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Household- and Market-Level Impacts of Value Chain Interventions

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Notices

Abstract

Agriculture, in Mozambique, is characterized by production systems that are based predominantly on rainfed conditions and on low use of yield enhancing agricultural inputs. The Innovation for Agribusiness (InovAgro) interventions were designed to increase incomes for poor smallholder farmers in northern Mozambique. Using a market systems development (MSD) approach, the InovAgro implemented value chain interventions (VCIs) to promote the development of inclusive and sustainable market systems such that the interventions impacts were felt long beyond the project's lifespan. This study evaluated the impact of the InovAgro VCIs on households (considering a range of outcomes related to farmers' use of yield-enhancing agricultural inputs, access to information on agricultural input and output markets, maize productivity, women and youth empowerment, and household welfare. The study also explored InovAgro VCIs outcome indicators to evaluate market-level effects, namely: systemic (long-term), sustainability, large-scale (spillover or multiplier), and unintended (positive or negative) effects. We conducted a modified randomized controlled trial (RCT) using a spatial identification strategy to classify beneficiary and nonbeneficiary households; this was supplemented with three waves of household-level panel data (2015, 2017 and 2019). We also complemented key informant interviews (KIIs) and focus group discussions (FGDs) with local stakeholders, including market actors and local authorities, with two rounds of geospatial data (2017 and 2019). Our findings show that InovAgro VCIs had a positive and significant impact on beneficiaries' use of yield-boosting agricultural inputs and on access to information on agricultural input and output markets. Our analysis also reveals that the InovAgro VCIs boosted maize productivity and increased the marketable surplus of maize among beneficiaries. InovAgro VCIs were seen to have unintended negative effects on access to, and control over, land by women and youth in the short term; in the longer term; however, these adverse effects were reversed and became positive and significant. Our findings also show that simultaneous exposure to all three VCIs under the complete package had a positive impact on overall household welfare. We also find evidence in support of the InovAgro VCIs having a systemic market effect and producing more sustainable long-term usage of yield-boosting agricultural practices than non-InovAgro VCIs. Our results elucidate that InovAgro VCIs benefitted large numbers of smallholder farmers beyond the project's direct sphere of influence and targeted beneficiaries. The key takeaway message from our findings is that a more intense VCI, that is, delivery of the complete package, appears to be necessary to achieve a long-term positive effect on overall household welfare.

Keywords: InovAgro, market system development, impact evaluation, value chain, Mozambique

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1 Introduction

Data from the nationally representative Household Budget Surveys, referred to as IOF, 2008 and 2015 show that poverty incidence in Mozambique declined by 5.6 percent, dropping from 51.7 percent in 2008 to 46.1 percent in 2015 (INE, 2008; INE, 2015). Poverty incidence remains widespread, however, with a considerably higher incidence in rural areas (50.1 percent) than in urban areas (37.4 percent). The same data reveal that over the same period, poverty prevalence declined considerably more in urban areas (decreasing by 9.4 percent, from 46.8 percent to 37.4 percent) than in rural areas (where there was a decrease of only 3.7 percent, from 53.8 percent to 50.1 percent). This difference, combined with the fact that 66.6 percent of the population lives in rural areas, makes poverty a predominantly rural phenomenon. Poverty incidence is also more pronounced in northern (55.1 percent) and central Mozambique (46.2 percent) than in southern Mozambique (32.8 percent) (INE, 2015).

Data from IOF 2020 reveal that agriculture ranks first in terms of the proportion of smallholder farmers who generate income from it: 65.9 percent of the household heads have agriculture as their main income-generating activity with substantially higher proportion in rural than urban areas (82.5 percent versus 31.6 percent) (INE, 2020). Agriculture, however, is characterized by production systems that are based predominantly on rainfed conditions and on low use of yield-enhancing agricultural inputs. According to data from the nationally representative Integrated Agricultural Survey, referred to as IAI, 2020, 10.9 percent of smallholder farmers used improved seed in any grown crop, 5.1 percent used fertilizer, 3.5 percent used irrigation, 1.4 percent used pesticide, and 0.5 percent used herbicide (MADER, 2020). This low usage of yield-enhancing agricultural inputs leads to low agricultural production and productivity. Dorosh and Thurlow (2018), on the other hand, reveal that among the economic sectors, agriculture has the largest poverty elasticity estimated at -2.6 percent, which is more than triple of that of the other sectors. This suggests that agriculture has the largest potential for reducing poverty.

Against this backdrop, the Innovation for Agribusiness (InovAgro) interventions were designed to increase incomes for poor smallholder farmers in northern Mozambique. The InovAgro value chain interventions (VCIs) were designed to primarily promote the development of inclusive and sustainable market systems such that their impacts are felt long beyond the project's lifespan. (Altenburg, 2007; Donovan et al., 2015; Weyori et al., 2018). This is known as the market systems development (MSD) approach (Osorio-Cortes and Lundy, 2018).

In terms of coverage of the InovAgro interventions, this study encompassed four dimensions. First, InovAgro had four phased interventions areas: (1) access to agricultural inputs specifically certified seeds, (2) output marketing mainly through commodity aggregator traders (CATs), (3) smallholder farmers' access to finance and (4) smallholder farmers' land tenure and economic security. However, this study evaluated only one of the InovAgro's intervention areas: access to agricultural inputs (certified seed). Moreover, the study did not cover all InovAgro's interventions in the access-to-agricultural-inputs intervention area but focused on agricultural input interventions through three channels (agrodealers, lead farmers, and demonstration plots), leaving out other intervention modalities in this intervention area such as broader interventions in the seed sector at national level where several seed companies benefited. Second, the study covered 2 out of 11 InovAgro-targeted districts: Alto Molocue and Molumbo, both in northern Zambezia province. Third, although InovAgro project lasted 11 years spanning 2011 through 2021, this study assessed InovAgro agricultural input interventions that began implementation in early 2016 and continued until at least 2019 in both Alto Molocue and Molumbo. Fourth, although InovAgro interventions targeted five high-potential value chain crops (maize, pigeon peas, soya beans, sesame, and groundnuts), this study assessed the InovAgro impact on three value chains, namely maize, pigeon peas and soya beans.

Several studies have employed randomized controlled trials (RCTs) to examine the causal relationship between information and communication, extension services and technology adoption in sub-Saharan Africa (SSA) (see Van Campenhout, 2017; Kondylis et al., 2017; Benyishay and Mobarak, 2019; Van Campenhout et al., 2020; Yitayew et al., 2021). In Ethiopia, for example, Yitayew et al. (2021) found that introducing demonstration trials and field days at the same time as improving development agents' facilitation and communication capacity significantly increased the adoption of improved wheat varieties. Van Campenhout et al. (2020) similarly found that improved information and communication technologies increased maize yield by about 10.5 percent relative to a control group that did not receive audiovisual messages conveying agricultural information.

We followed a similar approach, but a modified RCT was conducted using a spatial identification strategy to classify beneficiary and nonbeneficiary households to evaluate the impact of the InovAgro VCIs. This study investigated the household-level impacts of one intervention (certified seed supply) and the three modalities used to reach smallholder farmers (agrodealers, lead farmers, and demonstration plots) using a fixed effects (FEs) technique on a matched sample. The impact evaluation study employed three waves of household-level panel data (*wave one*: InovAgro Impact Evaluation Survey [IIES] conducted in 2015 [baseline study], hereafter referred to as IIES 2015; *wave two*: IIES 2017 conducted in 2017 [midline survey]; and *wave three*: IIES 2019 conducted in 2019 [endline survey]). All three waves of the IIES covered two districts (Alto Molocue and Molumbo). We also evaluated the impact of InvoAgro VCIs on market systems (macro-level) effects, namely: systemic (long-term), sustainability, large-scale (spillover or multiplier), and unintended (positive or negative) effects.

By examining the impact of InovAgro VCIs, which applied a MSD approach, our study contributes a new empirical evidence on the causal effects of the InovAgro VCIs, for which there is an abundance of opinion pieces but still relatively scant empirical evidence on actual impacts of MSD VCIs. The findings from our study provide useful insights to policymakers and donors for the development of better policies for addressing agricultural productivity challenges confronting smallholder farmers in the developing world. Our results show that the InovAgro VCIs had an overall positive and significant impact on farmers' use of yield-enhancing farming practices, access to information on agricultural input and output markets whether they were exposed to a single VCI or all three VCIs (the "complete package"). Our analysis also showed that the InovAgro VCIs boosted maize productivity, increased their likelihood of selling maize produce in an agricultural output market, and led to an increased marketable surplus. The InovAgro VCIs were also found to have unintended negative effects on access to, and control over, land by women and youth in the short term; in the longer term, however, these adverse effects were seen to have been reversed and to become positive and significant. With regard to overall household welfare, we found that exposure to the complete package of VCIs had a positive effect. On the market systems (macro-level) effects, we found evidence in support of the InovAgro VCIs having a systemic market effect and producing more sustainable long-term usage of yield-boosting agricultural practices than non-InvoAgro VCIs. Our results provide evidence that InovAgro VCIs benefited large numbers of smallholder farmers beyond the project's direct sphere of influence and targeted beneficiaries.

The remainder of this paper is organized as follows. Section 2 provides brief background information on the InovAgro interventions and describes the project's theory of change. Section 3 lays out the impact evaluation research design; it outlines the challenges in evaluating the impacts of MSD programs, presents the data used, and gives a brief description of the sampled households. Section 4 presents the empirical and identification strategies, Section 5 presents key results, and the final section presents a summary and offers conclusions.

2 Theory of Change of the InovAgro Project

The overall objective of the InovAgro project was to increase income and improve economic security for poor male and female smallholder farmers in northern Mozambique.[1] It aimed to do so through improving agricultural productivity and developing high-potential value chains. InovAgro applied a MSD intervention approach by implementing VCIs to stimulate the inclusion of the economically active poor farmers in productive agricultural value chains. According to Tschumi and Hagan (2008), the MSD approach examines both input and output market systems to see what is working and what is not. It then identifies the constraints to well-functioning market systems, which can include, for example, inadequacies in infrastructure or deficiencies in the rules – both formal and informal – that regulate the market system. Value proposition – proving the net benefits of a product – leads naturally to enhanced private investment in smallholder farmers' upgrades. Small-scale farmers can use such profit-seeking investments to generate more product sales, increase their client base, and build their market participation. In the process, private actors become more willing to collaborate in programs to scale up outreach and sustainability. Increasing the effectiveness of market systems can in this way lead to greater outreach and a more sustainable impact.

