created by IAR4D through market linkages as the instrument. Market linkage captures all the collective actions and innovations undertaken by IPs, under IAR4D aimed at facilitating farmers to buy inputs and to sell their produce. The market linkage variable is proxied by the randomly assigned IAR4D variable. The market linkage (created by IAR4D) is a relevant instrument because it is correlated with market participation and can only affect maize yield through market participation.

Now let  $Z$  be a binary variable taking the value 1 if a household is exposed to IAR4D and 0 otherwise. The binary variable  $D_z$  represents potential treatment status given  $Z = z$ . Suppose, for example, that  $Z$  is an indicator of market linkage. Then  $D_0 = 0$  and  $D_1 = 1$  for a particular individual means that such an individual would participate in a market if he or she is exposed to IAR4D, but would not do so otherwise. The treatment status indicator variable can be expressed as  $D = Z \cdot D_1 + (1 - Z) \cdot D_0$ . In practice, we observe  $Z$  and  $D$  (and therefore  $D_z$  for individuals with  $Z = z$ ), but we do not observe both potential treatment indicators.

The actual or realised value of the endogenous variable is

$$D = Y(Z) = \begin{cases} D_1 & \text{if } Z = 1 \\ D_0 & \text{if } Z = 0 \end{cases} \tag{1}$$

So we observe the triple  $Z, D = D(Z)$  and  $Y = Y(D(Z))$ .

According to the terminology of Angrist *et al.* (1996), any intervention or treatment partitions the population into four groups defined by the potential treatment indicators  $D_1$  and  $D_0$ . Compliers are those who have

$$D_1 > D_0 \text{ (or equivalently, } D_0 = 0 \text{ and } D_1 = 1 \text{). Likewise, always takers are defined by } D_1 = D_0 = 1 \text{ and never takers by } D_1 = D_0 = 0 \text{.}$$

Finally, defiers are defined by  $D_1 < D_0$  (or  $D_0 = 1$  and  $D_1 = 0$ )  $D_1 < D_0$  (or  $D_0 = 1$  and  $D_1 = 0$ ). Notice that since only one of the potential indicators  $(D_0, D_1)D_0, D_1$  is observed, we cannot identify which one of these four groups any particular individual belongs to.

Now, if we assume that  $Z$  is independent of the potential outcomes  $D_i$ ,  $Y_i$  and  $Y_0$  (i.e. assumption similar to the assumption  $Z$  is random in the population), then the mean impact of market participation on the sub-population of compliers (i.e. the LATE) can be estimated as follows according to Imbens and Angrist (1994) and Lee (2005):

$$E(y_1 - y_0 | d_1 = 1) = \frac{E(y | z = 1) - E(y | z = 0)}{E(d | z = 1) - E(d | z = 0)} \quad (2)$$

The right hand side of equation (2) can be estimated by its sample analogue:

$$\left( \frac{\sum_{i=1}^n y_i z_i}{\sum_{i=1}^n z_i} - \frac{\sum_{i=1}^n y_i (1 - z_i)}{\sum_{i=1}^n (1 - z_i)} \right) \times \left( \frac{\sum_{i=1}^n d_i z_i}{\sum_{i=1}^n z_i} - \frac{\sum_{i=1}^n d_i (1 - z_i)}{\sum_{i=1}^n (1 - z_i)} \right)^{-1} \quad (3)$$

which is the *Wald* estimator.

The assumption that  $Z$  is random in the population is unfeasible as it is the case with IAR4D because even if an individual farmer lives in an IAR4D village where market linkage was facilitated, their market participation can be influenced by a number of socio-economic (observed and unobserved) and institutional variables (Angrist and Imbens, 1991). We use Abadie's (2003) LATE estimator, which only requires the conditional independence assumption. That is, the instrument  $Z$  is independent of the potential outcomes  $D_i$ ,  $Y_i$  and  $Y_0$  conditional on a vector of covariates  $x$  that determine the observed outcome  $Y$ . With these assumptions, the following results can be shown to hold for the conditional mean outcome response function for potential beneficiaries  $f(x, d) \equiv E(y | x, d; d_i=1)$  and any function  $g$  of  $(y, x, d)$  (see, Abadie, 2003; Lee 2005):

$$f(x, 1) - f(x, 0) = E(y_1 - y_0 | x, d_1 = 1) \quad (4)$$

$$E(g(y, d, x) | d_1 = 1) = \frac{1}{p(d_1 = 1)} E(\kappa \cdot g(y, d, x)) \quad (5)$$

Where  $\kappa = 1 - \frac{z}{p(z=1|x)} (1 - d)$   $\kappa = 1 - \frac{z}{p(z=1|x)} (1 - d)$  is a weight function that takes the value 1 for a potential beneficiary and a negative value otherwise. The function  $f(x, d)$  is known as the *local average response function*

(LARF) by Abadie (2003). Estimation proceeds by a parameterization of the LARF  $f(\theta, x, d) = E(y|x, d; d_1 = 1)$  using multiple regression methods. The actual estimation of LARF was done in STATA 11.2 using the STATA add-on impact command developed by Diagne & Demont (2007). Our decision to estimate LARF is based on the assumption that impact is not homogenous across the population.

