Smallholder Risk Management Solutions (SRMS) in Malawi and Ethiopia Replicable Business Model, Malawi: Social inclusion and impact evaluation Prepared by Oxford Policy Management o...

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SAIRLA

Sustainable Agricultural Intensification Research and Learning in Africa

Smallholder Risk Management Solutions (SRMS) in Malawi and Ethiopia

Replicable Business Model, Malawi: Social inclusion and impact evaluation

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Acronyms

Acronym	
AHCX	Agricultural Holdings Commodity Exchange
ATT	Average Treatment Effect on the Treated
C1	First-generation Certified seed
C2	Second-generation Certified seed
DFID	Department for International Development
EPA	Extension Planning Area
FAO	Food and Agriculture Organisation of the United Nations
FHH	Female-headed household
FISP	Farm Input Subsidy Program
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IHS	Integrated Household Survey
LUANAR	Lilongwe University of Agriculture and Natural Resources
MHH	Male-headed household
MWK	Malawian Kwacha
NGO	Non-Governmental Organisation
NSO	National Statistical Office
OPM	Oxford Policy Management
P4P	Purchase for Progress
PPP	Purchasing Power Parity
PSM	Propensity Score Matching
RBM	Replicable Business Model
SAIRLA	Sustainable Agricultural Intensification Research and Learning in Africa
SPSS	Statistical Package for the Social Sciences
SRF	Seed Revolving Fund
SRMS	Smallholder Risk Management Solutions
US$	United States Dollar
WFP	World Food Programme

Note: in August 2019 1 US Dollar (US$) = 956 Malawi Kwacha (MWK)

Abstract

A Replicable Business Model (RBM) using a revolving seed fund and managed by a cooperative was introduced in Phalombe district, southern Malawi to increase the supply of certified seed of improved pigeonpea varieties. After two years of operation, a household survey was conducted in the 2018-19 cropping season to evaluate the RBM in terms of social inclusion and the commercialisation of pigeonpea. The survey compared a treatment group of participants with a control group of non-participants. A poverty scorecard showed that 42% of households participating in the RBM fell below the national poverty line, while 76% fell below the international poverty line of $1.90 per day in 2011 ($1.25 per day in 2005). This compares closely with the corresponding figures for the control group of 46% and 78%, respectively. Significant differences between participants and non-participants were found for some additional poverty indicators not included in the Poverty Scorecard, but these showed no consistent bias towards the treatment group. Propensity Score Matching was used to measure the impact of the RBM on commercialisation. In terms of improved pigeonpea varieties, the RBM increased farmers' awareness of improved varieties, access to seed, and adoption by 46%. In terms of production, the RBM increased pigeonpea production by 65 kg per household, reflecting both a higher area planted (0.4 acres) and a higher yield (30 kg/acre). In terms of commercialisation, the RBM increased the share of households selling pigeonpea by 24%, the average quantity sold by 16 kg, and the average income from pigeonpea sales by MWK 4,741/household (US$ 5). The RBM also significantly increased the amount of pigeonpea used for home consumption by an average of 49 kg/household. We conclude that, although participants and non-participants differed in some poverty indicators, based on national and international poverty lines the RBM was socially inclusive. The RBM has also had a significant impact on improving access to certified seed and the adoption of improved varieties. However, the impact on commercialisation was modest. One third of the RBM participants did not sell any pigeonpea and two-thirds of pigeonpea production was not sold but kept for home consumption. In the case of staple food crops like pigeonpea, the twin objectives of social inclusion and commercialisation may prove too difficult to combine. On the other hand, by successfully combining social inclusion with higher household food security the RBM has benefitted poorer smallholders.

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1 Introduction

The commercialisation of staple food crops is widely viewed as a pathway from poverty for smallholders in Africa (DFID, 2015). However, commercialisation may exclude poorer smallholders if they lack access to these markets, or are risk-averse, or lack the necessary resources, knowledge and skills. Half the maize sales in Zambia, Kenya, and Mozambique are made by just 2% of farm households (Jayne et al., 2010). One way to reduce these barriers is through collective action. Organised into groups, smallholders can share risks, reduce transaction costs, and increase access to new technology. While collective action does not guarantee social inclusion – poorer farmers may not meet the criteria for membership, and groups may be captured by wealthier farmers – it has the potential to make commercialisation more socially inclusive than it would otherwise be if participation was left entirely to market forces.

The value chain for pigeonpea in Malawi is attractive to smallholders for several reasons. Pigeonpea (*Cajanus cajan*) is a grain legume whose deep roots make it resistant to drought. Because pigeonpea is usually intercropped with maize, it does not reduce household food security by taking land away from the staple food crop. Finally, pigeonpea is a source of cash income. About 35% of pigeonpea in Malawi is sold, with most sales going to the export market (Lo Monaco, 2003). Pigeonpea is exported either as whole grain or as processed grain, i.e. split, decorticated grain, known in Hindi as *toor dhal*. Whole grain is exported to India, whereas *toor dhal* is exported to the Indian diaspora in Europe (mainly the UK) and the USA. About 10% of *toor dhal* stays in Malawi for domestic consumption (Makoka, 2003). India imports about 35% of its requirements for pigeonpea. Myanmar is the biggest source of imports, followed by Tanzania, Mozambique and Malawi. While pigeonpea in Malawi is harvested mainly between July and September, the price of pigeonpea in India peaks in November–December, so exports from Malawi coincide with a period of relative shortage and high prices in India (Lo Monaco, 2003). Smallholders in Malawi are therefore well-placed to capture the gains from international trade in pigeonpea.

The Southern region is the centre of production for pigeonpea in Malawi. The SRMS project identified Sukamphete Cooperative in Phalombe district as its location for action research.[1] A stakeholder workshop that included agricultural extension, agricultural researchers, and smallholders was held to identify strategies to address systemic risks in the pigeonpea value chain (Weber and Tiba, 2017). This workshop identified two challenges. One was the availability of certified seed. Improved varieties have four advantages: (1) they are more drought resistant, maturing in 5-6 months compared to the 8-9 months for local varieties; (2) they are resistant to fusarium wilt, a major disease affecting pigeonpea (3) they have large, cream-coloured grains, which produce the light yellow *toor dhal* preferred by Indian consumers, and (4) they are easier to dehull, which reduces the time required for processing (Orr et al., 2017). Despite these advantages, the adoption of improved varieties remains limited. The second challenge was price volatility. Over the period 2013-2017, the producer price of pigeonpea ranged from MWK 100 to 700/kg. In two of these five years, producer prices were below the break-even price of MWK 120-160/kg (Weber and Tiba, 2017).

To address these challenges the stakeholder workshop developed a Replicable Business Model (RBM). To increase the supply of certified seed the RBM introduced a revolving seed fund (SRF). In Year 1, farmers would receive 2 kg of certified improved pigeonpea seed, of which 1 kg would be the improved variety Mwaiwathualimi and 1 kg would be the improved variety Chitedze 1. After harvest, each farmer would repay 4 kg of pigeonpea grain to the SRF or double the amount of grain for each kg of certified seed received, giving a total repayment of 8 kg. At least 400 kg of pure C1 seed from the returned pigeonpea would subsequently be included in the SRF, while the rest would be sold as grain and the income used to buy more certified seed for distribution in Year 2. To address price volatility, the SRMS project agreed to broker contacts with the World Food Programme (WFP) as a potential buyer, through the Purchase for Progress (P4P) initiative and by

1 The cooperative is located in Chitekasa village, one of 13 villages in the Bona village group, within Temani Environmental Planning Area, Jenala Traditional Authority and Blantyre Agricultural Development Division

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registering the Cooperative with the Agricultural Holdings Commodity Exchange [2] (Weber and Tiba, 2017). This was achieved before the start of the 2017-18 planting season.