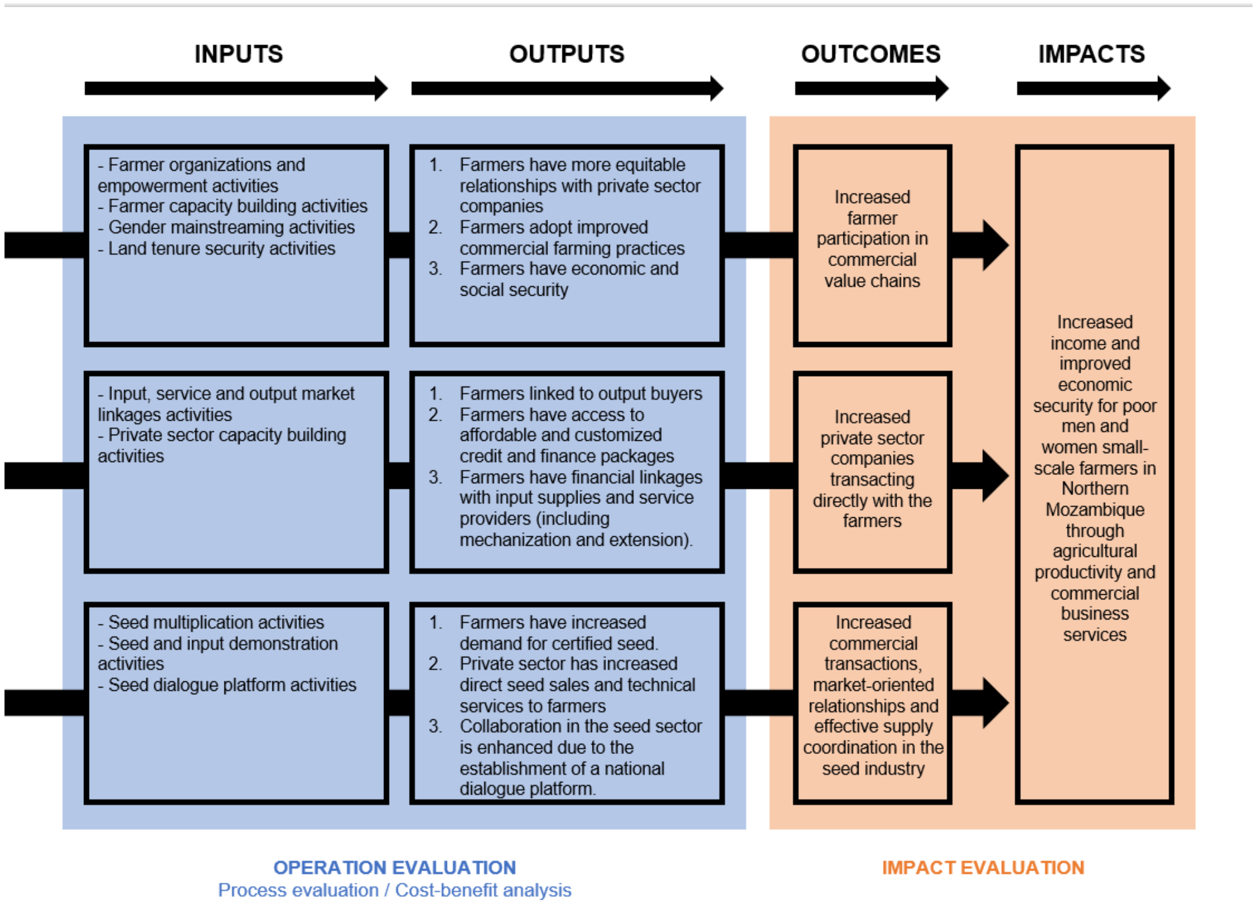
The InovAgro project had a carefully articulated theory of change, which is illustrated in Figure 1. This figure outlines three major InovAgro outcomes: (1) increased participation by smallholder farmers in commercial value chains and a resulting enhanced competitiveness; (2) increased direct transactions between private sector companies and smallholder farmers; and (3) increased commercial transactions, market-oriented relationships, and effective supply coordination in the seed industry. These outcomes were to be achieved through the implementation

[1] InovAgro project implemented VCIs in 11 districts from 3 provinces (6 districts in Zambezia province, 3 in Nampula province and 2 in Cabo Delgado province). Administratively, Zambezia province belongs to the central region, while Nampula and Cabo Delgado belong to the northern region. However, consistent with other authors, we classify Zambezia as northern Mozambique. This is because Zambezia's agroecological conditions and cultural habits, especially in northern Zambezia where all 6 InovAgro target districts are located, are more like the northern region than the central region. Furthermore, surplus agricultural production from northern Zambezia to a large extent feeds into the Nacala corridor in the northern region, given their proximity.

of several InovAgro activities, primarily field days, extension services, and capacity building of local agrodealers. These activities served as a foundation for stimulating a crowding-in of other market actors, leading to the gradual build-up of local market system to provide the full range of services needed. The project's private-sector-led extension intervention strategy and organized field days was the main vehicles for improving farmers' production capacity. To provide greater extension service delivery to smallholder farmers, at district level, InovAgro partnered primarily with the local government entities referred to as District Services for Economic Activities (SDAE).

Providing digital scales, brand and price posters, and record-keeping training to agricultural output buyers was another area where the InovAgro interventions to promote agricultural output purchases from smallholder farmers. The InovAgro interventions also sought to help community aggregators to properly package their agricultural output as per the seed company brand, thus allowing the end-buyer to trace the source of the crop and its wholesale buyer. Finally, in addition to the above strategies, the InovAgro interventions also added an access-to-finance "economic security strategy" component to enable farmers to achieve access to the financial resources needed for inputs and services procurement (Cole and Fernando, 2016; Tomich et al., 2019). This strategy has involved commercial bank linkages and savings groups (Karlan et al., 2014; Bold et al., 2017; Westermann et al., 2018).

Figure 1 InovAgro project theory of change



Source: Modified from Development Alternative Initiatives (DAI) (2013).

Increasing the number of companies selling inputs directly to smallholder farmers was one of the interventions' primary strategies for creating market linkages between agricultural output buyers, input suppliers, and smallholder farmers. Another aspect of InovAgro's seed market strategy was facilitating market access for a growing number of private sector seed suppliers through the establishment of a commercial distribution network. In the project areas, InovAgro trained seed suppliers to work with agrodealers in retailing certified seeds to local smallholder farmers. Technicians from seed companies worked to create demand among smallholder farmers for certified seeds. They did so by introducing, marketing, and promoting an assortment of seed products and by developing a commercial seed distribution network such that smallholder farmers have better access to certified seeds (Vanloqueren and Baret, 2009; Cole and Fernando, 2016; Tomich et al., 2019).

3 Experimental Design and Challenges in Impact Evaluation of MSD

3.1 Experimental design

In the two studied districts (Alto Molocue and Molumbo), eight communities were randomly selected to be the focus areas (treatment communities) for interventions implementation (four from each district); eight other communities (also four from each district) were identified as interventions nonbeneficiaries (control communities). Randomly assigning households to various treatment arms (treatment communities) was not possible in the context of the InovAgro VCIs. This was due to three main challenges: (1) ethical issues involved with the exclusion of households allocated to a control group; (2) the MSD (systemic) approach adopted by the InovAgro VCIs was one that supported private companies in adopting new approaches to reach more clients; the intervention modality itself thus made it impossible to have strict exclusion criteria to avoid contamination; in other words, it was extremely hard to isolate treatment activities such that they did not also affect the control groups; and (3) the adaptive nature of the MSD approach, which is highly responsive to supply and demand forces, made it difficult to randomize treatment exposure to the interventions; this was evident during the interventions monitoring phase, two years after the InovAgro II launch in 2014, in that certain of the units selected for treatment failed to receive the treatment or did not receive it in the fashion that was originally intended by the intervention.

The implementing agency instead selected four communities in each studied district for InovAgro VCIs. All selected treatment communities were located within a single administrative area within each district. To limit spillover effects, the control communities were selected from comparable localities – as defined by the implementing agency – in a different administrative area from where the treatment communities were located. The household listing exercise in both treatment and control areas secured information regarding age and gender of household head and about the household's soya beans and/or pigeon peas production. This listing information was used to select the final set of control communities, based on the extent of soya beans and/or pigeon peas cultivation. The communities and the corresponding sample distribution are summarized in Table 1 below.

Table 1 Study area and sample size

District	Administrative post	Community	2015 N	2015 %	2017 N	2017 %	2019 N	2019 %
Molumbo	**Treatment** Molumbo Sede	Benesse	117	6.2	114	6.5	111	6.4
		Macolocotxo	100	5.3	89	5.1	88	5.1
		Mugoliua	120	6.4	105	6.0	103	5.9
		Nandie	108	5.7	97	5.6	96	5.5
	Control Corromana Sede	Bediua	96	5.1	78	4.5	78	4.5
		Corromana Sede	119	6.3	107	6.1	107	6.2
		Impindula Sede	121	6.4	109	6.2	109	6.3
		Mucoco	125	6.6	116	6.6	115	6.6
Alto Molócue	**Treatment** Nauela	Mohiua	124	6.6	123	7.0	123	7.1
		Namilepe	120	6.4	114	6.5	112	6.5
		Carmano	123	6.5	123	7.0	123	7.1
		Caperula	125	6.6	124	7.1	124	7.2
	Control Alto Molócue Sede	Murico	119	6.3	116	6.6	113	6.5
		Napalaca	122	6.5	108	6.2	108	6.2
		Lugela	125	6.6	124	7.1	123	7.1
		Inrule	122	6.5	102	5.8	100	5.8
Total			**1,886**	**100**	**1,749**	**100**	**1,733**	**100**

Source: Authors' calculation using IIES 2015, IIES 2017, and IIES 2019.

Note: N stands for number of observations.

Power calculations during the planning stage of the research design – which were based on the more demanding methodology of an RCT rather than on the quasi-experimental approach ultimately pursued – indicated that about 2,000 households were needed, which is the approximate number generated when adjusting for design effect and attrition rate. As evidenced from the sample size in Table 1, a total of 1,886 households were interviewed during the IIES 2015 (baseline survey); of these, 937 were from treatment communities and 949 were from control communities. Due to attrition, during the IIES 2017 (midline survey) the number of interviewed households dropped to 1,749 (889 from treatment communities and 860 from control communities); during the IIES 2019 (endline survey), the sample size dropped further to 1,733 (880 from treatment communities and 853 from control communities). Attrition rates stood at 8.1 percent between IIES 2015 and IIES 2019, which is a quite small loss for a four-year period. We also examined this attrition and found no differences between treatment and control groups.

3.2 Challenges faced and mitigative measures taken

In this study, following Maestre et al (2017), VCIs refer to development activities, investments and innovations – usually focusing on business processes – along the value chain aimed at achieving certain economic or social objectives. We assessed InovAgro VCIs on agricultural inputs (certified seeds) delivered through three modalities: agrodealers, lead farmers, and demonstration plots. InovAgro interventions facilitated the linkages in the input distribution network by supporting private seed companies to strengthen the capacities of agrodealers and lead farmers to create smallholder farmers' demand for certified seeds. InovAgro convinced international private seed companies to start operations in InovAgro target districts (including Alto Molocue and Molumbo) and partnered with them to initiate activities with local agrodealers to expand these private seed companies' reach into rural areas, expanding private seed companies' distribution networks and consequently making certified seeds available to smallholder farmers in their communities.

As a result of the partnership with InovAgro, private seed companies delivered technical training to local agrodealers in basic business management concepts, entrepreneurship, leadership and communication emphasizing the use of small packs to respond to smallholder farmers' reduced purchasing power as well as certified seeds knowledge to explain to buyers how to use certified seeds bought from local agrodealers' shops. Furthermore, to create smallholder farmers' demand for certified seeds, these private seed companies in partnership with InovAgro hired field extension workers who organized demonstrations plots and field days to build awareness of the certified seeds' benefits in terms of yield and profitability gains.[2] On the other hand, InovAgro collaborated with private seed companies to train lead farmers in good agronomic practices to deliver demonstration plots and small local field days to fellow smallholder farmers, further strengthening smallholder farmers' demand for certified seeds.[3] For the purpose of this study, demonstration plots and field days delivered by lead farmers are referred to as a lead farmer modality; while those delivered by extension workers hired by private seed companies are referred to as a demonstration plot modality.

We encountered a major methodological challenge with using a geographic boundary (community boundary) to define treatment. One of the possible limitations, even in "gold-standard" randomized designs, is that the units selected for treatment may not, in fact, receive the treatment, or may not receive it in the fashion that was intended by the intervention. Conducting standard analysis without accounting for this potential discrepancy between

2 The number of demonstration plots (field days) organized by private seed companies increased from 7 (6) in 2015 to 94 (38) in 2016 to 299 (84) in 2017. As a result of this rapidly growing number of demonstration plots and field days, private seed companies' sales of assorted certified seeds to smallholder farmers jumped from 0 metric tons (MT) in 2015 to 111.3 MT in 2016 to 273.8 MT in 2017.