## 8 RESULTS

### 8.1 Determinants of market participation

Table 2 gives definition and summary statistics of the variables used in the market participation model. Notably, a small proportion of farmers participate in the maize market as sellers; only 0.36. Most of the households (83%) are male headed with an average family size of about 6 people. Households are typically middle aged (45) with relatively low education levels: only about 38 % attained primary education and beyond.

Table 2: summary of variables used in the probit model

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
mrkpart	Sold maize(1=yes 0=no)	1040	0.36	0.48	0	1
headage	Age of household head (yrs)	1113	45.89	15.61	3	92
gender	Gender of household head (1= male 0= female)	1135	0.83	0.38	0	1
hhsize	Household size	1128	6.17	3.26	0	28
Dedu_pry	Education level of HH (1= primary plus 0 = less than primary)	1160	0.38	0.48	0	1
asset_indx	Principal component analysis derived household asset ownership index	1156.00	0.00	1.75	-1.42	8.57
IAR4D	Received IAR4D treatment(1= yes 0=no)	1157	0.36	0.48	0	1
DcntryMw	Country dummy 1=Malawi	1160	0.41	0.49	0	1
DcntryZw	County dummy 1=Zimbabwe	1160	0.25	0.43	0	1

### 8.2 Estimated maize marketing model

Table 3 summarises results for the maize market participation model estimated using the probit specification. As indicated by the F test, overall the model is

valid in explaining probability of farmers participating in maize market as sellers. Consistent with expectations, older household were less likely to participate in the maize market. Older households are more likely stooped towards subsistence production than the younger households because of cultural reasons. Households with higher education levels were more likely to sell maize than those with less education. Again education may alter people’s tastes and preferences in consumption of goods, and may also improve farmers’ ability to access market information and general crop productivity. Asset endowment level positively and significantly influences farmers’ probability to participate in maize market. This finding lends support to calls for increasing farmers’ private assets in order to stimulate the ability to participate in markets (Barret, 2008). A remarkable finding is that exposure to IAR4D positively and significantly increases the likelihood of farmers participating in the maize market. In addition to linking farmers to markets, a number of actions were applied in IAR4D including improved access to research, capacitating and strengthening of farmer organisations and their interaction and networking with other stakeholder or actors along the commodity value chains. The finding supports the proposition that IAR4D could have removed constraints (usually embodied in transaction costs) that were preventing some farmers from accessing and participating in maize marketing as sellers. The country dummy variables indicate that farmers in Malawi and Zimbabwe were less likely to participate as maize sellers than those in Mozambique.

Table 3: Estimated market participation model

Variable	Coeff.	Std. Err.	Z	P-value
Headage***	-0.009	0.003	-3.14	0.0020
Gender	-0.068	0.121	-0.56	0.5750
Hhsize	0.013	0.014	0.93	0.3520
Dedu_pry**	0.228	0.099	2.31	0.0210
asset_indx***	0.107	0.030	3.62	0.0000
IAR4D***	0.414	0.087	4.75	0.0000
DcntryMw***	-0.494	0.107	-4.62	0.0000
DcntryZw***	-0.482	0.143	-3.37	0.0010
_cons	0.109	0.226	0.48	0.6300
Number of observations	993			
Prob > chi2	0.0000			
Log likelihood	-603.8019			

Notes: Asterisks indicate statistical significance at 1% (\*\*\*); 5%(\*\*) and 10% (\*)

### 8.3 Mean maize yields obtained

Table 4 summaries the maize yields obtained by farmers in ZMM by treatment. The average maize yields in the region are relatively low, ranging from about 700 to 1500 kg $ha^{-1}$ . There are no significant differences in the mean yields between IAR4D and the control sites in all countries except in Malawi where higher yields were observed for IAR4D. There were very high variations in the yields as shown by the high standard deviations and high coefficient of variation (CV), which for most sites is above 60%.