The RBM has now operated for two cropping seasons. This was judged insufficient time to measure the impact of the RBM on poverty. However, it was considered long enough to determine how representative participants in the RBM were of the wider farming population. While the RBM may be an effective instrument for increasing the supply of certified seed, if it excludes poorer smallholders it may be less effective in reducing poverty. Similarly, two years was considered enough time to determine what impact (if any) the RBM has had on commercialisation. The main research question was: Has improved access to certified seed increased the share of farmers selling pigeonpea, the average amount sold, or the value of sales?

The general objective of this report, therefore, is to assess the performance of the RBM in terms of social inclusion and impact. Specifically, the objectives are to:

1) Compare the poverty status of participating and non-participating households; and
2) Measure the impact of the RBM on the commercialization of pigeonpea.

A subsidiary objective is to measure the rate of repayment of first-generation certified seed (C1) that was received in 2018-19, and to review the agronomic performance of C1 seed received in the previous year (2017-18) that was replanted as second-generation certified seed (C2) in 2018-19. This information is presented in Appendix 2.

2 AHCX is a subsidiary of Agricultural Holdings Limited. It buys a minimum quantity of 1 ton (20 bags of 50kg). The Agricultural Commodity Exchange for Africa buys all crops, paying cash on the spot. AHCX also operates a warehouse receipt system where farmers store crops after harvest in an AHCX warehouse and sell later when prices are higher (Orr et al., 2017).

2 Data and Methods

2.1 Data

Survey design: The treatment group consisted of households in Bona village group that participated in the RBM in the 2017-18 and 2018-19 crop years. The treatment households for survey were selected from households that received 4 kg of certified pigeonpea seed (the improved variety Mwaiwathualimi or Chitedze 1 in the first survey year (2017-18). The same households did not receive certified seed in both years. In 2017-18, seed was distributed to 253 households, while in 2018-19 seed was distributed to a new cohort of 200 households. However, if households replanted grain from certified seed received in 2017-18, this would give them two years' experience with improved varieties. This allows a fairer test of the impact of improved varieties on pigeonpea production and sales, gave more information about the spread of improved varieties through farmer-to-farmer diffusion, and gave a better evaluation of a revolving seed fund where farmers planted first-generation certified seed (C1) in year 1, and planted recycled second-generation certified seed (C2) the next year. Unfortunately, the reporting deadline for the SRMS project of December 2019 did not give enough time to include information on pigeonpea sales in the second year of the RBM. Thus, the reference period for the survey is the RBM's first year of operation (2017-18). This means that the impact of the RBM is based on the experience of just one year.

The control group consisted of households which grew pigeonpea in 2017-18 but did not participate in the RBM. These households lived in village groups that met three criteria (1) they had similar agro-ecosystems (2) they were sufficiently far away to prevent diffusion of improved pigeonpea seed from the treatment village group, and (3) they were accessible by foot from Sukamphete cooperative. Two village groups were selected as control villages with the assistance of the cooperative committee and the village chiefs. To verify their suitability, they were visited by the lead researcher. The chiefs of these two village groups told us that very few farmers had access to seed of improved varieties. Based on these field visits, Ngundu and Temani village groups were selected as control villages. A list was prepared for each of these village groups of 150 households growing pigeonpea in 2017-18.

Sample size:

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Table 1 shows the sample households for the treatment and control groups. In 2017-18, a household survey collected household-level information on poverty indicators, crops, and crop management from 249 of the 253 households that had received certified seed in 2017-18 (Orr et al., 2018). In the household survey for 2018-19, information was collected from a randomly selected sub-sample of 120 of these same 249 households. This is the treatment group. In addition, the household survey in 2018-19 collected information from a sub-sample of 120 households in two village groups (60 households in each village group). This sub-sample was randomly selected from a list of 300 households growing pigeonpea in 2017-18. This is the control group. The total sample size was 240 households, equally divided into treatment and control groups. A sample of 120 is considered a safe sample size for Propensity Score Matching (PSM), since non-matched households are dropped from the analysis.

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Table 1: Sampling for 2018-19 survey

	Treatment	Control		Total
Village Group	Bona	Ngundu	Temani	
Farmers receiving C1 seed in 2017-18	253	Nil	Nil	253
Farmers interviewed in 2018	249	Nil	Nil	249
Farmers receiving C1 seed in 2018-19 Same farmers as in 2017-18 Different farmers from 2017-18	0	Nil Nil	Nil Nil	0
Sample size for 2018-19 survey	120	60	60	240

Source: SRMS Household Survey, 2018-19

Data collection and processing: The questionnaire was pre-tested by the lead author between 8-12th July 2019. New administrative requirements left insufficient time to contract our usual research partner, the Lilongwe University of Agriculture and Natural Resources (LUANAR), for data collection. Instead, the questionnaire was administered by a single (male) investigator resident in Bona village group over a period of six weeks in August-September 2019. While this was slow it meant that the data, which was collected on a hand-held tablet, could be checked in real time by the programmer and errors quickly identified and corrected the next day. To save time for the investigator, interviews were conducted at the Sukamphete cooperative building in Chitekesa village and lasted an average of 45 minutes. The data were processed using the Statistical Package for the Social Sciences (SPSS), Version 23.

2.2 Methods

Social inclusion: The World Bank defines social inclusion as:

1. The process of improving the terms for individuals and groups to take part in society, and
2. The process of improving the ability, opportunity, and dignity of those disadvantaged on the basis of their identity to take part in society (World Bank, 2019).

For the purpose of this report, we define social inclusion in terms of the ability to take part in the process of agricultural commercialisation. In the context of the RBM, this means that participation should not be restricted to the non-poor but include a representative share of households below the poverty line. Inclusion, therefore, was measured by comparing the poverty status of the treatment and control groups. This was done in two ways:

a) Comparison with the national and international poverty lines

The questionnaire used the Poverty Scorecard for Malawi that calculates a household poverty score based on 10 indicators from Malawi's Second Integrated Household Survey (IHS) of 2004/5 to estimate the likelihood that a household has a consumption below a given poverty line (Schreiner, 2015). The 2004/5 IHS was conducted by the National Statistical Office of Malawi (NSO) from March 2004 to March 2005. Unfortunately, a Poverty Scorecard based on the IHS for 2010/11 is not available; however, the share of households in Malawi below the national poverty line showed no significant change between 2004/5 and 2010/11.[3] Thus, our use of a Poverty Scorecard based on the 2004/05 IHS should not unduly distort the results.

The Scorecard thus allows us to relate poverty levels in the sample households to a given poverty line, including the national poverty line for Malawi and a range of international poverty lines. All points in the Poverty

3 The share of households in Malawi below the national poverty line in 2010/11 was estimated at 50.7%, which was not significantly different (at the 95% confidence level) from the estimate of 55.9% in 2004/05 (Government of Malawi, [2012], p. 206, Table 13.2. The national poverty line based on the IHS conducted in 2016/17 has not yet been published (Government of Malawi, 2017).

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Scorecard are non-negative integers, and total scores range from 0 (most likely below a poverty line) to 100 (least likely below a poverty line). To get absolute units, scores must be converted to poverty likelihoods, or the probability of being below a poverty line. This is done using look-up tables. In the case of the national poverty line, for example, scores of in the range 40-44 have a likelihood of falling below the national poverty line of 39.6% (Schreiner, 2015). The likelihood of falling below a poverty line can also be used to calculate the poverty rate, or the percentage of households below a given poverty line. This is calculated by averaging the poverty likelihood for individual households. For example, suppose there are three sample households with poverty scores of 20, 30, and 40, corresponding to poverty likelihoods of 77.6, 55.1, and 39.6% of the national poverty line (Schreiner, 2015). The poverty rate is the households' mean poverty likelihood of 57.4% ((77.6 + 55.1 + 39.6) ÷ 3))

b) Comparison with other poverty indicators

Additional poverty indicators (not included in the Poverty Scorecard) were identified from published literature. Based on this literature, we identified seven poverty indicators:

Table 2: Additional poverty indicators

No.	Indicator	Source
1	Female household head	Mukherjee and Benson (2003)
2	High dependency ratio[1]	Mukherjee and Benson (2003)
3	Household food insecurity	Devereux et. al. (2006)
4	Small farm size/land *per capita*	Mukherjee and Benson (2003)
5	Sale of labour as a source of cash income	Devereux et. al. (2006)
6	Value of livestock	Mukherjee and Benson (2003)
7	Selected for Farm Input Subsidy Program (FISP)	Chirwa and Dorward (2013)

[1] i.e.. a high ratio of children/adults of non-working age to working adults.

