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Impacts of Quality Seeds of Improved Legume Varieties on Incomes and Poverty in Mozambique: An Ordered Choice Endogenous Switching Regression Analysis

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Abstract

This study assessed the impacts of improved seed technology adoption on farm income and poverty using data from 830 households in Mozambique. The sampled households face three ordered choices, including local varieties (24.58%), recycled seeds/grains of improved varieties (26.51%), and good quality seeds of improved varieties (48.92%). Results from endogenous switching regression (ESR) model show that adoption of good quality seeds triggers significant increases in net farm income, with an average gain of $207.51 per ha. Households who use improved varieties must procure good quality seeds for higher returns. Similarly, household daily per capita income increased by $0.66 for those who used good quality seeds. The data further show that adoption of good quality seeds reduces poverty by 8 percentage points, closes poverty gap, and minimizes the severity of poverty. The results point to the need to strengthen access to good quality seeds of improved varieties as part of strategies for promoting adoption of improved legume varieties, increasing farm and household incomes, and lifting smallholder farmers out of poverty.

1. Introduction

Efforts to achieve the Millennium Development Goals resulted in significant decline in global poverty by 2015. Sub-Sahara Africa (SSA), however, continues to record high incidence of poverty with increasing absolute number of persons living in poverty (World Bank, 2016). Mozambique is one of the countries in the sub-region with the highest incidence of poverty, about 48.4% of the population (32% in urban areas and 56% in rural areas) (World Bank, 2018).

While several factors may contribute to this, increasing productivity, especially in the agricultural sector, has been identified as one of the major strategies that can reduce poverty at the micro level. There is, in fact, huge opportunity for agricultural growth and development, through investments to develop and deploy technologies and innovations to unlock the potentials of the abundant land, labor and untapped water resources in SSA (World Bank, 2013). Application of improved agricultural technologies and innovations can significantly improve farm-level performance and wellbeing of smallholder households, who dominate the agricultural production systems in the region.

In Mozambique, agriculture is considered as a strategic and sustainable option for development, because it is the major source of livelihood, employing about 66% of economically active persons in the country (INE, 2019), source of income and food for rural economies. “Poverty Reduction” is actually a guiding principle for the Strategic Plan for Agricultural Sector (PEDSA), 2010-2019 (Ministry of Agriculture, 2010). The Government of Mozambique and its development partners have implemented interventions that aim at boosting agricultural growth and reduce poverty. For example, between 2013 and 2016, a team of researchers from the International Institute of Tropical Agriculture (IITA) and collaborators on the Tropical Legume II (TL II) project, through participatory variety selection (PVS), developed and promoted high yielding varieties of soybean in Kenya, Nigeria, Malawi and Mozambique (Chigeza et al., 2019). Similarly, between 2013 and 2016, optimum quantities of fertilizers required for high yields in cowpea production systems were identified and promoted by a team in Mozambique (Kyei-Boahen et al., 2017). The Soil Health Project (SHP) of Alliance for a Green Revolution Africa (AGRA) have been promoting integrated soil fertility management practices in the country since 2009 (AGRA, 2020). Conservation agricultural practices have also been developed and promoted in Mozambique because they present opportunity for agricultural intensification (Nyagumbo, 2016). All these interventions were intended to create resilience to climate change and variability, improve farm level performance, increase incomes and reduce poverty, and enhance food security among farm households in the country.

Available evidence in the country suggest that agricultural interventions, which range from improved technologies, innovations and institutional support, do not always benefit the very poor. A randomized control trial to examine the effects of input subsidies on technology adoption in 2012 and 2013 revealed that subsidies increase technology adoption but was accompanied with high consumption risk among smallholder farmers in the country (Carter et al., 2016). Agricultural extension services is also shown to increase farm income by 12% among adequately resourced farmers in rural Mozambique (Cunguara and Moder, 2011). Improved maize varieties adoption did not significantly improve incomes for all households, but for those who had access to markets and tractor serves, and used improved maize seeds (Cuguara and Darnhofer, 2011). This corroborated similar findings by Leonardo et al. (2018) who, in their ex-ante assessment of scenarios that can improve performance, concluded that adoption of agricultural intensification practices is only guaranteed when interventions facilitate access to labor and land, otherwise better-resourced farmers should be targeted. These findings suggest that selection of recipient of the benefits of interventions needs to be controlled.