3 Lead farmers are influential local farmers who can promote changes in not only farming practices but also social and cultural norms. They are also referred to as "trend setters".

intention-to-treat and actual treatment could lead to underestimation of the impact of the intervention. This was also the case in our context, given that a household that was presumably residing in a control community (hence considered to be a control household) could be located in close proximity to an InovAgro-facilitated intervention in one of the designated treatment communities; the presumed control household would thus be fairly exposed to the intervention.

Such scenarios became more apparent during the scoping field visits that were conducted after the baseline survey to monitor the compliance of the interventions' implementation with the agreed study design of randomization at community level. Hence, we employed methods from the body of quasi-experimental approaches. This was mainly to account for any potential discrepancies in observable and unobservable characteristics between treatment and control groups, each of which addresses selection bias in different ways and has different strengths and limitations, with none being unambiguously superior in all circumstances (Ravallion, 2007; Angrist and Pischke, 2008).

We conducted careful discussions with the implementing agency about the importance of adhering to a predetermined study design. Even with these measures in place, however, it appeared to be impossible to completely rule out all potential discrepancies between the treatment that was specified in the study's design and actual treatment because in some cases it was hard to obtain full field information about the actual features of the treatment. To account for such discrepancies and potential bias, we supplemented the three-wave household-level panel dataset of intended beneficiaries and nonbeneficiaries with "intention-to-treat" data as an instrument for treatment (Abadie et al., 2002; Ashraf et al., 2009; Ravallion, 2009; Duflo et al., 2011; Bulte et al., 2014). Hence, for IIES 2017 and IIES 2019, we conducted a unique georeferenced census of every VCI that was operational in the 16 studied communities; we also set a median terrain adjusted distance to these VCIs (60 minutes) as a cutoff for defining the catchment area of the treatment.

The resulting spatial database on the location of these VCIs also included further data on type of VCIs (MSD approach versus direct service delivery approach); years of establishment; and type of service provision (namely agrodealers, lead farmers, and/or demonstration plots). As shown in Table 2, the spatial data collection covered the Global Positioning System (GPS) coordinates of 185 operational VCIs in Molumbo (72) and Alto Molocue (113). These data enabled us to use "physical accessibility" as an identification strategy for defining comparable treatment and control households.

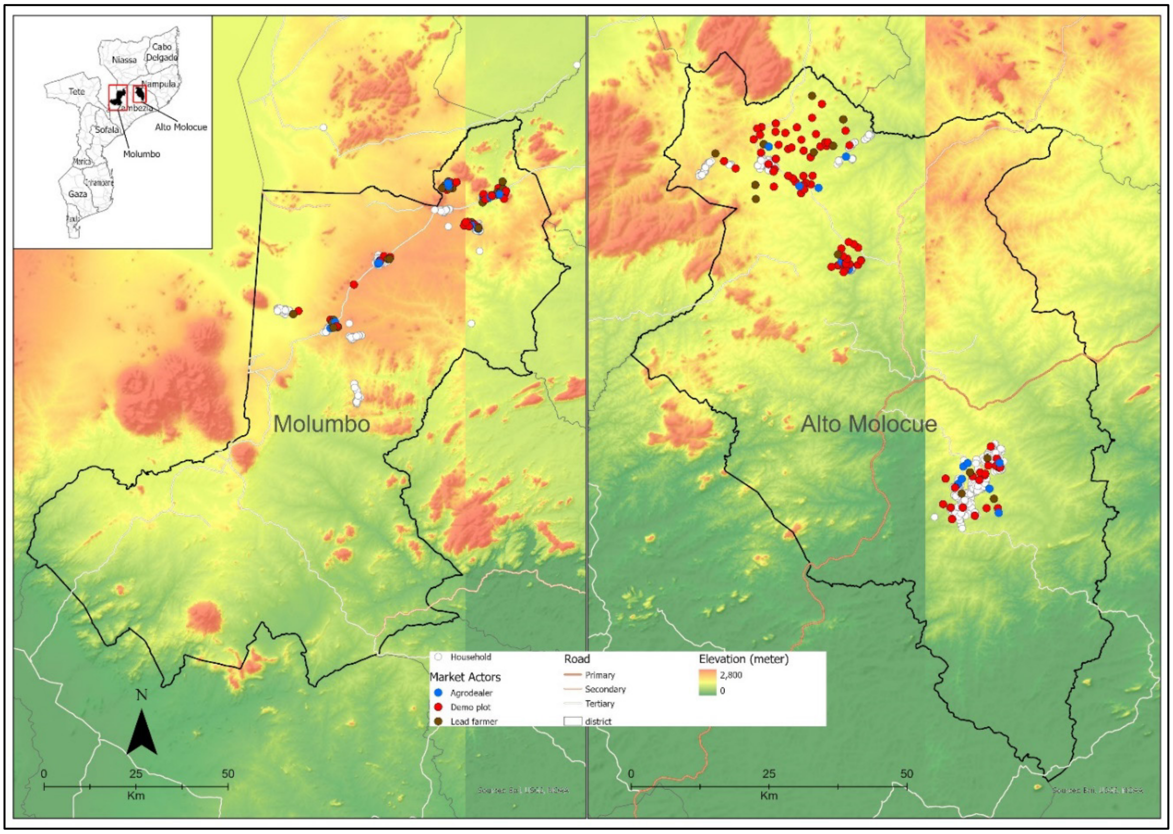
Table 2 Distribution of value chain interventions by study district

	District		
Value chain intervention	Alto Molocue	Molumbo	**Total**
Agrodealer	14	17	**31**
Lead farmer	14	24	**38**
Demonstration plot	85	31	**116**
Total	**113**	**72**	**185**

Source: Authors' calculations using InovAgro geospatial data (2019)

To quantitatively measure the level of physical accessibility, various studies employ distance and time-model approaches (Cairns, 2012; Schmidt et al., 2020). It is well argued that in a diverse geographic situation, traditional straight-line distance measures tend to overlook local topographic variations and impedances (Kosmidou-Bradley and Blankespoor, 2019; Banick and Kawasoe, 2019). Accessibility measures that employ travel-time-based models built in Geographic Information System (GIS) environments integrate on-road and off-road geospatial layers that include roads, land cover, rivers, and digital elevation grids (Uchida and Nelson, 2010; Chamberlin et al., 2014; Weiss et al., 2018); such models allow for more accurate accessibility computation than do straight-line distance measures. Figure 2 below shows the locations, using GPS coordinates, of all VCIs as well as of our sampled households.

Figure 2 Locations of sampled value chain interventions and households



Unlike other comprehensive market accessibility models, however, this study estimates merely on-foot travel to the nearest VCIs; topographic factors are thus considered as the main impediment to movement, given that the study area is dominated by agricultural land where walking speed is likely most affected by down and upward slopes.[4] The accessibility model was constructed and computed in an ArcGIS environment using ArcPy Python script. Travel time was

[4] The model calculates off-road travel time over an approximately 30m x 30m gridcell resolution, using the Shuttle Radar Topography Mission (SRTM) data model to adjust for walking speed. Despite differences in how land cover impedes walking speed, given the size of the study area a uniform 5km/hour average walking speed was used to estimate the time of on-foot travel. For the terrain (topographic) variation adjustment, Tobler's hiking function is used to account for up and downward slope movement (Tobler, 1993). The GPS location of each household and VCI in the Molumbo and Alto Molócue districts was collected during both midline and endline surveys. At the time of the endline survey, Collector for ArcGIS application was implemented to capture the entire spatial location of VCIs and approximately one-third of all household locations.

calculated from the sampled households to each of the value chain actor types; the travel time of other attribute-based scenarios was also calculated.

To define beneficiary and nonbeneficiary groups in the context of the spatial identification strategy and using the intention-to-treat definition for treatment (exposure to intervention), we used terrain adjusted walking distance, measured in time, to classify households. Using a cutoff point of 60 minutes median walking time to the nearest VCI, households within this distance are classified as treatment households, and those with a longer walking time are classified as control households. We further divided treatment households into those exposed to an MSD approach and those not exposed. Among MSD exposed households, we distinguish those exposed to an InovAgro-facilitated MSD approach and those exposed to a non-InovAgro-facilitated MSD approach. Among the control households, we used a cutoff point of 60 minutes median walking time to the nearest treatment household. Control households with walking times less than the cutoff are classified as indirect control households and those with longer walking times are classified as pure control households. We further divided indirect control households into those exposed to an MSD approach and those not exposed. Even after applying this approach for defining the treatment group, however, major challenges such as natural learning, self-selection, interventions targeting, and the adaptive nature of MSD projects like InovAgro remain as causes for concern in making causal inferences.

Following Ravallion (2007) and Angrist and Pischke (2008), we thus employed a Fixed Effects (FEs) method on a matched sample. We used the three-wave panel data (IIES 2015, IIES 2017, and IIES 2019) to isolate InovAgro effects and to account for the possible influence of external factors such as government policy, improved infrastructure, natural disasters, natural learning, and/or adaptation. The double-difference analysis compares the change in outcomes before and after the InovAgro VCIs among intended beneficiaries and nonbeneficiaries. The FEs method also helps account for any pre-treatment differences among beneficiaries and nonbeneficiaries (Angrist and Pischke, 2008). The advantage of the FEs method is that it nets out the effects of additive factors that have fixed (time-invariant) impacts on outcome indicators or that reflect common trends affecting treatment and non-treatment households equally, such as changes in prices, devaluation, flood, or drought (Ravallion, 2007; Angrist and Pischke, 2008).

4 Estimation and Identification Strategies

4.1 Household level estimation

We employed a FEs estimation technique to assess the impact of exposure to InovAgro interventions on selected household-level outcomes. We used the following specification:

$$Y_{ijt} = \beta_0 + \beta_1 C_j + \beta_2 T_t + \gamma C_j \times T_t + \varepsilon_{ijt}, \tag{1}$$

where Y_{ijt} denotes the outcome variable of interest for household i in community j at time t; C_j is a binary treatment indicator equal to one if community j was exposed to the InovAgro VCIs (treatment community) and zero otherwise (control community); T_t represents a dummy variable equal to one if year is equal to 2017 (midline survey year) or 2019 (endline survey year) and zero if year is equal to 2015 (baseline survey year) capturing aggregate trends in outcome variables; and ε_{ijt} is an error term that absorbs any remaining unobservable factors that may generate variations in outcome variables. The interaction term and associated coefficient capture potential differential trends and give the average impact of the exposure to the InovAgro VCIs on a given outcome variable (the average difference between treatment and control groups).

One of the key assumptions behind the Fes approach is that covariates other than the InovAgro VCIs do not change between the baseline, midline, and endline years. In our case, this is violated; following literature (e.g., Fischer and Qaim, 2012; Amare et al., 2012; Amare and Asfaw, 2012; Platteau et al.,2017), we controlled for household-level characteristics that could affect the difference in trends between treatment and control groups by modifying the above specification as follows:

$$Y_{ijt} = \beta_0 + \beta_1 C_j + \beta_2 T_t + \gamma C_j \times T_t + \beta_3 X_{ijt} + \varepsilon_{ijt}, \tag{2}$$

where X_{ijt} represents a set of household-level characteristics. We were interested in estimating the effects of intention-to-treat (ITT) on the treated with regard to a range of outcomes of InovAgro VCIs, rather than actual treatment effects on the treated (ATT), that is, the impact on actual beneficiaries of InovAgro VCIs. Put differently, we were interested in assessing whether the InovAgro VCIs were generating the intended effects among beneficiaries. In our study context, however, where most farming households are small scale, ITT and ATT estimates are not expected to differ substantially. In the worst case, our ITT estimates should be interpreted as lower bounds of the actual impact of InovAgro VCIs on beneficiaries.