Risk aversion ranking: To measure farmers' degree of risk aversion, we adapted the approach used by Holden and Westberg (2016), which asked farmers to choose between two alternatives, the first with a high yield in a good year and a low yield in a bad year, the second with a lower yield in a good year but a higher yield in a bad year. By progressively reducing yields over six choices, farmers can be categorised into six ranks based on their degree of risk aversion. The higher the rank, the greater the degree of risk aversion. We have called this a "risk aversion ranking". Pretesting this approach revealed that farmers were confused by the labels 'good' and 'bad' years, relating the suggested crop yields to experience on their own fields. This confusion was overcome when we re-labelled 'good' and 'bad' years as 'Year 1' and 'Year 2' and explained that this was an imaginary experiment and not based on their own experience.[4]

Impact evaluation: Since the RBM has operated for only two years it is too soon to measure the full impact of improved pigeonpea seed on household welfare. However, it is possible to measure the partial impact on pigeonpea commercialisation. In total, we compared differences in 14 outcome variables (

4 For example, a maize crop that gave 12 (50 kg) bags/acre in Year 1 and 0 bags in Year 2, OR a crop that gave 11 bags/acre in Year 1 and 2 bags in Year 2.

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Table 3).

Table 3: Outcome variables for impact evaluation

Potential impact	Outcome variable	Variable name (see Table 19)
Production	Total production of pigeonpea (kg)	ppharvest
	Area planted to pigeonpea (acres)	pparea
	Yield of pigeonpea (kg/acre)	ppyield
Commercialisation	Sold pigeonpea (1=Yes, 0 =No)	seller
	Quantity of pigeonpea sold (kg)	ppsold
	Income from sale of pigeonpea (MWK)	ppinc
	Income from sale of cereals (maize, sorghum, rice) (MWK)	cerinc
	Income from sale of other crops (MWK)	othcropinc
	Quantity of pigeonpea kept for home consumption (kg)	ppcons
	Value of fuelwood saved (MWK)	firewsav
Awareness, access, and adoption	Heard about of improved pigeonpea varieties (1=Yes, 0=No)	heardmv
	Ever planted improved pigeonpea varieties (1=Yes, 0=No)	evermv
	Planted in 2017-18 (1=Yes, 0=No)	adoption
	Adoption gap (8-9)	adoptgap

Impact evaluation using observational data requires a quasi-experimental approach. In a randomised experiment, the treatment and control groups are statistically identical, except that one received the treatment. With observational data, however, the treatment and control groups are not identical because of non-random differences between the two groups, which may lead to self-selection by the treatment group. Selection bias makes it difficult to be sure that we are observing the effect of the treatment or the effect of these non-random differences. Hence, we cannot be certain that the difference between the two groups is truly caused by the effects of the treatment.

Propensity Score Matching (PSM) controls for non-random differences by matching treatment cases with control cases that are as similar as possible (Calindo and Kopeinig, 2005). Closeness is measured by the propensity score, which is the probability of receiving the treatment based on a common set of observed characteristics. The aim is to identify a set of treatment and control cases that have a similar propensity score. Essentially, PSM is a retrospective randomization that creates the counterfactual situation found with experimental data, allowing us to say that the differences between control and treatment groups were caused by the treatment. PSM uses the matched sample to measure the Average Treatment Effect (ATE) on the population and the Average Treatment Effect on the Treated (ATT).

The quality or 'balance' of the match can be measured in two ways. One is to compare the distribution of the propensity scores between the matched treatment and control groups. A balanced sample shows a similar distribution for both groups (i.e. both groups have an equal chance of being selected for the treatment). The second is to test for significant differences in the means of independent variables used to match the sample. A balanced sample shows no significant difference in these means and a mean bias of 5% or less (Grilli and Rampichini, 2011). PSM is based on the matching of observable characteristics. However, there may also be unobserved characteristics that result in non-random differences between the treatment and control groups. This hidden bias can be detected using Rosenbaum bounds, which uses the Wilcoxon signed-ranks test to develop a sensitivity test for matched pairs. Since the degree of hidden bias cannot be observed, the test measures how much bias must be present to significantly change the effect obtained by matching. Rosenbaum bounds are based on a sensitivity analysis of the *p* values for the null hypothesis and measure the degree of bias required to be unable to reject the null hypothesis ($p < 0.05$). The PSM analysis was made using STATA version 14.0.

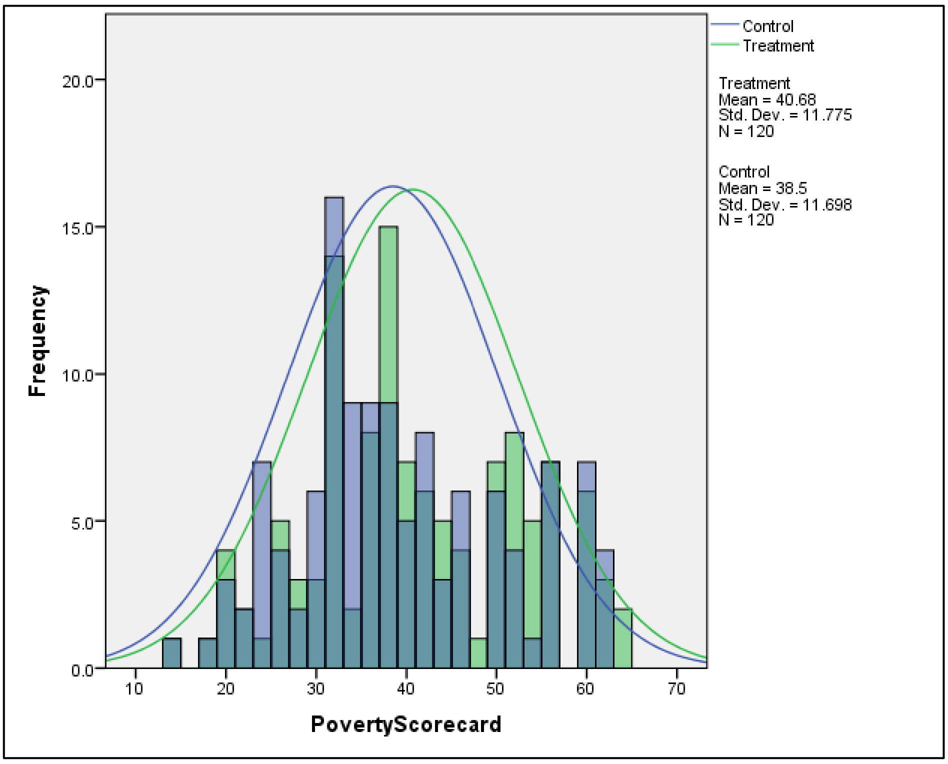
3 Results: Social Inclusion

The first specific objective of the household survey in 2018-19 was to measure social inclusion. This section presents the results, arranged as follows. Using univariate statistics, we compare treatment and control groups in two ways. First, we compare them using the poverty scorecard. Second, we compare them using additional poverty indicators.

3.1 Poverty scorecard

Figure 1 compares the poverty score for the sample households in the 2018-19 cropping season. This represents the poverty score in the cropping season for 2019, or one year after the treatment. The treatment households are represented by the green line and the control households by the blue line. The poverty score for both groups follows the normal distribution. However, a slightly higher number of treatment (green) households have higher poverty scores. As a result, the mean score for the treatment households (40.68) is higher than for the control households (38.50), but the difference (2.18 points) is not statistically significant ($p = .152$). Thus, the treatment households have the same poverty score as the control households.