All these studies, except Carter et al. (2019) assumed that the use of technologies and innovations promoted through the interventions were based on observable factors. Evidence from other parts of the sub-region suggest that improved technologies and innovations have improved crop yields and farm income, and reduced poverty and food insecurity in agricultural production systems when observed and unobserved biases are controlled. Adulai (2016), demonstrated that conservation agriculture technology adoption increased maize output and farm throughput accounting ratio, and reduced household poverty in Zambia. Soil and water conservation technology adoption is also shown to increased rice yields and net returns in Ghana (Abdulai and Huffman, 2014). Adoption of improved varieties of various crops have also increased crop yields and net returns to investments, crop incomes, and household incomes and asset ownerships in Ethiopia and Nigeria (Manda et al., 2019a; Manda et al., 2019b; Kassie et al., 2011). In Kenya, Kabunga et al. (2012) found that the use of improved planting materials, made available through tissue culture techniques, increased banana yields by 7% when adopted alone. Yields increased by 20% when it was complemented with irrigation.

Despite the robustness of the approaches applied by these studies, most of them consider technology adoption as binary treatment where in reality, these technologies are adopted as a package or in stages, as with the case of tissue culture technology and supplementary irrigation. The conservation agriculture technology package examined by Abdulai (2016) includes minimum tillage, maintenance of permanent or semi-permanent organic soil cover, and diversification of crop species. Since farmers do not have equal capacity, they may adopt various combinations of the components. A farmer may adopt only minimum tillage, or combine with maintenance of organic soil cover or all the three. As such, lumping them together as a single treatment can either overestimate or underestimate impacts.

In the case of such multiple treatment problem, there is the need to isolate the impacts of the various combinations applied by beneficiaries. Kassie et al (2014) addressed this challenge by applying a multinomial endogenous switching regression procedure to examine the impact of alternative choices of sustainable intensification practices on food security and production risk in Malawi. The study shows that simultaneous adoption of crop diversification and minimum tillage has high impact on food security and risk reduction, suggesting complementary benefit of the two components. The approach was also applied by Martey et al (2020) to show that planting drought tolerant maize (DTM) seeds in rows has relatively higher impact compared to DTM seeds or row planting alone.

The multinomial endogenous switching regress is useful, as it isolates the impacts of the different components and combinations of the technology packages. The approach is based on the assumption that the components of a technology package are independent. While this assumption may be true for some technology packages, there are situations where the adoption of one component of a technology depends on the other. A typical example is the use of good quality seeds of improved crop varieties. For this scenario, farmers are faced with three or more ordered choices. Farmers may adopt seeds of local varieties, recycled seeds of improved varieties or good quality seeds of improved varieties. Since farmers who choose either recycled seeds or improved seeds implicitly apply improved varieties, the two choices are not independent. Rather, farmers are faced with ordered choice, and therefore the multinomial endogenous switching regression will not produce consistent estimate of the impacts of the technology.

To address the challenge this paper applies the endogenous regime-switching regression procedure with an ordered choice proposed by Sirchenko (2017). Using data from a cross section of farmers in Mozambique, we estimate the impact of good quality seeds of improved legume varieties on farm productivity, income and poverty.

2. Quality seed dissemination in Mozambique

Since 2009, the International Institute of Tropical Agriculture (IITA), has been leading legume research activities in Mozambique, resulting in the release and dissemination of several improved varieties of cowpea and soybean, and complementary practices (Savala and Kyei-Boahen, 2020; Kyei-Boahen e al., 2017). During the period, the country recorded some improvements in legume productivity but those of most smallholder farmers were significantly below farm-level potentials, with reported yield gap of 41% and 64% for cowpea and soybean, respectively (Ronner and Franke, 2012). This was partly attributed to inadequate access to good quality seeds of improved varieties, compelling farmers to use recycled seeds and grains as seeds.

Access to good quality seeds is also highlighted in the PEDSA 2010-2019 as a major constraint to productivity increases (Ministry of Agriculture, 2010). The importance of seeds has also been identified as critical for the expected impacts of technologies and innovations in Mozambique (Cuguara and Darnhofer, 2011), and Ghana (Martey et al., 2020). These evidences informed modification to the interventions to include the promotion of good quality seeds of improved varieties. Through the refreshed approach, involving partnerships with seed companies and producers, 7,459 tons of good quality seeds were made available to farmers. A total of 366,591 farmer from 18 districts across Manica, Nampula, Tete, and Zambezia provinces, received training in improved legume production, which included awareness about the availability and sources of seeds of improved varieties (IITA, 2020).