If we attempt, however, to use nonbeneficiary households to estimate the average outcome variable among beneficiary household that did not benefit from the InovAgro VCIs, we would be faced with a selection bias problem. Households may also self-select themselves into treatment in InovAgro-facilitated activities (MSD approaches) depending on their characteristics; for example, households that are less able (having poorer labor endowments) or households with liquidity constraints may decide not to take part in InovAgro-facilitated activities because they are not able to engage in intensive market-oriented agriculture and/or are not able to afford yield-enhancing agricultural inputs. The study thus also adopted a matching approach which enabled us to produce a subsample of beneficiaries and nonbeneficiaries with comparable household- and parcel-level characteristics at the baseline year. Matching – the probability of being assigned to the InovAgro VCIs conditional on the basis of before-intervention characteristics – is specified as follows:

$$p_i = p(X_{ijt}) = Pr(C_j = 1|X_{ijt}) = E[C_j = 1|X_{ijt}] = F\{h(X_{ijt})\}, \tag{3}$$

where $F\{\cdot\}$ can be a normal or logistic cumulative distribution. Matching controls for selection bias by constructing a counterfactual for households that benefited from the InovAgro VCIs by matching every household from the treatment communities with one from the control communities with similar characteristics. Once the matching is estimated, the ITT can be calculated as follows:

$$\begin{aligned} ITT &= \{Y_i^T - Y_i^C|C_i = 1\} = E[E\{Y_i^T - Y_i^C|C_i = 1, p_i\}] \\ &= E[E\{Y_i^T|C_i = 1, p_i\} - E\{Y_i^C|C_i = 0, p_i\}|C_i = 1], \end{aligned} \tag{4}$$

where Y_i^T and Y_i^C denote the outcome variable if household i benefited (treatment communities) and did not benefit (control communities), respectively, from InovAgro VCIs.

4.2 Market level estimation

We defined the treatment and control groups using a spatial identification strategy that enabled us to conduct a modified RCT to evaluate the impact of InovAgro VCIs on market systems (that is, the systemic, sustainability, large-scale and unintended [positive or negative] effects). We investigated the market system impacts of one intervention (certified seed supply) and three modalities used to reach smallholder farmers (agrodealers, lead farmers, and demonstration plots) using the three waves of the IIES (2015, 2017 and 2019) and multiple comparison tests.

Long-term systemic effects: to investigate the potential crowding-in or "copying" effect of InovAgro VCIs, we used two proxy indicators. First, we did a comparison test on the number of InovAgro-facilitated MSD VCIs with non-InovAgro-facilitated MSD VCIs before and after the launch of InovAgro activities in the study communities in 2015. To claim any systemic (crowding-in) effect of InovAgro VCIs, we expected a more significant increase in the number of non-InovAgro-facilitated MSD VCIs after 2015 (after the launch of the InovAgro activities). Second, we also compared the average time elapsed since the intervention's launch for InovAgro-facilitated versus non-InovAgro-facilitated MSD VCIs. Again, a significant reduction in the average time elapsed since the VCI began operation for non-InovAgro-facilitated MSD VCIs is considered indicative evidence of InovAgro having a systemic effect.

Sustainability effects: we investigated the potential sustainability effect of InovAgro VCIs using data from IIES (2015, 2017 and 2019) to monitor the household's usage history of yield-enhancing farming practices (such as use of fertilizer, other agrochemicals and certified seeds), comparing those who benefit from MSD VCIs with those only exposed to non-MSD VCIs. Table 3 shows trajectory of the interviewed households' use of yield-enhancing farming practices, comparing IIES 2017 with IIES 2019, that is, two and four years, respectively, after InovAgro VCIs were launched in the study locations in 2015.

Table 3 Trajectory of households' use of yield-boosting farming practices

<table>
<tr><td colspan="3" rowspan="3"></td><td colspan="2">IIES 2019
2018/2019 agricultural season</td></tr>
<tr><td colspan="2">Use of yield-boosting agricultural inputs</td></tr>
<tr><td>YES</td><td>NO</td></tr>
<tr><td rowspan="2">IIES 2017
2016/2017 agricultural season</td><td rowspan="2">Use of yield-boosting agricultural inputs</td><td>YES</td><td>I
(continue usage)</td><td>III
(become nonusers)</td></tr>
<tr><td>NO</td><td>II
(become new users)</td><td>IV
(continue nonusage)</td></tr>
</table>

Source: Authors' compilation

To claim a sustainability effect of InovAgro VCIs, we compared the four scenarios in the quadrants shown in Table 3. We expected that we had a sustainability effect if the proportion of

MSD exposed households under quadrant I ("continue usage") is significantly larger than the proportion of non-MSD exposed households. Stated differently, if the InovAgro MSD VCIs was indeed more sustainable than non-MSD VCIs, we expected the proportion of households that abandoned usage of yield-boosting farming practices (quadrant III) to be significantly larger among non-MSD exposed households (exposure to direct service delivery) than among MSD exposed households.

Spillover effects: again, comparing the four scenarios (quadrants) shown in Table 3, we investigated the possible spillover effects of the InovAgro MSD VCIs by focusing on nonbeneficiary households (households not exposed to any MSD or non-MSD VCIs). We compared usage of yield-enhancing farming practices among indirect control households (those with terrain adjusted walking distance less than 60 minutes to the nearest MSD exposed households) versus pure control households (those with walking distance longer than 60 minutes to the nearest MSD exposed households).[5]

To claim spillover or multiplier effects of the InovAgro (MSD) VCIs, the proportion of households under quadrant II ("become new users") must be significantly larger for indirect control households than for pure control households. This is because we also expect a higher likelihood of peer-to-peer social learning for indirect control households compared to pure control households. Similar to the sustainability effects, we used 10 alternative definitions of yield-boosting farming practice use disaggregated by 3 types of VCIs and ran 30 tests of the spillover hypotheses by combining the 10 yield-enhancing input use definitions.

Unintended effects: we evaluated if InovAgro VCIs had unintended effects using data from the 3 rounds of IIES (2015, 2017 and 2019). We hypothesized that InovAgro VCIs could be prone to unintended effects (positive or negative) on both intended beneficiaries and nonbeneficiaries. We assessed potential unintended effects of InovAgro VCIs on crop diversification, household income diversification, intrahousehold bargaining power as well as women and youth land use rights.

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[5] Due to insufficient observations in our dataset of indirect control households (those within the 60-minute cutoff proximity to non-MSD exposed households), we were not able to test potential spillover effects of non-MSD VCIs and, hence, not able to compare potential spillover effects of MSD VCIs over non-MSD VCIs.

4.4 Outcome variables definition

Following the project’s theory of change, our analysis focuses on investigating the effects of exposure to the InovAgro VCIs on selected outcome variables; these include the impact on use of yield-boosting farming practices, access to information on agricultural input and output markets, maize productivity, overall household welfare, and any other unintended positive or negative effects. Table 4 outlines the definition of each of the outcome variables, together with the expected sign of the interventions effect.

Table 4 Outcome variables definition and expected signs

Variable	Definition	Expected sign
Use of modern farm practices		
Agrochemicals	Dummy variable equal to one if the household has utilized herbicide, pesticide, inoculant, etc. on at least one of their agricultural parcels	(+)
Fertilizer	Dummy variable equal to one if the household used fertilizer	(+)
Certified seed variety	Dummy variable equal to one if the household used certified seeds for one of the value chains crops (maize, soya beans and pigeon peas)	(+)
Access to agricultural market information		
Input market information	Dummy variable equal to one if the household has reported receiving information about input markets from sources such as District Services for Economic Activities (SDAE), extension agents, radio, fliers, etc.	(+)
Output market information	Dummy variable equal to one if the household has reported receiving information about output markets	(+)
Maize productivity and market participation		
Maize productivity	Obtained by dividing total value of quantity produced using median community-level price of each crop (total output value) by total area cultivated	(+)
Sale of agricultural output	Dummy variable equal to one if household sold maize in the most recent agricultural season	(+)
Extent of market participation	Obtained by dividing total value of output sold by the total value of output produced	(+)
Household welfare and income diversification		
Asset index	Computed using principal component analysis (PCA), taking into account asset ownership. We grouped assets into three categories: (1) functioning assets (for example, land area), (2) functioning durable assets (for example, motorbike), and (3) functioning nondurable assets (for example, livestock ownership)	(+)
Nonagricultural employment	Dummy variable equal to one if the household has reported having at least one household member aged 15 or older who is generating income from a nonagricultural sector	(+)
Temporary migration	Dummy variable equal to one if the household has reported having at least one household members aged 15 or older who was absent from the household in the 12 months preceding the interview date	(+)
Empowerment of vulnerable groups--women and youth		
Women's land rights	Dummy variable equal to one if the household has at least one adult female member with the right to own, sell, give, or rent land, or who has the right to contribute to the purchase of land	(+/-)
Youth land rights	Dummy variable equal to one if the household has at least one youth member (25 to 34 years of age) with the right to own, sell, bequeath, or rent land, or who has the right to contribute to the purchase of land	(+/-)
Nonagricultural employment		
Women's nonagricultural employment	Dummy variable equal to one if the household has at least one adult female member aged 15 or older who generated income from a nonagricultural sector	(+/-)
Youth's nonagricultural employment	Dummy variable equal to one if the household has at least one youth member (25 to 34 years of age) who generated income from a nonagricultural sector	(+/-)
Temporary migration		
Women's migration	Dummy variable equal to one if the household has at least one adult female member aged 15 or older who was absent from the household in the 12 months preceding the interview date	(+/-)
Youth migration	Dummy variable equal to one if the household has at least one youth member (25 to 34 years of age) who was absent from the household in the 12 months preceding the interview date	(+/-)

Source: Authors' compilation

6 Results and Discussion

6.1 Descriptive results

Table 5 summarizes the descriptive statistics of selected variables of interest and outcome variables at baseline. It reveals stark differences in key household characteristics (such as age, marital status, and gender and education of the household head) and selected outcome variables (such as access to information on agricultural input and output markets, agricultural production and productivity, income, and crop diversification). On the other hand, and with particular relevance to our concern regarding selection or endogeneity bias, nonbeneficiaries started from a more favorable baseline condition in all of the core outcome variables except for three use-related variables, namely use of fertilizers and agrochemicals (which showed no significant difference) and use of certified seeds (which favored the treatment group).

Table 5 Household characteristics by treatment status at baseline

	Treatment		Control		*p*-value for mean difference (treatment vs control)
	Mean	Standard error	Mean	Standard error	
Age of household head (HH) (years)	39	12	34	12	0.000
HH head is married	0.605	0.489	0.700	0.459	0.001
Female-headed household	0.277	0.448	0.198	0.399	0.002
HH has at least primary education	0.156	0.363	0.195	0.396	0.096
Landholdings (hectares)	1.767	1.061	1.621	1.673	0.083
Outcome variables					
Household used agrochemicals	0.000	0.000	0.002	0.047	0.253
Household used fertilizer	0.002	0.041	0.002	0.047	0.851
Household used certified seeds	0.049	0.215	0.004	0.066	0.000
Received input market information	0.325	0.469	0.424	0.495	0.001
Received output market information	0.173	0.378	0.337	0.473	0.000
Maize production per hectare (MZN)	11481	9316	5449	3216	0.000
Household sold maize	0.271	0.445	0.136	0.343	0.000
Maize sales as a share of production	0.480	0.256	0.551	0.215	0.097
Wealth index	-0.178	1.278	0.247	1.340	0.000
A Household member working in nonagricultural sector	0.366	0.482	0.613	0.488	0.000
A Household member is a temporary migrant	0.111	0.314	0.163	0.369	0.012
Number of observations	762		1,124		

Source: IIES 2015

Note: Treatment refers to exposure to any VCI (agrodealer, lead farmer, and/or demonstration plots)

Such stark differences in the key variables of interest at baseline – with control nonbeneficiaries starting out in a favorable condition compared to beneficiaries – reinforces the validity of the endogeneity concern about a potential downward bias affecting our estimates. We thus accounted for such potential selection bias (either due to self-selection or interventions targeting) using a propensity score matching (PSM) method. Table 6 presents the descriptive results from the reduced sample, with treatment and control households that are comparable based on observable household and parcel characteristics at baseline.