Figure 1: Distribution of poverty scorecard for treatment and control groups



Source: SRMS Household Survey, 2019.

Table 4 compares the poverty status of the treatment and control groups against four poverty lines in Malawi. As already noted, since the RBM has operated for only two crop years, which was considered too soon for participation to have resulted in any change in poverty as measured by the poverty scorecard. Rather, the objective in comparing poverty scores between treatment and control groups was to determine whether poverty status had determined participation in the RBM. Table 4 shows the *likelihood of being poor* for four different poverty lines:

1) The *food poverty line* in Malawi for 2010/11, based on a mean consumption of Kcal 2,200. The food poverty line is MWK 58.52 per adult equivalent per day,
2) The *national poverty line* in Malawi for 2010/11, based on a mean consumption of Kcal 2,200 plus an allowance for basic needs. The national poverty line is MWK 94.33 per adult equivalent per day.
3) The *international poverty line* of US$ 1.00/day PPP in 2005, updated to US$ 1.90/day PPP in 2010/11.
4) The *international poverty line* of US$ 1.25/day in 2005, updated to US$ 3.10/day PPP in 2010/11.

The poverty score is related to a poverty line using look-up tables, which calibrate the poverty score in five-point intervals. The score for the treatment group (40.68) falls in the interval 40-45, while the poverty score for the treatment group (38.50) falls in the interval 35-39. As a result, the treatment and control households have different poverty likelihoods and poverty rates (Table 4). However, the confidence intervals for these five-point intervals show that these differences are not statistically significant at the 5% level. For a poverty score in the interval 35-39 the confidence interval is + 2.3% for the food poverty line, + 4.7% for the national poverty line, 2.1% for the US$ 1.90 international poverty line, and 1% for the US$ 3.10 international poverty line. Hence, the differences for the food poverty line, the national poverty line, and the international poverty line of US$ 1.90 per day are not statistically significant. We have therefore used the mean value of the poverty likelihood and the poverty rate for both groups.

Table 4: Poverty scorecard, by treatment and control groups

Poverty Lines	Group		
	Treatment	Control	Total
Poverty Score	40.68	38.50	39.59
	Likelihood of living below poverty line (%)		
Food Poverty Line MWK 58.52/day/adult equivalent)	14.7	20.0	20.0
National Poverty Line MWK 94.33/day/adult equivalent)	39.6	55.1	39.6
International Poverty Line (US$ 1.90/day/adult equivalent)	78.0	84.1	78.0
International Poverty Line (US$ 3.10/day/adult equivalent)	94.4	96.9	96.9
	Poverty Rate, or households living below poverty line (%)		
Food Poverty Line (MWK 58.52/day/adult equivalent)	18.8	21.1	20.0
National Poverty Line (MWK 94.33/day/adult equivalent)	42.1	45.5	43.8
International Poverty Line (US$ 1.90/day/adult equivalent)	75.6	77.8	76.7
International Poverty Line (US$ 3.10/day/adult equivalent)	92.9	93.6	93.3

Source: SRMS Household Survey, 2018-19 and Schreiner (2015).

In terms of poverty likelihood, there is a 40% likelihood that both treatment and control households lie below the national poverty line of MWK 94.33/day, and a likelihood of 78% that both groups lie below the international poverty line of US$ 1.90/day. In terms of the poverty rate, 44% of the sample households lie below the national poverty line, and 77% below the international poverty line of US$ 1.90/day. For rural

Southern Malawi in 2010/11, the corresponding figures were 36.4% and 66.7%, respectively (Schreiner, 2015:158-159).

3.2 Additional poverty indicators

In addition to the variables included in the poverty scorecard, we compared treatment and control households using a range of poverty indicators. Table 5 reveals some significant differences between the two groups, including the sex of household head, farm size, household food security, and hiring-in and hiring-out casual labour. However, no significant difference was found in the dependency ratio or in livestock units. Table 5 also compares one direct indicator of poverty, namely whether the household received a seed/fertiliser coupon under the FISP. Again, this was not significantly different between the two groups.

Table 5: Additional poverty indicators, by treatment and control groups

Poverty indicator	Treatment (n = 120)	Control (n=120)	All (n=240)	Sig.-level (*P*> 0.000)*
1. Sex of household head				
Male-headed households (no.)	87	100	187	.031
Female-headed households (no.)	33	20	53	
Never married	0	5	5	.011
Widowed	8	16	24	
Separated	10	5	15	
Divorced	2	7	9	
De jure (no.) (2+4)	21	18	39	.016
De facto (no.) (1+3)	12	2	14	
2. Dependency ratio				
Children aged < 15 (no.)	2.20	1.79	2.00	.020
Adults aged 60 > (no.)	1.23	1.18	1.21	.677
Adult females aged 15-60 (no.)	1.08	1.17	1.13	.373
Adult males aged 15-60 (no.)	0.28	0.27	0.28	.896
Total household size (no.)	4.80	4.43	4.61	.158
Dependency ratio (children + adults aged 60 > /adult males + adult females aged 15-60)	1.15	1.05	1.10	.424
3. Household food security				
Household self-sufficient in maize? (Yes)	9	3	12	
Household runs out of maize (month)	July	August	August	.000
4. Farm size				
Total farm size (acres)	2.39	1.77	2.08	.000
Households with *dimba* land (no.) **	64	49	113	.035
Households renting-in land (no.)	15	15	30	.577
Households renting-out land (no.)	11	8	19	.317

5. Ownership of livestock				
Oxen (no.)	0.03	0.02	0.03	1.000
Improved cows (no.)	0.26	0.12	0.19	.248
Local cows (no.)	0.23	0.08	0.15	.172
Goats (no.)	1.33	0.77	1.05	.028
Total livestock units (no.) **	0.418	0.202	0.310	.140
6. Use of hired labour				
Share of household income from casual labour (*ganyu*) (%)	19.2	15.8	17.5	.135
Households hiring-out *ganyu* labour (no.)	79	88	167	.207
7. Food aid as a source of income				
Households receiving seed/fertiliser coupon from FISP in 2019 (no.)	28	24	52	.319

Source: SRMS Household survey, 2019.

*ANOVA for continuous variables, or Chi-square value for categorical variables.

** Land that can be irrigated from a stream or well

*** Ox, 0.7 units; improved cow, 0.6 units; local cow, 0.5 units; goat, 0.1 units.

4 Results: Impact Evaluation

A second objective of the household survey was to measure the impact of the RBM in terms of its key objective, which is to accelerate the commercialisation of pigeonpea by increasing access to certified seed of improved varieties. This section presents the results, arranged as follows. Using univariate statistics, we compare treatment and control groups in three ways. First, we compare the production and management of pigeonpea. Second, we compare levels of commercialisation. Third, we compare awareness, access, and adoption of improved pigeonpea seed. Finally, we use multivariate analysis (PSM) to measure the impact of the RBM on these variables.

4.1 Crop production and management

Table 6 presents information on pigeonpea production and management in 2017-18. The results show that the treatment households planted significantly more pigeonpea, planted more intercropped pigeonpea, and harvested more pigeonpea than the control group. However, there was no significant difference in the share of households applying pesticide to pigeonpea.