These provinces are within the United States Agency for International Development (USAID) Feed the Future (FTF) Zones of Influence (ZOI) in Mozambique, and are known for significant share of legume production in Mozambique (MASA, 2017). This study contributes additional information about the performance of the initiative by providing evidence of the impacts of good quality seed adoption on farm performance and poverty in the 18 districts.

3. Methodology

3.1 Sampling and data collection

This study is based on data from a household survey conducted between October and November 2018 in the 18 intervention districts. Within each district, six communities were randomly selected from a list of legume producing communities, generated together with staff of the District

Extension Services. Similarly, eight legume producing households were randomly selected from a list of legume producing households, generated together with community leaders. Overall, 864 legume producing households were selected and interviewed. However, after cleaning the data and removing outliers, data from 830 households were used for the study. The 4% sample loss does not significantly affect the results and inferences from the analysis.

After generating the sample, trained enumerators were deployed to conduct informal interviews with the heads of the selected households or their representatives, using the Computer Assisted Personal Interviewing (CAPI) system. Each interview lasted for nearly an hour and half, and generated information on the characteristics of the households, their livelihood activities and welfare.

3.2 Description of variables in the data

As indicated in earlier sections, this study groups the respondents into three categories. Among the 830 households are those who cultivated legumes with seeds of local varieties (25%), those who cultivated with recycled seeds of improved varieties (27%), and those who cultivated with refreshed or good quality seeds of improved legume varieties (48%) (Table 1). The summary statistics of the location variables, which take the value 1 if the household is found in a location and 0 otherwise, suggest that the distribution of the three category of households are the same in Nampula and Zambezia, while Manica and Tete have relatively higher proportions of local variety and recycled seed households, respectively. The socioeconomic and agro-ecological conditions in the provinces are expected to have different influences on adoption, performance and welfare (Asfaw et al., 2005).

Table 1: Summary statistics of data

Variable	Sample (N=830)	Variety			Prob.>F
		Local (n=204)	Improved variety seeds		
			Recycled (n=220)	Refreshed (n=406)	
Manica	0.05	0.08	0.04	0.04	0.09
Nampula	.52	0.54	0.53	0.50	0.67
Tete	0.16	0.11	0.18	0.17	0.10
Zambezia	0.27	0.27	0.25	0.28	0.67
Community adoption	3.72	2.57	3.95	4.17	0.00
Male heads	0.90	0.89	0.90	0.90	0.93
Age of head	42.11	42.79	42.30	41.67	0.64
Years of education	5.02	4.69	4.54	5.45	0.00
Access to extension	0.41	0.27	0.29	0.54	0.00
Association	0.26	0.17	0.15	0.37	0.00
Household size (N)	6.49	5.77	6.16	7.04	0.00
Economically active persons	0.53	0.52	0.55	0.53	0.19
Asset index	1.26	1.33	1.16	1.28	0.40
Tropical livestock unit	0.81	0.52	0.62	1.07	0.01
Dist. to input source	2.23	1.10	1.32	3.30	0.01
Market sales	0.46	0.41	0.43	0.50	0.05
Price index	0.00	0.02	-0.03	0.01	0.58
Off-farm activities	0.44	0.42	0.40	0.48	0.14
Land size (ha)	7.57	2.62	16.94	4.98	0.29
Number of plots	1.67	1.50	1.53	1.83	0.00
Poor soils	0.03	0.03	0.03	0.03	0.98
Mechanized land preparation	0.15	0.14	0.12	0.72	0.21
Crop rotation	0.32	0.27	0.26	0.37	0.01
Seed index	8.16	8.07	8.16	8.19	0.29
Labor cost ($/ha)	28.96	28.00	20.18	34.20	0.05
Legume income ($/ha)	770.43	626.51	620.26	996.87	0.01
Daily per capita income ($)	1.11	0.84	0.65	1.49	0.00

Community adoption, in terms of the number of households who apply improved variety within a community, is used to measure neighborhood or peer effects (Baerenklau, 2005). Farmers are likely to adopt improved technologies when they have first-hand appreciation of the benefits accrued to their neighbors. It can also measure community idiosyncrasies like norms and regulations (Alemu et al., 2017).

The variable “Male head”, 1 for male household heads and 0 for female household heads, represents the gender of the household head. This variable has been extensively explored as proxies for access to productive resources. The effect on technology adoption and welfare may vary depending on the technology type, production system, and sociocultural dynamics in the study area (Theis et al., 2018). Similarly, age (years) can influence agricultural technologies in various ways. Obisesan (2014) for instance, showed that age negatively affected technology adoption, while Biru et al (2020) found no effect of age on technology adoption. Age and sex are thus, included in the analysis to examine whether their influence vary across the category of seeds applied by the farmers.