Table 4: Mean maize yields 2010 planting season (kg $ha^{-1}$ )

Country	N	Mean	Std. Dev	CV(%)	Min	Max
Malawi						
Control	273	905.89a	721.84	79.68	2.65	5714.29
IAR4D	162	1115.42b	849.20	76.13	12.50	4081.63
Mozambique						
Control	176	696.98a	741.08	106.33	3.33	5000.00
IAR4D	110	896.66a	1007.28	112.34	2.57	5000.00
Zimbabwe						
Control	197	1470.65a	897.58	61.03	24.99	3924.65
IAR4D	90	1326.00a	808.76	60.99	1.75	3928.57
ZMM						
Control	658	1014.39a	837.28	82.54	2.65	5714.29
IAR4D	362	1101.30a	902.59	81.96	1.75	5000.00

Notes:

Different superscripted letters denote statistically significant ( $p < 0.05$ ) difference between sites with a T-tests.

### 8.4 Estimated impact

The results of the impact of IAR4D on maize yield, computed as Local Average Treatment Effect (LATE) are presented in Table 5. LATE captures effects on maize yields due to change in market participation induced by the exogenous change in the instrument, IAR4D. It is only identified for the sub-population of compliers,

in other words those farmers whose market participation behaviour would have changed due to IAR4D exposure.

Table 5: Estimated Local Average Treatment Effect (LATE)

Country	Coeff.	Z	P-value
Malawi (n= 382)	107.46 (38.06)	2.82	0.005***
Mozambique (n=242)	132.84(45.25)	2.94	0.003***
Zimbabwe (n=276)	149.26(57.31)	2.60	0.009***
ZMM (n=900)	127.10(47.48)	2.68	0.007***

Notes:

In parenthesis are the standard errors.

Asterisks indicate statistical significance at 1% (\*\*\*); 5%(\*\*) and 10% (\*)

In all regressions used the following variables were used as covariates: age, gender, education level and asset endowment level. A dummy variable indicating implementation of IAR4D or not was used as the instrument in all regressions.

The LATE is positive and highly significant in all countries. Zimbabwe has the highest magnitude of LATE, with IAR4D inducing a yield increase of 149 kg $ha^{-1}$ . Similarly the response in Mozambique is high with a LATE value of about 133 kg $ha^{-1}$ . This means that in all countries, limited access to remunerative markets constrained farmer productivity. Once this constraint was removed farmers were able to respond and increase their maize productivity. In Zimbabwe, where the impact was highest, this can be easily explained. Most farmers in the country were cash constrained due to a protracted period of economic instability. With practically no credit facilities, farmers could only earn cash income from the sale of their produce. Due to the withdrawal of government subsidies and the active role in the maize market, most farmers had limited outlets for their maize. In addition most farmers were reluctant to take their maize to the national maize marketing board because of delays in payment. As a result of all these factors farmers have difficulties raising cash to purchase inputs such as seeds and fertilizers for the next season, or would get it late into the season – all this reduced maize yields. Market solutions generated by IPs include securing of better maize buyers who paid cash on delivery, such as brewery and milling companies located away in urban areas. To reduce cost farmers collectively marketed their grain, sharing the cost of transporting. Some also used the same hired trucks to bring back fertilisers and seeds. In Malawi and Mozambique, similar innovations were applied to improve farmer linkages. The success of such innovations requires high levels of trust and cooperation within farmer communities.

## 9 CONCLUSION

The study has explored the issue of market participation, which is considered a key ingredient for intensification and commercialisation, hence growth of smallholder farmers' agriculture. It has quantified factors influencing the probability of farmers to enter the maize market as sellers. The results lend support to the private asset hypothesis of market participation (Codet *et al.*, 2006; Barret *et al.*, 2008), which put private asset accumulation as a prerequisite for smallholder's escape from subsistence production. It has also verified the efficacy of an innovations-driven strategy, IAR4D, in stimulating crop intensification (maize yields). The study shows that farmers in IAR4D villages had higher probability to participate in the maize market than those in the control villages. Viewed as a policy mix, it implies IAR4D was a relevant leverage point in reducing transaction costs, creating market linkage for farmers. This proposition is further supported by the positive local average treatment effect (LATE), obtained for IAR4D. The LATE showed that in all the countries in the ZMM pilot site, exogenous influences of IAR4D on market participation increased maize yields by as much as about 150 kg $ha^{-1}$ . This finding, which was robust in all countries, gives credence to the proposition that innovation systems approaches are more effective than the conventional ARD in solving farmers' development constraints. Probably the advantage of IAR4D stems from the fact that development initiatives are more endogenously driven than under conventional ARD. Therefore capacitating farmers' organisations to better mobilise and interact with relevant development stakeholders may foster faster agricultural growth.

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