Table 6: Pigeonpea production in the 2017-18 season, by treatment and control groups

Variable	Treatment (n = 120)	Control (n=120)	All (n=240)	Sig.-level (*P*> 0.000)*
Area planted to Mwaiwathualimi (acres)	0.88	0.44	0.66	.000
Area planted to Chitedze 1 (acres)	0.72	0.28	0.50	.000
Area planted to Mthawajuni (acres)	0.24	0.59	0.41	.000
Area planted to wa Hybrid (acres)	0.03	0.06	0.04	.167
Area planted to Nazombe (acres)	0.013	0.006	0.009	.703
Area planted to Forty-One (acres)	0.008	0.006	0.007	.310
Area planted to wa Local (acres)	0.004	0.008	0.006	.638
Area planted to other pigeonpea (acres)				
Total area planted to pigeonpea (acres)	1.88	1.39	1.64	.000
Area planted to Mwaiwathualimi that was intercropped (acres)	0.473	0.163	0.318	.000
Area planted to Chitedze 1 that was intercropped (acres)	0.429	0.163	0.296	.000
Total area planted to pigeonpea that was intercropped (acres)	1.17	0.731	0.951	.001
Did Mwaiwathualimi receive pesticide? (Yes)	3	9	12	.068
Did Chitedze 1 receive pesticide? (Yes)	1	1	2	.751
Quantity of Mwaiwathualimi harvested (kg)	49.91	11.64	30.77	.000
Quantity of Chitedze 1 harvested (kg)	44.22	7.88	26.05	.000
Quantity of Mthawajuni harvested (kg)	19.92	26.32	23.13	.270
Quantity of Wa Hybrid harvested (kg)	1.64	1.82	1.73	.880
Quantity of Nazombe harvested (kg)	0.00	0.00	0.00	Na.
Quantity of Forty-One harvested (kg)	0.00	0.00	0.00	Na.
Quantity of Wa Local harvested (kg)	0.00	0.00	0.00	Na.

Quantity of other pigeonpea harvested (kg)	1.51	0.67	1.09	.416
Total quantity of pigeonpea harvested (kg)	117.20	48.33	82.77	.000

Source: SRMS Household survey, 2019.

* ANOVA for continuous variables, Chi-square test for categorical variables.

Table 7 compares the use of inorganic fertiliser between the two groups. Only one in five households applied fertiliser in 2017-18. There was no significant difference between the groups in the share of households applying fertiliser (19%). Similarly, total expenditure on fertiliser was the same for both groups, although control households spent significantly more on urea (MWK 1213 compared to MWK 683). Both groups were equally likely to buy fertiliser from agro-dealers or using a seed/fertiliser coupon from the FISP.[5] Similarly, the reasons given for not buying fertiliser were the same for both groups.

Table 7: Fertiliser use in 2017-18, by treatment and control groups

	Treatment (n = 120)	Control (n=120)	All (n=240)	Sig.-level (*P*> 0.000)*
Used fertiliser in 2017-18? (Yes)	23	21	46	.434
Source of fertiliser (no.)				
Agro-dealer/AGORA retail outlet	7	5	12	.830
Coupon	12	11	23	
Other	3	5	8	
Total cost of basal (MWK)	629	775	702	.583
Total cost of urea (MWK)	683	1213	948	.089
Total cost of fertiliser (MWK)	1313	1988	1650	.190
Reasons for not buying fertilizer (no.)				
Fertiliser not available	4	4	8	.986
No money to buy fertiliser	94	95	189	
Quality of fertilizer is not good	0	0	0	
Don't know best way to apply	0	0	0	
Other	0	0	0	

Source: SRMS Household survey, 2019.

* ANOVA for continuous variables, Chi-square test for categorical variables.

4.2 Commercialisation

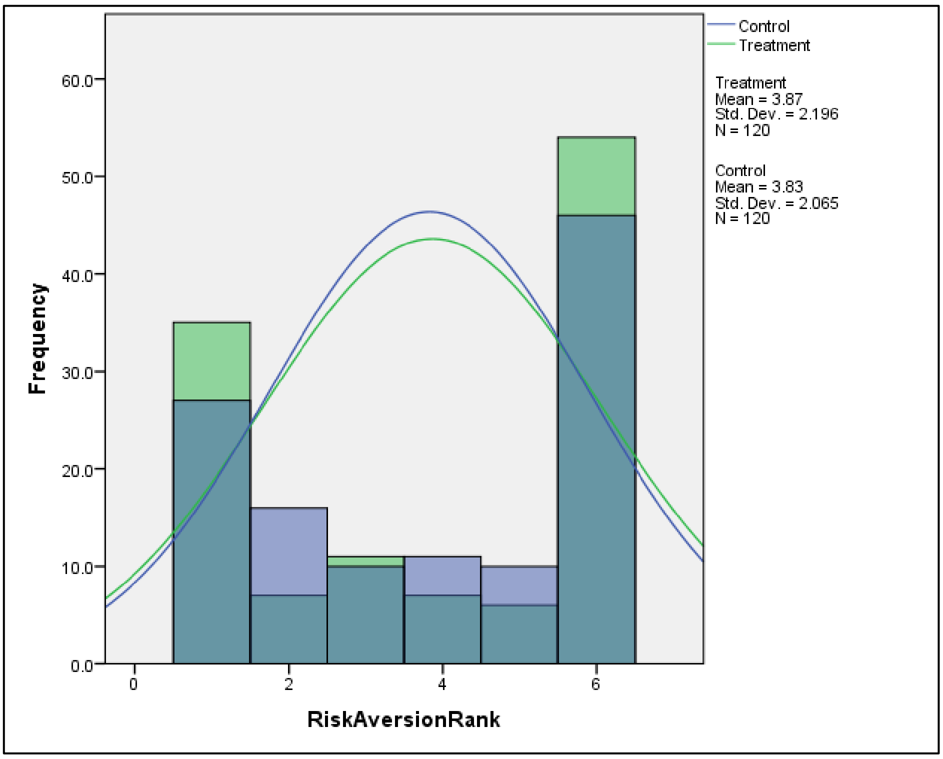
4.2.1 Risk aversion ranking

Smallholders may be reluctant to commercialise pigeonpea if they are risk averse. Consequently, it is important to compare aversion to risk between the treatment and control groups. Figure 2 compares the frequency distribution for the risk-aversion ranking conducted by the household survey for the treatment households

5 According to households in the sample that received vouchers in 2017/18, the vouchers entitled them to receive one 50 kg bag of basal fertiliser (diammonium phosphate), one 50 kg bag of top-dressing (calcium ammonium nitrate), and seed (maize, pigeonpea, and sorghum). The total value of the voucher was MWK 21,000, including MWK 10,000 for each bag of fertiliser and MWK 1,000 for seed (OPM 2018a).

(green line) and control households (blue line). The frequency does not follow the normal distribution but shows higher frequencies at the extremes ranks 1 (low risk aversion) and 6 (high risk aversion). The t-test showed no statistically significant difference in mean risk ranking for the treatment group (3.87) and the control group (3.85). (p = .880).

Figure 2: Distribution of risk aversion ranking for treatment and control groups



Source: SRMS Household survey, 2019.

4.2.2 Income from sales

The share of households selling pigeonpea in 2017-18 was significantly higher among the treatment group (63% compared to 48% in the control group). The amount of pigeonpea sold was also significantly higher among the treatment group (42 kg compared to 27 kg), as was the total income from pigeonpea (MWK 9886 compared to MWK 5047, or US$ 10.3 compared to US$ 5.3). Most of this extra income came from the sale of improved varieties. To assess the scope for commercialisation, households were asked if they could increase the area planted to pigeonpea. A significantly higher share of treatment households (75% compared to 58% of control households) reported that this was possible. Control households reported that the main constraint on expansion was a shortage of labour.