Information about available technology and their effective use is important for agricultural technology adoption and greater impacts (Shiferawa et al., 2012). Educated farmers have the capacity to acquire and use knowledge to make decisions about alternative choices (Mittal and Kumar, 2000). Extension and farmer associations have been linked to technology adoption and improved welfare in rural Nigeria (Wossen et al., 2017). In this study, the effects of years of education, access to extension services (dummy), and membership of farmer associations (dummy) on farmers’ decisions to adopt different qualities of seeds, farm income and poverty are examined. The knowledge of the farmers, as a measure of their exposure to information, was represented by their perception of the quality of their soils (dummy). Farmers may not invest a lot of resources into a field when they know that the soil cannot sustain production. In the absence of alternatives, however, farmers may be compelled to invest in improved technologies to reverse the trend of low productivity of their poor soils (Martey and Kuwornu, 2021). In addition to these, the study included variables that represent market access, including distance (km) to input sources and sales in market places (dummy) in the models. In the rural society, markets provide opportunity for socialization and exchanges, and can therefore influence adoption decisions.

Studies have examined the effect of household size (i.e. the number of persons living in the household) on technology adoption. Wossen et al., (2014) demonstrated that the probability that farmers adopt new resource management techniques is high among farmers who belong to larger household size. The size of the household can represent availability of labor, access to information and consumption needs. These factors may compel larger households to explore technologies that promise higher benefits. This study also examines the effects of the number of economically active persons in the household on quality seed adoption, income and poverty.

Apart from human labor resources, livelihood assets have been shown to increase probability of adoption (Kuang et al., 2020), and hence welfare. This study represented livelihood assets with total land area (ha), number of plots, off-farm income generating activities (dummy), household asset index computed, with the principal component analysis (PCA) (Jolliffe and Cadima, 2016), and total livestock unit (Rothman-Ostrow et al., 2020). It was expected that households who had adequate physical assets or livestock can easily transform them to cash and invest in improved technologies or purchase of their basic needs. To capture the effect of changes in prices (Wossen et al., 2018) on adoption decisions and impacts on farm income and productivity, a price index, also computed with PCA was introduced in the analysis.

Labor cost, measured in USD per hectare, was expected to influence the choice of seed qualities. The alternative that has high adoption potential may not significantly increase labor cost (Yigezua et al., 2018), or may even reduce labor cost. In addition to the purchase value of a seed quality alternative, the transaction cost of procuring the alternative increase the total cost of the seed by 20%, compelling farmers to explore most convenient source, regardless of the quality of the technology (Minten et al., 2013).

Instead of quantity or cost of seeds, this study examines the effects of seed use index on quality seed adoption and impact. Asfaw et al. (2012) recommends that improved variety development and delivery should create access to seeds to ensure increased adoption. For this study, the seed index represents access to seeds, and was expected to increase probability of good quality seed adoption (Shiferaw et al., 2008).

Complementary technologies facilitate the expression of the full potentials of a technology of interest, and thus expected to increase the probability of adoption. In this study, mechanized land preparation and crop rotation were expected to increase adoption of good quality seeds.

Two main outcome indicators, namely legume farm income and daily per capita income, were examined. Following Cunguara and Darnhofer (2011), farm income is computed as the value of legume production less the paid-out cost, including hired labor, fertilizers and agrochemicals used during the production process. Table 1 shows that the observed legume farm income for farmers who adopted good quality seeds of improved varieties is significantly higher. Similarly, their per capita daily income is higher than those who used recycled seeds and local varieties. Per capita income was computed as the total annual income from all income streams, including farm and off-farm income and remittances, divided by the household size and total number of days in the year.

3.3 Specification of the ordered treatment framework

The characteristics of the legume producing households presented in Table 1 determines their capacities and production decisions, z_i, which translates into farm and per capita incomes (y_i). With regards to the seed technologies, the households are faced with categorical choices, including local variety (1), recycled seeds (2) and quality (3). The decision to adopt alternative seed technologies is a categorical choice model with a latent variable z_i^*, a vector of parameters (σ_j), independent variables, w_i, and a standard normal shock μ_i with an infinite lower boundary. This is expressed as,

$$z_i^* = \widehat{\sigma} w_i + \mu_i$$

$$z_i = \begin{cases} 1 \quad \text{if} \quad -\infty < z_i^* \leq \mu_1 \\ 2 \quad \text{if} \quad \mu_1 < z_i^* \leq \mu_2 \\ 3 \quad \text{if} \quad \mu_2 < z_i^* \leq \mu_3 \end{cases} \tag{1}$$