Table 6 Household characteristics by treatment status at endline

	Treatment		Control		*p*-value for mean difference (treatment vs control)
	Mean	Standard error	Mean	Standard error	
Age of household head (HH) (years)	41	11	38	12	0.0000
HH head is married	0.319	0.466	0.284	0.451	0.2148
HH head has identification card	0.587	0.493	0.472	0.500	0.0002
Female-headed household	0.220	0.415	0.197	0.398	0.3550
HH has at least primary education	0.096	0.295	0.074	0.245	0.1572
HH can read and write	0.469	0.499	0.487	0.500	0.5548
Landholdings (hectares)	2.586	2.583	2.365	1.322	0.0921
Outcome variables					
Household used agrochemicals	0.138	0.345	0.039	0.193	0.000
Household used fertilizer	0.208	0.406	0.082	0.275	0.000
Household used certified seeds	0.270	0.444	0.136	0.343	0.000
Received input market information	0.657	0.475	0.602	0.490	0.061
Received output market information	0.701	0.458	0.619	0.486	0.005
Maize production per hectare (MZN)	10962	7064	8885	6464	0.000
Household sold maize	0.630	0.483	0.463	0.499	0.000
Maize sales as a share of production	0.468	0.270	0.429	0.253	0.123
Wealth index	0.067	1.303	-0.104	1.172	0.025
A HH member worked in nonagricultural sector	0.579	0.494	0.629	0.484	0.095
A household member is a temporary migrant	0.206	0.404	0.104	0.305	0.000
Number of observations	689		1009		

Source: IIES 2019
Note: Treatment refers to exposure to any VCI (agrodealer, lead farmer, and/or demonstration plots).

Between 2015 (baseline) and 2019 (endline), usage of yield-enhancing agricultural inputs among treatment households increased substantially compared to control households. In the treatment group, the share of households that used agrochemicals (insecticide or herbicide) increased from 0.0 percent at the baseline to 13.8 percent at the endline, and in the control group it increased from 0.0 percent to 3.9 percent. Similar patterns were registered for fertilizer use (increasing from 0.0 percent to 20.8 percent among treatment households and from 0.0 percent to 8.2 percent among control households), and for use of certified seeds (jumping from 4.9 percent to 27.0 percent among treatment households and from 0.0 percent to 13.6 percent among control households). Between 2015 and 2019, perceptions of household demand for certified seeds (expressed willingness to use in future) declined in both the treatment and the control groups; however, the reduction was considerably higher in the control group (a decline of 37.6 percent, from 52.6 percent to 15.0 percent) than in the treatment group (a decline of 7.9 percent, from 36.2 percent to 28.3 percent).[6]

Between baseline and endline surveys, access to information on agricultural output markets in the treatment group jumped from 17.3 percent to 70.1 percent, a much higher increase than in the control group, which increased from 33.7 percent to 61.9 percent. A similar pattern was registered in access to information on agricultural input markets, which went from 32.5 percent to 65.7 percent in the treatment group and from 42.4 percent to 60.2 percent in the control group. During the same period, increases in the value of production per hectare for maize were consistently higher in the treatment group than in the control group; in the treatment group, the value increased from MZN 10,962 to MZN 11,481, while the control group experienced an increase from MZN 5,449 to MZN 8,885. Over the same period, the increase in the proportion of households that sold maize was higher in the treatment group (35.9 percent, from 27.1 percent to 63.0 percent) than in the control group (32.7 percent, from 13.6 percent to 46.3 percent). It is worth noting that in the baseline, maize sales as a share of production were slightly higher in the control group (55.1 percent) than in the treatment group (48.0 percent); this was potentially because members of the control group were better informed. By the endline, however, maize sales as a share of production were comparable in the treatment and control groups (46.8 percent and 42.9 percent).

For both treatment and control groups, crop diversification remained largely unchanged between 2015 and 2019. In both years, however, crop diversification was slightly lower in the treatment than in the control group (2.2 versus 2.7 in 2015 and 2.3 versus 2.5 in 2019). Exposure to MSD appeared to have increased participation in the nonagricultural sector and in temporary migration. The share of household members that were engaged in the nonagricultural sector increased considerably in the treatment group, moving from 36.6 percent in 2015 to 57.9 percent

[6] This result could perhaps be due to the overall behavioral effect of external factors that affected both treatment and control households, for example, weather shock, floods, or price inflation.

in 2019; in the control group it increased only slightly, from 61.3 percent in 2015 to 62.9 percent in 2019. The proportion of household members in the treatment group who engaged in temporary migration jumped from 11.1 percent in 2015 to 20.6 percent in 2019; in the control group, by contrast, it dropped from 16.3 percent to 10.4 percent. Treatment households were worse off (as measured by wealth index) than control households during the baseline, but by the endline the situation was reversed, with treatment households becoming better off than control households.

6.2 Household level impacts

We estimated the effects of intention-to-treat (ITT) on treatment groups with regard to the impact of a range of InovAgro VCIs; the outcomes of interest included: farmers' use of yield-boosting agricultural inputs, access to information on agricultural input and output markets, maize productivity, women and youth empowerment effects, and household welfare. We sought to assess whether the channel of InovAgro VCI had an impact on the outcome variables; these channels included exposure to an agrodealer (Model T1), to a lead farmer (Model T2), to a demonstration plot (Model T3), and to all three interventions simultaneously, that is, to a "complete package" (Model T4). For this, we compared independent regression estimates by defining treatment based on exposure to each of the three VCIs and to a complete package, and then compared the magnitude of impact. We also differentiated short- and long-term impacts of VCIs. We used a two-year gap between the IIES 2015 and IIES 2017 to evaluate the short-term impact of the interventions, and a four-year gap between the IIES 2015 and IIES 2019 to identify a long-term impact of the interventions. Such disaggregation informs the design and implementation of future MSD impact evaluations and the determination of the time period needed to capture respective impacts on outcome variables.

6.2.1 Use of yield-boosting agricultural inputs

To investigate the InovAgro VCI impacts on farmers' use of yield-enhancing agricultural inputs, we used three proxy outcome variables. These are defined in Table 4 above and include: use of agrochemicals, use of fertilizer, and use of certified seeds. Table 7 shows the impacts of the InovAgro VCIs on household use of yield-enhancing agricultural inputs.

The results show that InovAgro VCIs had a positive and significant impact on smallholder farmers' use of fertilizer in both the short and long term. The result remained robust regardless of whether the households were exposed to a single VCI or to all three VCIs; however, the interventions had a stronger impact on farmers' use of fertilizer in the long term than in the short term. A complete package of InovAgro VCIs (agrodealers, lead farmer and demonstration plots), for example, increased a farmer's likelihood of using fertilizer by 15 percent in the long term compared to 5 percent in the short term. Intensity of treatment seemed to matter little when it came to the long-term effects of farmers' use of fertilizer. Our results are consistent with several studies that demonstrate that improving market efficiencies affects technology adoption, including input and output market efficiencies (for example, Zeller et al., 1998), missing credit markets (Gine and Yang, 2009), and information market efficiencies (Cole and Fernando, 2016).

Table 7 FEs estimates of the impact of InovAgro VCIs on farmers' use of yield-boosting agricultural inputs

		Agrodealer (T1)	Lead farmer (T2)	Demonstration plot (T3)	Complete package (T4)
Fertilizer use					
	Short term	0.042***	0.049***	0.060***	0.045***
		(0.012)	(0.012)	(0.015)	(0.013)
	Long term	0.153***	0.144***	0.130***	0.144***
		(0.016)	(0.016)	(0.018)	(0.017)
Agrochemicals					
	Short term	0.058***	0.063***	0.080***	0.062***
		(0.011)	(0.011)	(0.013)	(0.012)
	Long term	0.149***	0.143***	0.174***	0.144***
		(0.015)	(0.015)	(0.018)	(0.016)
Certified seeds					
	Short term	0.107***	0.117***	0.153***	0.116***
		(0.015)	(0.016)	(0.019)	(0.017)
	Long term	0.014	0.009	0.011	0.009
		(0.014)	(0.014)	(0.016)	(0.015)

Source: IIES 2015, IIES 2017, and IIES 2019.
Note: *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels; standard errors adjusted for clustering at the community level are in parentheses; all regression estimations include household- and parcel-level characteristics.

Similar to its effect on farmers' use of fertilizer, the results show that InovAgro VCIs had a positive and significant impact on a household's likelihood of using agrochemicals. This positive impact on the use of agrochemicals remained robust whether households were exposed to a single VCI or to the complete package. It also remained robust across the short term and the long term, with a stronger impact in the long term. A complete package of InovAgro VCIs, for example, increased a farmer's likelihood of using agrochemicals by 15 percent in the long term but by only 6 percent in the short term. The results also show that the impact of InovAgro VCIs had a positive and significant impact on farmers' use of certified seeds in the short term but not in the long term. The short-term impacts of the interventions on farmers' use of certified seeds seems to depend less on the type or intensity of treatment (exposure); this is indicative of the potential long-term spillover benefits of the interventions, as nonbeneficiaries may catch up on the use of certified seeds by learning from interventions beneficiaries.

6.2.2 Information on agricultural input and output markets

According to Kijima et al. (2012) and Latynskiy and Berger (2016), a project's impact on the productivity, income, and overall welfare of smallholder farmers depends on the quality and timely information farmers get regarding information on agricultural input and output markets. This can include, for example, where they can buy yield-enhancing agricultural inputs, how to differentiate various qualities and prices, and where they can sell their produce. We thus investigated smallholder farmers' access to information on agricultural input and output markets as potential intermediary outcomes of the interventions. Table 8 below presents detailed econometric results for the two project outcomes, with a disaggregated analytical approach to project outcomes that is similar for type and intensity of exposure.

Table 8 FEs estimates of the impact of InovAgro VCIs on access to market information

		Agrodealer (T1)	Lead farmer (T2)	Demonstration plot (T3)	Complete package (T4)
Output market information					
	Short term	0.215***	0.404***	0.209***	0.234***
		(0.026)	(0.027)	(0.027)	(0.028)
	Long term	0.310***	0.440***	0.302***	0.340***
		(0.026)	(0.029)	(0.026)	(0.027)
Input market information					
	Short term	0.179***	0.198***	0.178***	0.196***
		(0.026)	(0.030)	(0.027)	(0.028)
	Long term	0.288***	0.222***	0.281***	0.298***
		(0.027)	(0.032)	(0.027)	(0.028)

Source: IIES 2015, IIES 2017, and IIES 2019.
Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels; standard errors adjusted for clustering at the community level are in parentheses; all regression estimations include household- and parcel-level characteristics.