Table 8: Income from pigeonpea in 2017-18, by treatment and control groups

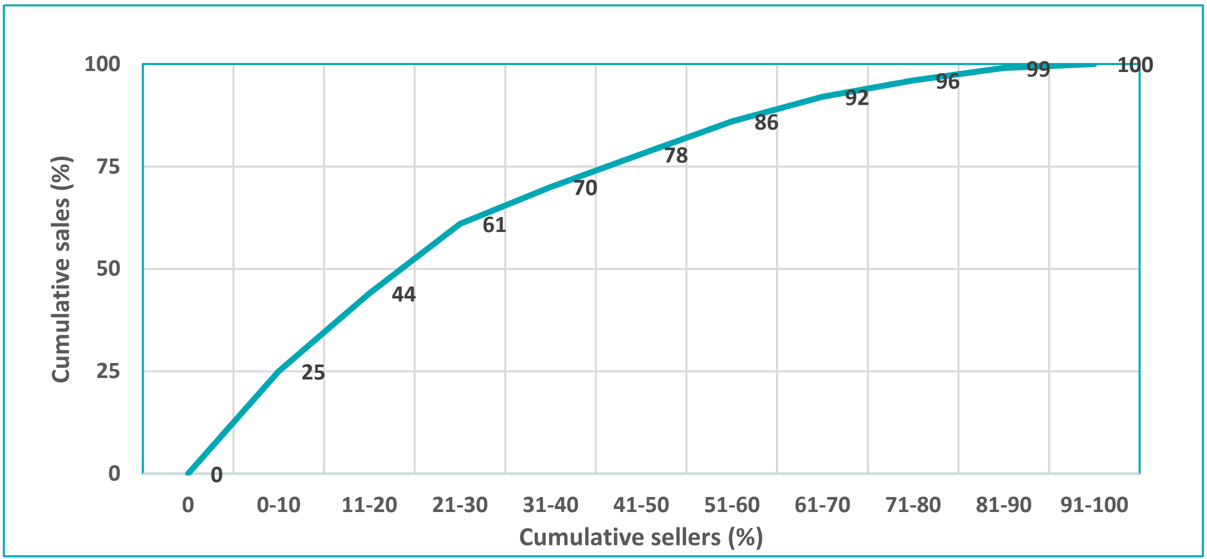
	Treatment (n = 120)	Control (n=120)	All (n=120)	Sig.-level (*P*> 0.000)*
Growers selling pigeonpea (no.)	76	57	133	.010
Quantity of pigeonpea sold (kg):				
Mwaiwathualimi	20.50	5.88	13.19	.000
Chitedze 1	15.34	5.04	10.19	.000
Mthawajuni	4.56	14.65	9.60	.004
Wa Hybrid	0.00	0.83	0.42	.157
Forty-One	0.00	0.00	0.00	Na.
Nazombe	0.00	0.00	0.00	Na.
Wa Local	0.00	0.00	0.00	Na.
Other	1.17	0.45	0.81	.418
Total pigeonpea sold	41.56	26.85	34.21	.015
Income from pigeonpea sales (MWK):				
Mwaiwathualimi	5057	1441	3249	.000
Chitedze 1	3668	1194	2437	.000
Mthawajuni	901	2138	1520	..029
Wa Hybrid	0	167	83	.157
Forty-One	0	0	0	Na.
Nazombe	0	0	0	Na.
Wa Local	0	0	0	Na.
Other	241	108	184	.446
Total pigeonpea sold	9886	5047	7467	.000
Price (MWK/kg)				
Mwaiwathualimi	249	249	249	.971
Chitedze 1	238	234	237	.686
Mthawajuni	190	176	180	.633
Can increase area planted to pigeonpea? (no.)				
Yes	90	69	159	
No	30	51	81	.003
If No, what is the reason?				
Shortage of land	19	12	31	.000
Other land not suitable	0	0	0	
Shortage of labour	12	41	53	
Other	0	0	0	

Source: SRMS Household survey, 2019.

* ANOVA for continuous variables, Chi-square test for categorical variables.

Pigeonpea sales are not spread evenly among sellers. Figure 3 shows the cumulative quantity of pigeonpea sold by the cumulative number of sellers. The results show that 10% of sellers account for 25% of total sales, while 50% of sellers account for 78% of total sales. In concrete terms, only 39 sellers (29%) sold 100 kg or more while the maximum quantity of pigeonpea sold was 250 kg.

Figure 3: Ogive of pigeonpea sales



Source: SRMS Household Survey, 2019.

Improved varieties have specific traits that attract a price premium on the Indian market. Table 9 compares the prices received by growers for three different varieties. The producer prices are "implicit" because they do not control for the type of buyer but were derived by dividing the total income received from the sale of each variety by the quantity sold. Mean prices were significantly different at the 1% level for all three varieties. The prices of the two improved varieties were higher than for the "local" variety Mthawajuni. The price premium over Mthawajuni for Mwaiwathualimi was 28% (MWK 69/kg) while for Chitedze 1 it was 24% (MWK 57/kg.

Table 9: Implicit producer prices for pigeonpea in 2017-18, by variety (MWK/kg)

Variety	Mean	n
Mwaiwathualimi	249	82
Chitedze 1	237	76
Mthawajuni	180	42

Source: SRMS Household survey, 2019. Note: All prices were statistically different at the 1% level of confidence.

Households in the study area have many sources of income besides pigeonpea. Among the sample, about one-third of cash income came from sources other than own-agricultural production, of which the most important was casual labour (*ganyu*) (

Table 10). however, most cash income came from the sale of crops. Of these, the most important were cereals, including rice.

Table 10 shows that there were few significant differences between the treatment and control groups in terms of income. Control households reported a significantly higher share of income from agriculture (68% compared to 62%) but no significant difference was found in the mean value of crop sales (MWK 23,761).

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Table 10: Household income, by treatment and control groups

	Treatment (n = 120)	Control (n=120)	All (n=120)	Sig.-level (*P*> 0.000)*
Sources of household cash income (%):				
Agriculture	62.0	68.4	65.2	.020
Casual labour (*ganyu*)	19.2	15.8	17.5	.135
Trade/business (*geni*)	15.6	15.6	15.6	1.00
Other	2.3	0.20	1.25	.058
Selling maize? (Yes)	33	16	49	.005
Selling sorghum? (Yes)	9	12	21	.324
Selling rice? (Yes)	11	14	25	.337
Income from selling cereal crops (MWK)	23,421	13,408	18,415	.267
Income from selling other crops (MWK)	5,139	5,554	5,347	.664
Total income from selling cereals and other crops (MWK)	28,560	18,962	23,761	.291

Source: SRMS Household survey, 2019.* ANOVA for continuous variables, Chi-square test for categorical variables.

Farmers were asked to identify the most important constraint on commercialisation of pigeonpea. The results were unambiguous. For both treatment and control groups, the main problem (84% of responses) was the low market price of pigeonpea. The availability and cost of improved varieties were not considered, even by the control group.

Table 11: Biggest problem growing pigeonpea for sale, by treatment and control groups

	Treatment (n = 120)	Control (n=120)	All (n=240)
Low market prices	98	103	201
Low production of pigeonpea	21	17	38
Market prices too variable	1	0	1
Seed of improved varieties is not available	0	0	0
High cost of seed of improved varieties	0	0	0
Poor quality of improved seed available in local markets	0	0	0

Source: SRMS Household survey, 2019. Chi-square = 1.545 *P* > .162

4.3 Awareness, Access and Adoption

A significantly higher share of RBM participants were aware about improved pigeonpea varieties (98% compared to 53% among the control group) and had access to these varieties, as evidenced by those reporting that they had ever planted them (93% of participants compared to 52% in the control group) (Table 12). On the principle that 'what farmers don't know can't help them', farmers unaware of improved varieties cannot be considered non-adopters. On the other hand, being aware of improved pigeonpea varieties but not planting them suggests that farmers lack access to seed.[6] We call this the "adoption gap". However, the adoption gap did not differ significantly between the treatment and control groups.

Table 12: Awareness, access and adoption of Improved pigeonpea varieties, by treatment and control groups

	Treatment (n = 120)	Control (n=120)	All (n=240)	Sig.-level (*P*> 0.000)*
Heard about Mwaiwathualimi (Yes)	108	53	161	.000
Heard about Chitedze 1 (Yes)	113	48	161	.000
Heard about Mwaiwathualimi OR Chitedze 1? (Yes)	117	64	181	.000
Ever planted Mwaiwathualimi? (Yes)	98	45	143	.000
Ever planted Chitedze 1? (Yes)	105	36	141	.000
Ever planted Mwaiwathualimi OR Chitedze 1? (Yes)	112	58	170	.000
Planted Mwaiwathualimi last season? (Yes)	98	45	143	.000
Planted Chitedze 1 last season? (Yes)	101	36	137	.000
Planted Mwaiwathualimi OR Chitedze 1 last season? (Yes)	110	59	169	.000
Heard about Mwaiwathualimi but never planted? (Yes)	10	9	19	.500
Heard about Chitedze 1 but never planted? (Yes)	8	12	20	.242
Heard about Mwaiwathualimi OR Chitedze 1 but never planted? (Yes)	5	6	11	.500

Source: SRMS Household survey, 2019.