Each choice can then be summarized as linear functions of vectors of parameters β_j, their observed characteristics (x_i), and independent error terms (ε_i) with 0 mean and correlation denoted as ρ_j.

$$y_i = \begin{cases} \widehat{\beta}_1 x_i + \varepsilon_{i,1} & \text{if} \quad (z_i = 1) \\ \widehat{\beta}_2 x_i + \varepsilon_{i,2} & \text{if} \quad (z_i = 2) \\ \widehat{\beta}_3 x_i + \varepsilon_{i,3} & \text{if} \quad (z_i = 3) \end{cases} \tag{2}$$

The objective is to estimate β_j (β_1, β_2 and β_3), but for a given choice y_i is not observed for all the categories so $\beta_j, \sigma_j,$ and ρ_j does not exist. Due to this missing data problem ordinary least squares (OLS) estimation of income will be biased.

3.4 Estimation of average treatment effect

Chiburis and Lokshin (2007) describes the two-step and Full Information Maximum Likelihood (FIML) estimation procedures that addresses the bias associated with OLS estimators of (1). In the case of this study, the two-step procedure would have applied ordered probit regression to produce consistent estimates of σ and μ_i from (2), then incorporate a derivative of the inverse mill (λ) ratio to estimate incomes in (1), only for cases where a treatment is observed.

The FIML procedure, on the other hand, simultaneously estimates the seed quality and income, produces parameter that maximizes the likelihood of observing the incomes of all the households. This results in the following equations,

$$E(y_{1i}|z_i = 1) = f(x_i, w_i, \beta_1\ ) + \lambda_{1i}\sigma_{1u} \quad (3)$$

$$E(y_{1i}|z_i = 2) = f(x_i, w_i, \beta_1\ ) + \lambda_{2i}\sigma_{1u} \quad (4)$$

$$E(y_{1i}|z_i = 3) = f(x_i, w_i, \beta_1\ ) + \lambda_{3i}\sigma_{1u} \quad (5)$$

$$E(y_{2i}|z_i = 1) = f(x_i, w_i, \beta_2\ ) + \lambda_{1i}\sigma_{2u} \quad (6)$$

$$E(y_{2i}|z_i = 2) = f(x_i, w_i, \beta_2\ ) + \lambda_{2i}\sigma_{2u} \quad (7)$$

$$E(y_{2i}|z_i = 3) = f(x_i, w_i, \beta_2\ ) + \lambda_{3i}\sigma_{2u} \quad (8)$$

$$E(y_{3i}|z_i = 1) = f(x_i, w_i, \beta_3\ ) + \lambda_{1i}\sigma_{3u} \quad (9)$$

$$E(y_{3i}|z_i = 2) = f(x_i, w_i, \beta_3\ ) + \lambda_{2i}\sigma_{3u} \quad (10)$$

$$E(y_{3i}|z_i = 3) = f(x_i, w_i, \beta_3\ ) + \lambda_{1i}\sigma_{3u} \quad (11)$$

Equation (3) is the estimated income of households who apply local varieties, while (4) and (5) are their counterfactual incomes if they had used recycle seeds or good quality seeds respectively. Similarly, (6) is the estimated income for households who applied recycle seeds, and (7) and (8) related counterfactuals. The same goes for good quality seeds in $(9), (10)$ and (11).

The results from the FIML estimation procedure enables the estimation of the effect of the treatment. Using local varieties as the base, the average treatment effect of good quality seeds adoption if given by$(11) - (9)$, and $(7) - (6)$ for the average treatment effect of recycle seeds adoption. To ensure identification model, distance to input sources, access to extension and the number of households who have adopted the technology within the community were included in the adoption model. These factors are expected to influence adoption but not incomes.

3.5 Estimation of poverty impacts

In this step of the analysis the estimated per capita incomes from the FIML estimation procedure are used to compute the Foster, Greer, and Thorbecke (FGT) poverty indices (Foster, Greer, and Thorbecke, 1984). The FGT is expressed as,

$$\mathrm{FGT}_{\alpha} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}-1}^{\mathrm{g}} \left(\frac{\mathrm{L} - \mathrm{y}_{\mathrm{i}}}{\mathrm{L}} \right)^{\alpha} \tag{12}$$

The variable N is the number of sampled households, g is the number of poor households, and L is the international poverty line of $1.9 per day. Poverty head count is obtained by setting $\alpha = 0$. The average depth of poverty is obtained by setting $\alpha = 1$, taking squared gives the poverty severity index.