The results show positive and significant impacts of InovAgro VCIs on beneficiary smallholder farmers' access to information on agricultural input and output markets, whether they are exposed to a single VCI or to the complete package. This positive impact remained robust both in the short and long term. A complete package of InovAgro VCIs, for example, increased a farmer's long-term likelihood of accessing information on agricultural output and input markets by 34 percent and 30 percent, respectively. This is consistent with evolving evidence that shows that an extension project that features agrodealers, demonstration plots, and lead farmers contributes to statistically significant increases in farmers' access to information on both agricultural input and output markets (Kijima et al., 2012; Latynskiy and Berger, 2016). Our findings also suggest that strengthening farmers organizations and associations is critical to increasing access to yield-enhancing agricultural inputs and to increasing access to output markets. Stronger farmers organizations are shown to result in improved quality of produce and better access to information and knowledge; they also facilitate engagement with policymakers (Zeller et al., 1998; Gine and Yang, 2009; Cole and Fernando, 2016).

6.2.3 Maize productivity and marketing

This section focuses on maize. According to data from IIES 2015, 2017, and 2019, maize is grown by 82 percent of interviewed households, making it one of the most-cultivated crops in terms of number of farmers; it is also one of the value chains targeted by the InovAgro interventions. The fact that we did not collect input and output production data during the baseline survey constrains the productivity analysis in its investigation of the long-term benefits of the interventions in terms of maize productivity. As a result, this section only focuses on short-term interventions effects, comparing production data from the 2016/2017 agricultural season (IIES 2017) with that from the 2018/2019 agricultural season (IIES 2019). Table 9 shows the positive and significant impacts of InovAgro VCIs on not only boosting the maize productivity of beneficiaries but also increasing their likelihood of market participation (that is, their likelihood of selling maize) as well as the volume of marketable maize surplus. This positive impact on productivity and on agricultural market participation remains robust whether households are exposed to a single VCI or to the complete package. Maize productivity is 6.7% higher in the short term among beneficiaries exposed to the complete package than among those who were not exposed.

Table 9 FEs estimates of the impact of InovAgro VCIs on maize productivity and market participation

		Agrodealer (T1)	Lead farmer (T2)	Demonstration plot (T3)	Complete package (T4)
Productivity (output per hectare)					
	Short term	0.524***	0.241***	0.464***	0.670***
		(0.125)	(0.091)	(0.127)	(0.094)
Sale of agricultural output					
	Short term	0.575***	0.605***	0.558***	0.846***
		(0.161)	(0.114)	(0.164)	(0.195)
Ratio of marketable surplus to total production					
	Short term	0.060***	0.115***	0.059***	0.134***
		(0.022)	(0.021)	(0.022)	(0.019)

Source: IIES 2017 and IIES 2019.
Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels; standard errors adjusted for clustering at the community level are in parentheses; all regression estimations include household- and parcel-level characteristics.

6.2.4 Empowerment of women and youth

This section discusses the potential unintended impacts of the InovAgro VCIs on land rights, nonagricultural income generation, and temporary migration of vulnerable members of households, that is to say on women and on youths (between 25 and 34 years of age).

Table 10 shows the unintended negative effects of the InovAgro VCIs on access to, and control over, land by women and youth in the short term – an adverse interventions effect on youth land rights that was wiped out in the longer term. Short-term adverse effects of the interventions could be associated with the fact that a more commercialized agricultural practice may not always guarantee a desirable outcome for the land tenure security of vulnerable groups, since more profitability in agriculture could increase competition for land and could lead to the exclusive control of such resources by the (usually male) household head.[7] Hence, unless deliberate measures are taken to mainstream gender and youth issues into the designing and implementation of MSD interventions like InovAgro, such negative effects on the land rights of these groups may undermine the full potential of MSD interventions to generate outcomes that are uniformly desirable.

[7] The vast majority of households in our sample are male headed. The shares of male-headed households stand at 72.3 percent among treatment households compared to 80.2 percent among control households at the baseline survey year and 78.0 percent among treatment households compared to 80.1 percent among control households at the endline survey year.

Table 10 FEs estimates of the impact of InovAgro VCIs on women and youth empowerment

		Agrodealer (T1)	Lead farmer (T2)	Demonstration plot (T3)	Complete package (T4)
Women's land access					
	Short term	-1.006***	-1.053***	-0.898***	-0.975***
		(0.026)	(0.030)	(0.028)	(0.029)
	Long term	0.119***	0.119***	0.101***	0.146***
		(0.028)	(0.030)	(0.027)	(0.030)
Youths' land access					
	Short term	-0.099***	-0.095***	-0.082***	-0.081***
		(0.015)	(0.019)	(0.015)	(0.016)
	Long term	-0.011	-0.002	-0.015	0.011
		(0.019)	(0.022)	(0.019)	(0.020)
Females in non-agriculture					
	Short term	0.087***	0.164***	0.070***	0.087***
		(0.017)	(0.020)	(0.017)	(0.018)
	Long term	-0.012	0.014	-0.009	-0.003
		(0.015)	(0.017)	(0.016)	(0.017)
Youths in non-agriculture					
	Short term	0.084***	0.175***	0.070***	0.083***
		(0.019)	(0.021)	(0.020)	(0.020)
	Long term	-0.059***	0.006	-0.052***	-0.046***
		(0.017)	(0.017)	(0.017)	(0.017)
Female is a temporary migrant					
	Short term	-0.094***	-0.078***	-0.081***	-0.079***
		(0.023)	(0.022)	(0.023)	(0.023)
	Long term	0.028	0.086	0.021	0.016
		(0.024)	(0.063)	(0.023)	(0.024)
Youth is a temporary migrant					
	Short term	-0.105***	-0.073***	-0.093***	-0.102***
		(0.024)	(0.024)	(0.024)	(0.025)
	Long term	0.008	0.068	0.015	0.029
		(0.025)	(0.047)	(0.025)	(0.026)

Source: IIES 2015, IIES 2017, and IIES 2019.
Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels; standard errors adjusted for clustering at the community level are in parentheses; all regression estimations include household- and parcel-level characteristics.

The results also show that InovAgro VCIs had a positive impact on nonagricultural income-generating activities for beneficiary women and youth in the short term, whether they were exposed to a single VCI or to the complete package. In the long term, however, beneficiary women and youth who were exposed to agrodealers and demonstration plots, or to the complete package, experienced a negative impact on nonagricultural employment; for women, however, this adverse impact vanished in the longer term. With regard to migration, the results show that the InovAgro VCIs had a negative impact on both women and youth in the short term, regardless of the VCI; in the longer term, however, the interventions had no impact on the migration of women and youth.

6.2.5 Household income diversification and welfare

Following the project's theory of change, the study also investigates the potential effects of the InovAgro VCIs on household income diversification and overall welfare. The results are reported in Table 11. We employ two indicators as proxies for household income diversification: (1) if a household had at least one member who was absent for at least one month preceding the interview (temporary migrant); and (2) if a household had at least one member who was involved in the nonagricultural sector. Results show that InovAgro VCIs had a positive and significant impact on temporary migration at the household level in the short term while there was no evidence of such an effect in the long term. The impact of InovAgro VCIs on the likelihood of generating income from nonagricultural employment, on the other hand, was positive in the long term regardless of the channel of VCIs, while there was no evidence of such an effect in the short term. This finding is consistent with the notion that entry into employment in the nonagricultural sector is both financially and socially costly and that it must be financed by up-front cash (Carrington et al., 1996).

Table 11 FEs estimates of the impact of InovAgro VCIs on household income diversification and welfare

		Agrodealer (T1)	Lead farmer (T2)	Demonstration plot (T3)	Complete package (T4)
Has a member who is a temporary migrant					
	Short term	0.134***	0.265***	0.107***	0.135***
		(0.026)	(0.028)	(0.027)	(0.028)
	Long term	-0.023	0.051*	-0.013	-0.004
		(0.026)	(0.028)	(0.026)	(0.027)
Has a member involved in nonagriculture					
	Short term	-0.011	0.015	0.003	0.007
		(0.031)	(0.018)	(0.032)	(0.033)
	Long term	0.181***	0.115***	0.177***	0.208***
		(0.031)	(0.021)	(0.031)	(0.033)
Household wealth					
	Short term	-0.129	0.101	0.132	0192**
		(0.082)	(0.084)	(0.083)	(0.088)
	Long term	0.082	0.005	0.011	0.183**
		(0.085)	(0.096)	(0.084)	(0.082)

Source: IIES 2015, IIES 2017, and IIES 2019.

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels; standard errors adjusted for clustering at the community level are in parentheses; all regression estimations include household- and parcel-level characteristics.

The results also show no evidence of a welfare impact of InovAgro VCIs when beneficiaries were exposed to any one of the three types of VCIs; this absence of an effect remains in both the short- and long-term scenarios. When beneficiaries were exposed to the complete package treatment, however, a 0.2 standard deviation increase in a household's welfare index was seen in both the short and long term. This suggests that the design and implementation of future similar MSD projects like InovAgro should package interventions such that they complement each other and thus ensure forward and backward linkages.

6.3 Market level impacts

In the previous section, we assessed the InovAgro VCI impact on several outcome variables at household level. We now evaluate the extent to which InovAgro VCIs resulted in market changes by focusing on four result pathway parameters: i) long-term systemic effects; ii) sustainability effects; iii) large-scale (spillover) effects; and iv) potential unintended effects.

6.3.1 Long-term systemic effects

As part of the facilitative role InovAgro VCIs set out to achieve, one of major activity of the interventions was focused on understanding where market systems fail to serve the needs of the poor farmers and take action to correct those failings. For this purpose, a systemic change is hereby defined as "transformations in the structure or dynamics of a system that lead to impacts on the material conditions or behaviors of large numbers of people," either through crowding in or by copying other VCIs due to the InovAgro effect on improving the business environment (Ruffer and Wach, 2013).

Table 12 shows the results of both parameters, disaggregated by district. Overall, comparing the time before and after the launch of InovAgro VCIs (before and after 2015, respectively), a significant percentage increase occurs in the number of non-InovAgro-facilitated MSD VCIs. This trend remains consistent in both study districts. Similarly, on average, non-InovAgro-facilitated MSD VCIs had a significantly shorter time elapsed since the intervention's launch compared to InovAgro-facilitated MSD VCIs. Both results are indicative of the facilitative role InovAgro has played in bringing more MSD VCIs into the system (that is, crowding-in effects). Given the overall market (systemic) effects of InovAgro VCIs, the MSD effect/impact and InovAgro effect/impact are, hereafter, used interchangeably.

Table 12 Long-term systemic effects of InovAgro VCIs

Districts	Type of MSD VCIs	Number of MSD VCIs			Number of months since launch/began operation (as of December 2019)
		Before 2015	After 2015	% Increase	
Molumbo	InovAgro-facilitated MSD VCIs	3	15	400%	39.13 months
	Non-InovAgro-facilitated MSD VCIs	0	19	2,000%	26.68 months
	Mean comparison test				***
Alto Molocue	InovAgro-facilitated MSD VCIs	2	25	1,150%	31.24 months
	Non-InovAgro-facilitated MSD VCIs	7	58	729%	24.56 months
	Mean comparison test				***
Total sample	InovAgro-facilitated MSD VCIs	5	40	700%	34.7 months
	Non-InovAgro-facilitated MSD VCIs	7	77	1,000%	25.4 months
	Mean comparison test				***

Source: Authors' computation using data from the IIES 2015, IIES 2017 and IIES 2019.
Note: *** stands for hypothesis supported with at least 1% level of significance.