Note: Figures in parentheses are percentages. * Chi-square test for categorical variables.

Among the control group, the main reason given for non-adoption of improved pigeonpea varieties was ignorance. Sixty eight percent of the non-adopters in this group were unaware these varieties existed (

6 This inference is based on two plausible assumptions, namely: (1) farmers are not fully satisfied the varieties they already plant and (2) they are willing to experiment with new varieties that are reported to have certain advantages over the ones they already know.

Table 13). The second most important reason for non-adoption in the control group (31%) was that they were unable to find seed. The affordability of improved seed was not a constraint on adoption.

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Table 13: Reasons for not planting improved pigeonpea varieties, by treatment and control groups

Reason	Treatment (n = 120)	Control (n=120)	All (n=240)
I am not aware of these pigeonpea varieties (no.)	10	46	56
Seeds of these varieties are not available (no.)	3	21	24
I did not have money to buy seed of these varieties (no.)	0	1	1
I tried planting these varieties before and do not like them (no.)	0	0	0
I don't know how to best plant these varieties (no.)	0	0	0
I am happy with other pigeonpea varieties (no.)	0	0	0
Total (no.)	13	68	81

Source: SRMS Household survey, 2019. Chi-square = 56.668 *P* > .000

Besides cash income and food, pigeonpea is also an important a source of fuelwood. Scarcity of fuelwood was a universal problem, and nine in ten of the sample households used pigeonpea stems for fuel (*nkhuni*) (Table 14). All agreed that this reduced cash expenditure on firewood and reduced the drudgery of women searching for fuelwood. To test if improved varieties reduced the supply of fuelwood, we compared the use of pigeonpea stems for fuelwood between the treatment and control groups. The results showed no significant difference between the two groups in the number of weeks stems lasted or in the amount of firewood saved (Table 15).

Table 14: Pigeonpea as a source of fuelwood

Statement	Totally agree/agree	Totally disagree/disagree	total
Finding enough firewood is a problem for my household	236 (98.3)	4 (1.7)	240 (100.0)
My household needs pigeonpea stems for firewood	214 (89.2)	26 (10.8)	240 (100.0)
Using pigeonpea stems for fuel reduces the amount of money my household spends on buying firewood	233 (97.1)	7 (2.9)	240 (100.0)
Using pigeonpea stems for fuel reduces the time my household spends collecting firewood	231 (96.3)	9 (3.7)	240 (100.0)

Source: SRMS Household survey, 2019. Note: Figures in parentheses are percentages.

Table 15: Pigeonpea and firewood savings, by treatment and control groups

Reason	Treatment (n = 120)	Control (n=120)	All (n=240)	Sig.-level (*P*> 0.000)*
Use pigeonpea stems for fuelwood? (Yes)	93	92	185	.500
How many weeks does fuelwood from pigeonpea last? (no.)	6.72	6.97	6.85	.608
How many bundles of firewood needed for one week? (no.)	3.13	3.12	3.12	.958
Value of firewood saved (MWK)**	4,206	4.350	4,274	.657

Source: SRMS Household survey, 2019.

* ANOVA for continuous variables, Chi-square test for categorical variables.

** The market price of 1 bundle (*malo*) of firewood was MWK 200.

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4.4 Impacts

The results on social inclusion in Section 3 revealed significant socio-economic differences between the treatment and control groups. To evaluate the impact of the RBM on the commercialisation of pigeonpea, we need to control for these differences. In this section we use Propensity Score Matching (PSM) to obtain a matched sample of treatment and control groups that will give unbiased estimates of treatment effects.

4.4.1 The propensity score

We first estimate the propensity score using logit regression, identifying independent variables that might influence allocation to the treatment, or in this case bias the cooperative management to select some members to receive certified seed and exclude others. These variables include sex of the household head, age and education of the head, dependency ratio, poverty score, size of farm, receipt of a seed/fertiliser coupon under the FISP program. and when the household runs out of maize.

Table 16 shows the estimation results. Of the eight independent variables, two were statistically significant, indicating that selection to receive improved seed was biased. Households with larger farms and that were more self-sufficient in maize were significantly more likely to be selected. This is clear evidence of selection bias, which means the treatment group is not random, and makes it difficult to infer a causal connection between the treatment and its effects.

Table 16: Determinants of selection into RBM

```
Logistic regression                         Number of obs     =        230
                                            LR chi2(8)        =      40.97
                                            Prob > chi2       =     0.0000
Log likelihood = -138.86117                 Pseudo R2         =     0.1286
```

treatment	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
genderhh	.5085194	.3970569	1.28	0.200	-.2696977	1.286737
agehh	.0296177	.0117825	2.51	0.012	.0065244	.0527111
educhh	.0137048	.0488873	0.28	0.779	-.0821125	.1095221
depratio	.0531557	.1780822	0.30	0.765	-.2958789	.4021904
farmsize	.5344728	.1558253	3.43	0.001	.2290608	.8398849
povescore	.0216874	.0141906	1.53	0.126	-.0061257	.0495005
coupon	-.0244324	.3728758	-0.07	0.948	-.7552555	.7063907
maize	-.1421039	.0444399	-3.20	0.001	-.2292045	-.0550033
_cons	-2.463384	1.011551	-2.44	0.015	-4.445988	-.4807792

Source: SRMS Household Survey 2018-19

4.4.2 Treatment effects

To overcome selection bias, treatment households were matched with control households based on their propensity score, or likelihood of selection. We used four different matching algorithms (kernel, nearest neighbour, radius and caliper matching) to obtain a matched sample. The mean bias ranged from 7.5% with kernel matching to 24.5% with radius matching. Since kernel matching (which uses a weighted average of *all* the control households within the range of a specific propensity score) gave the mean bias closest to the recommended level of 5%, we selected kernel matching to estimate treatment effects.[7]

7 Using the STATA command: kernel k(normal) bwidth(0.05).

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The matched sample was tested for balance using t-tests for each independent variable in the logit regression, and for sensitivity using Rosenbaum bounds. Results from these tests are shown in Appendix 1. The t-tests on the eight independent variables showed that the match was well-balanced, with no statistically significant differences between the treatment and control groups (Table 18). The Rosenbaum bounds test for sensitivity of treatment effects showed that the estimated impacts were not significantly affected by unobserved variables at levels of gamma between 1 and 1.5 (Table 19). In combination, these tests confirm that we can have confidence in our estimates of impact.

Table 17 shows the treatment effects of the RBM, for the 14 outcome variables named and defined in

Table 3. The result of interest is the mean difference in the average treatment effect on the treated (ATT), which shows the impact of participation in the RBM. In 10 of the 14 outcome variables, the ATT was statistically significant at the 95% confidence level (t-value 2 >). These included the production effects (production, area and yield of pigeonpea in 2017-18), four commercialisation effects (selling pigeonpea, the quantity sold, income from pigeonpea sales, and home consumption of pigeonpea), and three adoption effects (awareness, access to seed of improved varieties, and adoption of improved varieties).

In terms of production, the RBM increased production of pigeonpea by 65 kg/household. This was due to both an increase in the area planted (0.4 acres/household) and in yield (29 kg/acre). However. the additional production of pigeonpea stems did not result in any saving in the cost of firewood. In terms of commercialisation, the RBM increased the proportion of households selling pigeonpea by 24%, and income from pigeonpea by MWK 4740 (US$ 5). Higher income from pigeonpea had no adverse effect on income from the sale of cereals or other crops. Not only did higher production increase income from sales, it also increased home consumption by 49 kg/household. In terms of the adoption of improved varieties, the RBM increased awareness by 46%, access to improved seed by 47%, and adoption by 46%. However, the RBM did not change the adoption gap, or the share of households that had heard about improved varieties but had never planted them.