4. Results and discussions

4.1 Estimated impacts of seed quality on incomes and poverty

The first part of the results in Table 2 shows the income gains when legume producing households adopt alternative seed technologies. Just like earlier studies on improved variety adoption and farm incomes (Manda et al., 2019b; Abdulai 2016; Awotide et al. 2015; Zeng et al., 2015), this study also found that adoption of good quality seeds of improved variety significantly increases farm income by $207.51 per ha.

Table 2: Impacts seed quality

Indicator	Refreshed			Recycle		
	Adoption	Non-adoption	Difference	Adoption	Non-adoption	Difference
<u>Income ($)</u>						
Net farm	941.58	734.07	207.51***	587.58	493.13	94.43
Per capita	0.98	0.32	0.66***	0.48	0.36	0.12***
<u>Poverty</u>						
Incidence	0.92	1.00	-0.08	0.99	1.00	-0.01
Gap	0.60	0.83	-0.23	0.75	0.81	-0.06
Severity	0.43	0.71	-0.28	0.61	0.68	0.07

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Even though the additional income per area is not significant for those who used recycled seeds, the gains from total land area cultivated is enough to meet household welfare needs. The results, however, suggest that lumping households who adopt refreshed and recycle seeds as improved variety adoption does not provide the true effects. The insignificant effect of recycled seeds of improved variety can pull down the significant effect of good quality seed, leading to underestimation of the impacts. This justifies the needs for agricultural technology impact evaluations to examine the effects of components of technologies instead of their aggregate effects. The results further suggest that there is however no incentive for recycled seed adoption because they are no longer vigorous and may have lost their original genetic attributes.

Increases in farm income reflect in significant increases in daily per capita income by $0.66 when the households adopt refreshed or good quality seeds. The per capita income gain from good quality seeds adoption is about a third of the minimum amount required ($1.9) to lift the households out of poverty. This serves as additional incentive for farm households to invest in good quality seeds if they want to move or stay out of poverty.

The results show that the incidence of poverty in the study area is far above the national average of 56% (World Bank, 2018). While this study applies the international poverty line of $1.9, the World Bank applies a poverty line of $1.49. In addition, the World Bank report computed income using aggregate consumption together with value of durable goods, while this study used the sum of income from all sources.

Despite the high incidence, good quality seeds adoption is shown to reduce poverty by 8 percentage points. This is higher than estimates obtained by Manda et al (2019b) who found 5 percentage points reduction in poverty due to improved cowpea variety adoption, and Wossen et al (2018) who found 4.6 percentage points poverty reduction due to improved cassava variety adoption. The similarity between the results of Manda et al. (2019b) and Wossen et al. (2018) may be due to the fact that they examined improved varieties, regardless of the quality of the seeds. This buttresses the argument that lumping adoption of good quality seeds together with recycled seeds may underestimate the impacts of improved varieties. Adoption of good quality seed reduces poverty gap by 23 percentage points and severity by 28 percentage points. The technology does not only reduce poverty incidence but also improves the ability of very poor households to escape poverty.

4.2 Determinants of good quality seed adoption

The two FIML models in Table 3 and Table 4 show that the likelihood of good quality seed adoption is low among households who are in Manica province, which, interestingly, has relatively higher number of seed companies among the four provinces. The province, by virtue of its location on the Beira corridor, is relatively commercialized which enables farm households to easily access off-farm income. Access to off-farm income can enable farmers to invest adequately in improve varieties but high level of commercialization can divert interest from agriculture and diminish the need to investment in improved technologies such as good quality seeds.

Households whose heads are females are less likely to adopt good quality seeds, a situation that is explained by existing sociocultural and institutional structures that create barriers to access to improved agricultural technologies (Rola-Rubzen et al., 2020). Usually, female headed households have limited access to productive resources, which impeded their ability to adopt improved agricultural technologies (Anang and Kudadze, 2019). Furthermore, inadequate financial resources limits the ability of female household heads in rural Africa to acquire quality seeds of improved varieties. In-deed the study also show higher number of plots increases likelihood of good quality seed adoption.

Education, extension and membership of association are important sources of information about availability and application of improved technologies, and have thus been shown to increase adoption of improved cowpea, maize and cassava varieties, and complementary technologies like improved granaries (Martey and Kuwornu, 2021; Biru et al., 2020; Manda et al., 2019; Takam-Fongang, et al., 2019; Wossen at el., 2018; Asante et al., 2017 ; Shiferaw et al., 2016; Cuguara and Darnhofer, 2011), and therefore increase the likelihood of good quality seed adoption. These factors also shape perceptions and knowledge of the quality of their soils and, thus, increases likelihood that they invest in good quality seeds to make the most out of their soils.