6.3.2 Sustainability effects

As shown in Table 13, the results support our hypothesis that the InovAgro MSD VCIs are more sustainable than non-MSD VCIs. Of the 30 tested hypotheses, 21 cases show that the proportion of households that continue to use yield-boosting agricultural inputs is significantly (at least at the 10 percent significance level) larger among InovAgro MSD exposed households compared to non-MSD exposed households. More interestingly, the result is more robust and consistent for two value chain crops selected by InovAgro. The proportion of households that continued to use improved soya beans and pigeon peas seeds is significantly larger for households exposed to InovAgro MSD VCIs compared to those exposed to non-MSD VCIs (such as direct service delivery or subsidy programs). The result remains robust regardless of the type of VCI. These findings are consistent with empirical evidence which show that the sustainable effects of using innovations at scale depend significantly on long-term engagement with local value chain actors equipped with sufficient capacity and resources to inform the objectives and vision (Cole and Fernando 2021; Hartmann and Linn 2008; Tomich et al. 2019; Vanloqueren and Baret 2009). Furthermore, our findings reinforce the skepticism around non-MSD VCIs that focus on free or subsidized delivery of services, which are prone to dropout as soon as such support is withdrawn.

Table 13 Sustainability effect: Proportion of households that continued using yield-boosting agricultural inputs between 2017 and 2019

	Treatment: Agrodealer				Treatment: Demonstration plot				Treatment: Lead farmer			
Use	MSD	Non-MSD	p-value for difference		MSD	Non-MSD	p-value for difference		MSD	Non-MSD	p-value for difference	
NPK	18.8%	11.1%	0.0314	**	18.8%	13.1%	0.0536	*	21.0%	3.6%	0.0060	***
Insecticide	22.2%	20.3%	0.1310		36.9%	11.6%	0.0080	***	21.5%	7.9%	0.0314	**
Herbicide	4.5%	0.0%	0.0380	**	2.9%	0.0%	0.5942		4.2%	0.0%	0.3819	
Inoculant	5.3%	5.3%	0.6886		5.2%	4.9%	0.2316		5.3%	0.0%	0.0000	***
Certified seed												
Soya beans	8.0%	3.3%	0.0341	**	6.4%	2.5%	0.0330	**	5.9%	3.2%	0.0052	***
Pigeon peas	8.0%	0.0%	0.0018	***	7.7%	0.0%	0.0938	*	8.5%	0.0%	0.0240	**
Maize	100.0%	100.0%	0.2482		100.0%	100.0%	0.3084		100.0%	0.0%	0.0000	***
Fertilizer												
Soya beans	16.7%	5.2%	0.0098	***	12.3%	7.2%	0.0685	*	11.1%	6.8%	0.0087	***
Pigeon peas	3.3%	0.0%	0.0271	**	2.1%	0.0%	0.2513		0.0%	0.0%	0.0544	*
Maize	28.6%	28.6%	0.7368		30.5%	23.3%	0.0292	**	12.5%	0.0%	0.0000	***

Source: Authors’ computation using data from the IIES 2017 and IIES 2019.
Note: ***, ** and * stands for hypothesis supported with at least 1%, 5% and 10% level of significance, respectively.

6.3.3 Spillover effects

Due to the expected facilitative role MSD programs like InovAgro play, such programs are expected to have a positive spillover benefit on households that are not necessarily direct program beneficiaries. For this purpose, we, hereby, define spillover or multiplier effects to refer to wider changes resulting from InovAgro by benefitting smallholder farmers beyond InovAgro's direct domain of intervention (beyond its intended beneficiaries).

Table 14 summarizes the spillover effects of the InovAgro MSD interventions. Overall, the results support the spillover hypothesis by showing project's effect in benefitting large numbers of smallholder farmers beyond its' direct sphere of influence and intended beneficiaries. Of the 30 tested hypotheses, 23 cases show that the proportion of households that were new users of yield-enhancing agricultural inputs (those who did not use them in the 2016/2017 agricultural season but did in the 2018/2019 agricultural season) was significantly larger (at least at a 10 percent significance level) for (InovAgro) indirect control households compared to pure control households.

Regardless of the proxy variables used to capture usage of yield-enhancing agricultural inputs, the spillover effects are more robust and consistent for indirect control households with access to a lead farmer compared to those with access to agrodealers and demonstration plots. This is perhaps not surprising given the role social capital can play in magnifying the potential spillover benefits where lead farmers have better comparative advantages compared to beneficiaries who interact with agrodealers or who only have access to a demonstration plot. Such empirical evidence exemplifies the need for future design and implementation of similar programs to integrate a proper focus on the "lead farmer modality of MSD service provision" and to ensure that program outcomes remain desirable not only for intended beneficiaries but also as they benefit those beyond the program's direct sphere of influence.

Table 14 Spillover effect: Proportion of households that became new users of yield-boosting agricultural inputs between 2017 and 2019

	Treatment: Agrodealer				Treatment: Demonstration plot				Treatment: Lead farmer			
	MSD control households	Pure control households	p-value for difference		MSD control households	Pure control households	p-value for difference		MSD control households	Pure control households	p-value for difference	
NPK	1.9%	1.6%	0.4370		13.5%	13.4%	0.8965		15.3%	7.4%	0.0004	***
Insecticide	17.8%	0.8%	0.0000	***	14.2%	12.3%	0.6117		19.0%	6.5%	0.0000	***
Herbicide	0.4%	0.0%	0.0079	***	4.7%	2.4%	0.0786	*	5.1%	2.0%	0.0094	***
Inoculant	5.7%	5.6%	0.6854		6.7%	6.5%	0.9521		11.0%	4.1%	0.0000	***
Certified seed												
Maize	10.8%	2.1%	0.0000	***	11.6%	10.4%	0.0453	**	13.4%	4.8%	0.0000	***
Pigeon peas	4.5%	0.0%	0.0146	**	3.2%	2.8%	0.2880		4.8%	1.8%	0.0000	***
Soya beans	13.4%	0.0%	0.0000	***	11.4%	7.3%	0.0001	***	13.1%	6.1%	0.0000	***
Fertilizer												
Maize	25.4%	6.3%	0.0001	***	23.2%	17.9%	0.0854	*	28.0%	7.3%	0.0033	***
Pigeon peas	6.4%	2.7%	0.0001	***	5.6%	5.7%	0.9625		6.0%	0.5%	0.0133	***
Soya beans	15.7%	1.6%	0.0001	***	12.1%	10.5%	0.2815		14.0%	7.9%	0.0094	***

Source: Authors' computation using data from the IIES 2017 and IIES 2019

Note: ***, ** and * stands for hypothesis supported at least with 1%, 5% and 10% significance level, respectively.

6.3.4 Potential unintended effects

By unintended effects we mean any VCI effect (positive or negative) not identified by the project's theory of change. For this purpose, we used the potential unintended effects of InovAgro VCIs on crop diversification, household income diversification, intrahousehold bargaining power and land use rights of vulnerable groups (such as women and youth). Table 15 summarizes the unintended effects of InovAgro VCIs. Overall, this table shows that both MSD and non-MSD VCIs had unintended effects on household crop diversification. This is expected since these VCIs encouraged smallholder farmers to specialize rather than diversify. We considered this a potential unintended effect of the InovAgro VCIs, since smallholder farmers often use crop diversification as a risk-coping or mitigation strategy to deal with potential crop failure.

Table 15 Unintended effects of the InovAgro VCIs

		Statistically significant change between 2015 and 2019	
Outcome	Proxy variables	InovAgro/MSD programs	Non-MSD programs
Crop diversification	Total number of crops cultivated	(Negative)***	(Negative)***
Income diversification	Household head engaged in nonagricultural sector	(Positive)***	(Negative)***
	Spouse engaged in nonagricultural sector	(Positive)***	(Negative)***
	Female engaged in nonagricultural sector	(Positive)***	(Negative)***
	Youth engaged in nonagricultural sector	(Positive)***	(Negative)***
	Household member engaged in nonagricultural sector	(Positive)***	(Negative)***
Migration	Household has a temporary migrant member	(Positive)***	(Negative)***
	Household has a permanent migrant member	(Positive)***	(negative)***
Intrahousehold bargaining	Household head has credit access		
	Female has credit access	(Positive)***	NS
	Youth has credit access	NS	NS
	A family member has credit access	(Positive)***	NS
Land rights	Spouse has access to or control over land	(Positive)***	(Positive)***
	Female has access to or control over land	(Positive)***	(Positive)***
	Youth has access to or control over land	(Negative)***	(Positive)***

Source: Authors' computation using data from the IIES 2015 and IIES 2019.
Note: *** stands for hypothesis supported with at least 1% significance level. NS stands for nonsignificant.

Results also show a potential negative effect of InovAgro VCIs on youth access to or control over land, while the opposite is true for non-MSD VCIs. Other results show contrasting evidence on household income diversification and migration. The unintended effect is positive for InovAgro MSD exposed households while a negative effect is found for non-MSD exposed households.

However, it is worth noting that such results have caveats since they take no account of other factors that might have affected such outcomes. Future studies will need to, (i) control for potential selection bias (due to self-selection or program targeting) and other factors that might influence the outcome variables of interest; and (ii) use regression analysis to obtain econometric estimates in a further investigation of the direct benefits of MSD VCIs on beneficiary households and their potential unintended effects.

7 Conclusions

This study evaluated the impact of InovAgro VCIs on a range of outcomes; the outcomes were related to farmers' use of yield-enhancing agricultural inputs, access to information on agricultural input and output markets, maize productivity, income diversification, welfare, and effects on women and youth empowerment. The InovAgro interventions applied a MSD approach to stimulate the inclusion of the economically active poor farmers in productive agricultural value chains in northern Mozambique. This study faced numerous empirical challenges including, but not limited to, the need to adequately mitigate and address ethical issues; it also faced challenges associated with the implementation of the interventions and with assessing its scope of impact. Ultimately, we employed a modified RCT approach that used spatial identification strategy for classifying beneficiaries and nonbeneficiaries. We conducted a four-year longitudinal impact assessment that included surveys of beneficiaries and nonbeneficiaries. We employed an approach that used a FEs estimation technique on a matched sample and examined temporal trends in the outcome variables of the impacts of InovAgro VCIs.

The results show that InovAgro VCIs had a positive and significant impact on households' likelihood of using agrochemicals such as pesticides and herbicides and on farmers' use of fertilizer. This positive impact on farmers' use of agrochemicals and fertilizers remains robust whether households were exposed to a single VCI or to the complete package. Our results are consistent with several studies that demonstrate that improving market efficiencies affects technology adoption, including input and output market efficiencies (for example, Zeller et al., 1998), missing credit markets (Gine and Yang, 2009), and information market efficiencies (Cole and Fernando, 2016). Our results also reveal that the impact of the InovAgro VCIs had a positive and significant impact on farmers' use of certified seeds in the short term; this short-term impact seems to depend only minimally on the type or intensity of treatment (exposure). Interestingly, however, this significant InovAgro VCI impact is wiped out in the long term, with the estimated impact remaining positive but not significant. Our analysis also demonstrates that InovAgro VCIs boosted the agricultural productivity of beneficiaries, increased the likelihood of their output market participation (that is, their likelihood of selling maize produce), and increased the ratio of marketable surplus to total production.

Similarly, the results show that InovAgro VCIs had a positive and significant effect on beneficiary households' access to information on agricultural input and output markets, whether they are exposed to a single VCI or to the complete package. This evidence is consistent with evolving evidence that shows that an extension intervention featuring agrodealers, demonstration plots, and lead farmers contributes to statistically significant increases in access to information on both agricultural input and output markets (Kijima et al., 2012; Latynskiy and Berger, 2016). The results show that InovAgro VCIs had an unintended effect on access to, and control over, land by women and youth in the short term, while this unintended effect on women's land rights was wiped out in the longer term. As documented by Holden and Ghebru (2016), such short-term unintended effect of the InovAgro VCIs on land rights of youth could be associated with the fact that a more commercialized agricultural practice may not always guarantee a desirable/favorable outcome for the land tenure security of vulnerable groups, since greater profitability in agriculture could mean more competition for land and exclusive control of such resources by the (usually male) household head. Moreover, the results show that InovAgro VCIs had a positive impact on nonagricultural income-generating activities for women and youth in the short term.