In addition to providing information about technologies, markets also provide access to technologies (Cuguara and Darnhofer, 2011), and therefore increases likelihood of good quality seed adoption. Contrary to expectations, distance to input sources increased likelihood of good quality seed adoption among the legume producing households. This finding accords with that of Shiferaw et al, (2014) who found positive effect of distance to markets on the adoption of improved wheat varieties in Ethiopia. Since good quality seeds are not adequately available within farming communities households who can afford to travel longer distance are more likely to gain access to and use good quality seeds. Provision of good quality seeds within these communities will enhance its subsequent adoption to achieve the desired impacts on incomes and poverty.

Table 3: FIML model for adoption impacts on farm income

	Adoption		Incomes					
			Local variety		Recycled seeds		Refreshed seeds	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Manica province	-0.43*	0.24	248.20	369.74	1487.36***	361.36	269.56	599.47
Nampula province	-0.11	0.13	193.22	225.82	248.16	174.05	692.42**	303.21
Zambezia province	-0.01	0.15	156.82	246.45	447.74**	203.43	660.87**	332.49
Sex of household head	-0.16	0.14	-29.17	212.25	-113.89	200.04	-101.44	345.56
Age of household head	0.01	0.02	-23.93	18.50	-23.33	22.52	-82.99*	47.35
Squared of heads age	-0.00	0.00	0.29	0.18	0.32	0.24	0.97*	0.52
Years of education of head	0.03**	0.01	-38.54*	23.31	-14.86	19.14	24.93	36.87
Household size	0.01	0.01	9.59	23.73	25.90	20.00	4.03	32.87
Econ. active persons	-0.18	0.21	708.37**	325.74	377.84	261.99	453.29	572.55
Association	0.29***	0.11	-115.75	191.08	249.34	178.06	-363.41	229.13
Tropical livestock unit	0.03	0.02	49.62	50.17	29.56	36.37	77.64*	42.20
Off-farm activities	-0.02	0.09	171.36	134.64	-16.87	124.75	-87.21	207.63
Asset index	0.03	0.04	93.84**	47.42	19.06	59.17	3.68	84.16
Land area	-0.00	0.00	-13.79	21.33	-0.02	0.30	-13.81	12.93
Number of plots	0.20***	0.06	149.39	105.30	-171.31**	84.11	-134.78	140.53
Mechanized land preparation	-0.00	0.14	75.92	220.53	-301.61	193.22	1128.24***	303.91
Crop rotation	0.01	0.10	-261.09*	148.20	-116.03	136.84	-273.82	219.27
Seed index	0.04	0.05	4.12	64.45	138.32*	80.02	121.69	122.60
Labor cost per ha	0.00	0.00	0.57	1.14	-0.63	0.82	0.24	1.52
Poor soil	0.13	0.24	28.58	350.81	-303.51	335.93	481.38	555.16
Sell produce in market	0.17*	0.10	141.34	138.62	-236.70*	137.91	486.65**	229.92
Price index	0.06	0.09	-133.12	177.13	-159.70	153.23	347.56**	177.23
Distance to input source	0.02***	0.01						
Extension	0.33***	0.10						
Number of adopters in community	0.37***	0.03						
Constant			319.76	732.25	-409.17	793.02	960.59	1477.50
LR test of independence (rho=0): Chi2(3)=7.38; Prob>chi2 0.0606								

Standard errors in second column

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: FIML model for adoption impacts on per capita income

	Adoption		Incomes					
			Local variety		Recycled seeds		Refreshed seeds	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Manica province	-0.45*	0.24	-0.37	0.43	1.02***	0.34	0.17	0.33
Nampula province	-0.09	0.13	-0.71***	0.26	-0.14	0.16	-0.32*	0.16
Zambezia province	-0.03	0.15	-0.08	0.29	0.70***	0.19	0.22	0.18
Sex of household head	-0.15	0.14	0.03	0.25	0.01	0.19	0.43**	0.19
Age of household head	0.01	0.02	-0.02	0.02	0.05**	0.02	0.00	0.02
Squared of heads age	-0.00	0.00	0.00	0.00	-0.00*	0.00	-0.00	0.00
Years of education of head	0.04**	0.01	0.02	0.03	-0.01	0.02	0.01	0.02
Household size	0.01	0.01	-0.10***	0.03	-0.10***	0.02	-0.07***	0.02
Econ. active persons	-0.19	0.21	0.10	0.38	0.56**	0.25	0.73**	0.30
Association	0.27**	0.11	-0.49**	0.22	-0.17	0.17	-0.21	0.13
Tropical livestock unit	0.04	0.03	0.02	0.06	0.12***	0.03	0.08***	0.02
Off-farm activities	-0.00	0.09	0.83***	0.16	0.61***	0.12	0.56***	0.11
Asset index	0.03	0.04	0.10*	0.05	-0.06	0.06	0.00	0.05
Land area	-0.00	0.00	-0.00	0.02	-0.00	0.00	0.02***	0.01
Number of plots	0.19***	0.06	0.24**	0.12	0.16**	0.08	0.03	0.08
Mechanized land preparation	-0.04	0.14	0.27	0.25	0.06	0.18	0.29*	0.16
Crop rotation	0.02	0.10	-0.08	0.17	0.05	0.13	-0.23**	0.12
Seed index	0.03	0.05	-0.08	0.07	0.17**	0.07	0.02	0.07
Labor cost per ha	0.00	0.00	0.00	0.00	0.00**	0.00	0.00*	0.00
Poor soil	0.14	0.24	-0.15	0.40	0.19	0.31	-0.02	0.30
Sell produce in market	0.16*	0.10	0.06	0.16	0.15	0.13	0.26**	0.12
Price- index	0.05	0.09	0.12	0.20	-0.27*	0.14	0.23**	0.10
Distance to input source	0.03***	0.01						
Extension	0.37***	0.09						
Number of adopters in community	0.35***	0.03						
Constant			-0.33	0.85	-4.02***	0.74	-1.08	0.81
LR test of independence (rho=0): Chi2(3)=20.62; Prob>chi2 0.0001								

Standard errors in second column
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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4.3 Determinants of incomes

In addition to good quality seeds, farm income is high for households in Manica, Nampula and Zambezia provinces. Manica and Nampula are relatively commercialized, and farmers may have access to relatively good prices for their produce. High prices and sales in markets actually increase farm income. Zambezia on the other hand, is recognized as the bread basket of the country. Conducive agro-ecological conditions together adequate knowledgeable in agricultural production may contribute to high levels of productivity.

The age of the household head was found to have positive significant effect on adoption of quality seeds, implying that older farmers are more likely to adoption quality seeds (Shiferaw et al., 2016). The effect of age indicates that accumulated experience in farm production can increase knowledge, and ability of households to make tactical farm decisions for increased farm productivity and income. Age like capacity to engage in economic activity, access to resources (seeds), physical assets endowment and livestock ownership are useful resources that can be harnessed for timely operations to increase farm productivity and incomes. Assets and livestock ownership enhance financial capacities of smallholder households to acquire vital inputs sch as quality seeds as well as other resources needed for production (Wossen at al., 2018; Manda et al., 2019b). Available assets such as livestock can easily be sold for cash and used to purchase needed inputs for crop production when needed.

Studies have shown positive relationship between education and adoption of quality seeds among maize farmers. Educated farmers are able to read, and hence have better judgment of issues relating to improved technology and hence more likely to adopt quality seeds (Takam-Fongang, et al., 2019; Shiferaw, et al., 2016; Biru et al., 2020). While education increases likelihood of improved technology adoption, higher education potentially keep households out of farming for white colored jobs. For those who remain in agriculture, they may not allocate adequate time for farm supervision, and hence, record low incomes.

With regards to income per capita, households who engage in off-farm income generation activities increased their sources and volume of income, which reflect in the positive effect. Economically active persons can contribute to household incomes by engaging in farm or off-farm income generating activities. This explains the observed relationship between the two. Off-farm work provides additional income for farm household which can be used for financing farm activities (Smale and Mason, 2014). More farm plots means larger production and sales volume that contribute to higher household income per capita.

5. Conclusion

This study applies an endogenous switching regime with ordered choice to show that good quality seed increases farm and household incomes, and reduce poverty. There is therefore the need to strengthen access to good quality seeds of improved varieties as part of the strategies of promoting the adoption of improved legume varieties. It also makes a case for further studies to disentangle agricultural technology packages to avoid under or overestimation of their impact on performance and welfare.

The high incidence of poverty among farm households, requires a concerted effort to consolidate and scale the modest gains made. The poor might need additional development interventions to fill the remaining income deficit and move out of poverty.

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