The potentially negative long-term effect of the interventions on nonagricultural employment-generating activity is evident in the more positive and statistically significant impact on interventions beneficiaries than on nonbeneficiaries in the long term. This is evidence of the greater challenges for rural household members in transitioning to non-farm employment. Results regarding the unintended effect on temporary migration by women or youth are consistent with the overall short-term negative effect. There was no evidence of a welfare impact of InovAgro VCIs when beneficiaries were exposed to only one of the three types of VCIs; this remains consistent in both the short- and long-term scenarios. In both scenarios, however, a positive and statistically significant effect on household welfare (wealth) was shown when beneficiaries were exposed to the most intense (complete package) treatment. This suggests that the design and implementation of future MSD VCIs like InovAgro should take an integrated approach whereby VCIs are packaged together and complement each other, ensuring forward and backward linkages. Hence, we recommend that future MSD VCIs like InovAgro mitigate the negative effects on land rights of vulnerable groups such as youth, by taking deliberate measures to mainstream youth issues into their design and implementation. Unless this happens, the negative effects on land rights of youth may undermine the full potential of MSD VCIs in generating desirable outcomes for all. Overall, the study provides evidence in support of the InovAgro VCIs' systemic market-level effect, benefitting larger numbers of smallholder farmers beyond the project's direct sphere of influence than non-MSD VCIs.

InovAgro VCIs helped private sectors to lead initiatives and transform the way that agricultural market systems operate in northern Mozambique. InovAgro VCIs also created good competition between private seed companies and built stronger relationships along the value chains. However, working with different private partners, private seed companies and donors that provide large subsidies are required move away from VCIs that distort markets and threaten the viability of agrodealers by bypassing the country's agricultural distribution networks.

References

Abadie, A., Angrist, J. and Imbens, G. 2002. Instrumental variables estimate of the effects of subsidized training on the quantiles of trainee earnings. *Econometrica* 70 (1): 91–117.

Altenburg, T. 2007. *Donor approaches to supporting pro-poor value chains.* Cambridge, UK: Donor committee for enterprise development.

Amare, M. and Asfaw, S. 2012. Poverty reduction impact of food aid in rural Ethiopia. *Journal of Development Effectiveness* 4(2): 235-256.

Angrist, J., and Pischke, J. 2008. *Mostly harmless econometrics: An empiricist's companion*. Princeton University Press. ISBN 978-0-691-12034-8.

Amare, M. Asfaw, S. and Bekele S. 2012. Welfare impacts of maize–pigeon pea intensification in Tanzania. *Agricultural Economics*, 43 (1) (2012), 27-43

Ashraf, N., Giné, X., and Karlan, D. 2009. Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya. *American Journal of Agricultural Economics* 91: 973–90.

Banick, R.S., and Kawasoe, Y. 2019. Measuring inequality of access: Modeling physical remoteness in Nepal. Policy Research Working Paper No. 8966. Washington, DC: World Bank.

Benyishay, A., and Mobarak, A.M. 2019. Social learning and incentives for experimentation and communication. *Review of Economic Studies* 86 (3): 976–1009.

Bold, T., Kaizzi, K., Svensson, J., and Yanagizawa-Drott, D. 2017. Lemon technologies and adoption: Measurement, theory and evidence from agricultural markets in Uganda. *Quarterly Journal of Economics* 132: 1055–100.

Bulte, E., Beekman, G., Di Falco, S., Hella, J., and Lei, P. 2014. Behavioral responses and the impact of new agricultural technologies: Evidence from a double-blind field experiment in Tanzania. *American Journal of Agricultural Economics* 96: 813–30.

Cairns, J. E., 2012. Does selling fruits or vegetables provide a strategic advantage to selling maize for smallholders in Mozambique? A double-hurdle correlated random effects approach to evaluating farmer market decisions, Department of Agricultural, Food and Resource Economics. Michigan State University, East Lansing, Michigan.

Carrington, W., Detraigiache, E., and Vishnawath, T. 1996. Migration with endogenous moving costs. *American Economic Review* 86 (4): 909–930.

Chamberlin, J., Jayne, T.S., and Headey, D. 2014. Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa. *Food Policy* 48: 51–65.

Cole, S.A., and Fernando, A.N. 2016. Mobile'izing agricultural advice: Technology adoption, diffusion and sustainability. Working paper 13-047. Boston: Harvard Business School.

Donovan, J., Franzel, S., Cunha, M., Gyau, A., and Mithöfer, D. 2015. Guides for value chain development: A comparative review. *Journal of Agribusiness in Developing and Emerging Economies* 5 (1): 2–23.

Dorosh, P., and Thurlow, J. 2018. Beyond agriculture versus non-agriculture: Decomposing growth poverty linkages in five African countries. *World Development* 109: 440–45.

Duflo, E., Kremer, M., and Robinson, J. 2011. Nudging farmers to use fertilizer: Theory and experimental evidence from Kenya. *American Economic Review* 101: 2350–90.

Fischer, E., and Qaim, M. 2012. Linking smallholders to markets: Determinants and impacts of farmer collective action in Kenya. *World Development* 40 (6): 1255–1268.

Gine, X., and Yang, D. 2009. Insurance, credit, and technology adoption: Field experimental evidence from Malawi. *Journal of Development Economics* 89 (1): 1–11.

Holden, S.T., and Ghebru, H. 2016. Land rental market legal restrictions in Northern Ethiopia. *Land Use Policy* 55 (Supplement C): 212–221.

INE. 2008. Household Budget Survey 2008. Maputo, Mozambique: National Institute of Statistics (INE).

INE. 2015. Household Budget Survey 2015. Maputo, Mozambique: INE.

INE. 2020. Household Budget Survey 2020. Maputo, Mozambique: INE.

Jones, S., and Tarp, F. 2013. Jobs and welfare in Mozambique. WIDER Working Paper, No. 2013/045. Helsinki: UNU-WIDER.

Karlan, D., R. Osei, Osei-Akoto, I., and Udry, C. 2014. Agricultural decisions after relaxing credit and risk constraints. *Quarterly Journal of Economics* 129: 597–652.

Kijima, Y., Ito, Y., and Otsuka, K. 2012. Assessing the impact of training on lowland rice productivity in an African setting: Evidence from Uganda. *World Development* 40: 1610–1618.

Kondylis, F., Mueller, V., and Zhu, J. 2017. Seeing is believing? Evidence from an extension network experiment. *Journal of Development Economics* 125: 1–20.

Kosmidou-Bradley, W., and Blankespoor, B. 2019. Measuring mobility in Afghanistan using time-cost raster models: Methodology note (English). Washington, DC: World Bank Group.

Latynskiy, E., and Berger, T. 2016. Networks of rural producer organizations in Uganda: What can be done to make them work better? *World Development* 78: 572–586.

MADER. 2020. Integrated Agricultural Survey 2020. Maputo, Mozambique: Ministry of Agriculture and Rural Development (MADER).

Maestre, M., N. Poole, and S. Henson. 2017. "Assessing Food Value Chains Pathways, Linkages and Impacts for Better Nutrition of Vulnerable groups." *Food Policy* 68: 31-39.

Osorio-Cortes, L.E., and Lundy, M. 2018. Behavior changes scale-up in market systems development: A literature review. Policies, Institutions and Markets (PIM) Working Paper. CGIAR.

Platteau, J.-P., De Bock, O., and Gelade, W. 2017. The demand for microinsurance: A literature review. *World Development* 94: 139–156.

Ravallion, M. 2007. Evaluating anti-poverty programs. In *Handbook of Development Economics*, Vol. 4, Chapter 59, edited by T. P. Schultz and J. Strauss, 3787–3846.

Ravallion, M., 2009. Evaluation in the practice of development. *The World Bank Research Observer* 24 (1): 29–53.

Schmidt, E., Dorosh, P., Kedir Jemal, M., and Smart, J. 2020. Urbanization and structural transformation. In *Ethiopia's Agrifood System: Past Trends, Present Challenges, and Future Scenarios*, edited by P.A. Dorosh and B. Minten. Part Three: Economywide Perspectives, Chapter 12, 379–422. Washington, DC: International Food Policy Research Institute.

Smart, J., Ghebru, H., and Mogues, T. 2019. Access to markets for smallholder farmers in Alto Molócue and Molumbo, Mozambique: Midline survey report of InovAgro II Impact Evaluation Project. Washington, DC: International Food Policy Research Institute.

Tobler, W.R. 1993. Three presentations on geographical analysis and modeling: Non-isotropic geographic modeling, speculations on the geometry of geography and global spatial analysis. Buffalo, USA: National Center for Geographic Information and Analysis.

Tomich, T.P., Preetmoninder, L., Coley, M., Gollin, D., Meinzen-Dick, R., Webb, P., and Carberry, P. 2019. Food and agricultural innovation pathways for prosperity. *Agricultural Systems* 172: 1–15.

Tschumi, P., and Hagan, H. 2008. A synthesis of the Making Markets Work for the Poor (M4P) approach. London: Department for International Development; Bern, Switzerland: Swiss Agency for Development and Cooperation.

Uchida, H., and Nelson, A. 2010. Agglomeration index: Towards a new measure of urban concentration. In *Urbanization and Development*, edited by J. Beall, B. Guha-Khasnobis, and R. Kanbur. Oxford: Oxford University Press.

Van Campenhout, B., David, S., and Lecoutere, E. 2020. Information and communication technologies to provide agricultural advice to smallholder farmers: Experimental evidence from Uganda. *American Journal of Agricultural Economics* 103 (1): 317–337.

Van Campenhout, Bjorn. 2017. There is an app for that? The impact of community knowledge workers in Uganda. *Information, Communication & Society* 20: 530–50.

Vanloqueren, G., and Baret, P. 2009. How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. *Research Policy* 38: 971–983.

Weiss, D.J., Nelson, A., Gibson, H.S., Temperley, W., Peedell, S., Lieber, A., Hancher, M., Poyart, E., Belchior, S., Fullman, N., Mappin, B., Dalrymple, U., Rozier, J., Lucas, T.C.D., Howes, R.E., Tusting, L.S., Kang, S.Y., Cameron, E., Bisanzio, D., Battle, K.E., Bhatt, S., and Gething, P.W. 2018. A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature* 553: 333–336.

Westermann, O., Wiebke, F., Thornton, P., Körner, J., Cramer, L., and Campbell, B. 2018. Scaling up agricultural interventions: Case studies of climate-smart agriculture. *Agricultural Systems* 165: 283–293.

Weyori, A.E., Amare, M., Garming, H., Waibel, H., 2018. Agricultural innovation systems and farm technology adoption: findings from a study of the Ghanaian plantain sector. *J. Agric. Educ. Ext*. 24 (1), 65–87.

White, H. 2013. The use of mixed methods in randomized control trials. *New Directions for Evaluation* 138: 61–73.

Yitayew, A., Abdulai, A., Yigezu, Y.A., Deneke, T.T., and Kassie, G.T. 2021. Impact of agricultural extension services on the adoption of improved wheat variety in Ethiopia: A cluster randomized controlled trial. *World Development* 146: 105605.

Zeller, M., Diagne, A., and Mataya, C. 1998. Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity, and crop income. *Agricultural Economics* 19 (1–2): 219–229.

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