Table 17: Treatment effects

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
ppharvest	Unmatched	116.151786	48.3050847	67.846701	12.9244939	5.25
	ATT	116.151786	51.1525565	64.9992292	14.8767695	4.37
pparea	Unmatched	1.88705357	1.39618644	.490867131	.123928369	3.96
	ATT	1.88705357	1.48266504	.404388529	.154640673	2.62
ppyield	Unmatched	62.8804463	33.4720339	29.4084124	6.13214754	4.80
	ATT	62.8804463	33.481648	29.3987982	7.35509249	4.00
seller	Unmatched	.651785714	.466101695	.185684019	.064665635	2.87
	ATT	.651785714	.412047117	.239738597	.084545904	2.84
ppsold	Unmatched	43.2892857	26.4576271	16.8316586	6.16156369	2.73
	ATT	43.2892857	27.0872366	16.2020491	7.71260709	2.10
ppcons	Unmatched	72.8625	21.8474576	51.0150424	12.2124155	4.18
	ATT	72.8625	24.0653199	48.7971801	13.700597	3.56
firewsav	Unmatched	5258.92857	5886.44068	-627.512107	592.257369	-1.06
	ATT	5258.92857	5134.82005	124.108517	788.333588	0.16
ppinc	Unmatched	10395.6875	4937.69492	5457.99258	1404.49105	3.89
	ATT	10395.6875	5655.15126	4740.53624	1685.86177	2.81
cerinc	Unmatched	24518.3036	13635.4407	10882.8629	9381.66635	1.16
	ATT	24518.3036	16748.854	7769.4496	10684.9544	0.73
othcropinc	Unmatched	5011.66071	5648.27966	-636.618947	987.366267	-0.64
	ATT	5011.66071	4966.08147	45.5792405	1288.18951	0.04
heardmv	Unmatched	.973214286	.525423729	.447790557	.049686582	9.01
	ATT	.973214286	.508993951	.464220335	.073133262	6.35
evermv	Unmatched	.946428571	.474576271	.4718523	.051762384	9.12
	ATT	.946428571	.474032683	.472395888	.074635083	6.33
adoption	Unmatched	.928571429	.483050847	.445520581	.053067461	8.40
	ATT	.928571429	.466048255	.462523174	.075620932	6.12
adoptgap	Unmatched	.026785714	.050847458	-.024061743	.025642655	-0.94
	ATT	.026785714	.034961267	-.008175553	.034994041	-0.23

Note: S.E. does not take into account that the propensity score is estimated.

Source: SRMS Household Survey 2018-19

5 Discussion

5.1 Social inclusion

Social inclusion – the extent to which smallholders below the poverty line were selected to participate in the RBM – was measured by comparing the poverty status of treatment and control households. The treatment group comprised members of the Sukamphete Pigeonpea Farmers' Cooperative, which became functional in 2017 (Weber and Tiba, 2017), while the control group consisted of randomly selected pigeonpea growers from two neighbouring village groups.

Social inclusion was measured using the poverty scorecard, which allows us to relate poverty among the sample households to poverty at the national level. We found no significant difference between the treatment and control groups in the likelihood of being below the national poverty line (44%) (Table 4). Some differences emerged when we compared the poverty rate or the share of households below the poverty line. However, these differences were small. In terms of the national poverty line, the poverty rate among treatment households was 3% lower than for control households, while for the international poverty line of $ 1.90 per day (equivalent to $1.25 in 2005), the rate was 2% lower. The poverty rate among the sample households was higher than for the Southern Region as a whole. Among the sample, 44% of households lay below the national poverty line and 76% below the international poverty line of US$ 1.90/day. For rural Southern Malawi, the corresponding figures are 36% and 67%, respectively (Schreiner, 2015:158-159). Thus, the treatment group has a higher than average share of poor households. In terms of the overall level of poverty in the Southern Region, therefore, the RBM was socially inclusive.

The cost of cooperative membership is unlikely to exclude poorer farmers. According to the management committee, members are required to pay a one-time joining fee of MWK 1,500 (US$ 1.6). Members are entitled to buy shares in the cooperative priced at MWK 5000 per share (US$ 5.3). Among the treatment group, the average number of shares owned was 1.82, worth MWK 9,100 or US$ 9.5 (Table 20). Hence, the barriers to entry for the cooperative are low.

On the other hand, some additional poverty indicators did suggest lower levels of poverty among the treatment group. Treatment households had larger farms and were more likely to own *dimba* land than the control group (Table 5). On the other hand, treatment households were more likely to be headed by women and ran out of maize one month before the control group. How can we reconcile these inconsistent results? Three reasons suggest themselves. The first is that the poverty scorecard for Malawi is a composite index based on ten different indicators (Schreiner, 2015). Hence, a low score for one indicator may be offset by a high score for another. Arguably, this makes a composite index a more reliable measure of poverty than a single indicator. The second reason is that these variables are *indicators* rather than *measures* of poverty. To be sure, some indicators – participation in the national safety net programme, for example – are a direct measure of poverty. But others, such as a higher dependency ratio, are not precise measures but continuous variables with no pre-determined threshold dividing the poor from the non-poor. Finally, the poverty scorecard uses a *rate* criterion of poverty, which conceals variation among the poor. Where the share of households living below the international poverty line of US$ 1.90 per day is as high as seven in ten, we would expect to find significant differences in some poverty indicators.

5.2 Commercialisation

The RBM is based on two assumptions: (1) increasing the supply of improved pigeonpea seed will accelerate commercialisation and (2) collective marketing will increase smallholders' income from pigeonpea sales.

The RBM has had a significant impact on the adoption of improved varieties. Comparing matched samples of participants and non-participants gives some striking results. In the space of a single year, the RBM increased farmers' awareness, access and adoption of improved varieties by 46% (Table 17). However, there was no change in the "adoption gap" – the share of farmers who had heard about improved varieties but had never planted them. Thus, farmers only became aware of these varieties once they had access to seed and could plant them. This suggests that information about improved varieties has been almost non-existent. Other evidence supports this argument. A survey of four districts in Malawi in 2007-8 revealed that only 24% of farmers had ever heard of improved pigeonpea varieties (Simtowe et al., 2010: 52-53). Treatment farmers were unanimous that the RBM had increased the availability of improved seed (Table 23). Besides this direct impact, the RBM also had an indirect impact on awareness and access, through farmer-to-farmer diffusion. However, these spillover benefits were smaller than expected. Only 27% of the treatment group reported giving harvested grain to family members, while the share who sold grain to non-family members was 23% (Table 22). This relatively slow rate of diffusion reinforces the need for an RBM based on a revolving seed fund that can accelerate the diffusion of improved pigeonpea varieties.

Our results confirm that Malawi's privatised seed system has failed to deliver certified pigeonpea seed to smallholders. The usual explanation for this is limited demand. Three factors limit smallholder demand for certified seed. Pigeonpea is self-pollinated, so seeds can be recycled for up to three years without significant loss of yield. Pigeonpea also has a relatively high seed multiplication rate, and farmers have little difficulty in storing the crop – both factors that are likely to reduce the demand for purchased seed. Finally, the practice of coppicing pigeonpea – allowing the crop to grow for two seasons – reduces demand for seed still further. As a result, private seed companies claim that marketing certified seed is unprofitable. However, our findings show that limited demand may be primarily due to lack of knowledge. Once growers become aware that improved varieties exist, they are willing to plant them and share them with others.

This suggests that the seed system for pigeonpea in Malawi needs an alternative business model. At present, certified seed of improved varieties is available only through international NGOs, the state extension service, or the FISP. However, these business models require external financing, which makes them difficult to sustain, and reduces the continuity of supply. By contrast, the RBM tested in this project – a revolving seed fund managed by farmers themselves – is sustainable, provided that the participants repay enough harvested grain to buy fresh certified seed each year. Since the repayment rate in Year 1 was 85% (Table 20), this business model seems to have a promising future.

A puzzling feature of the RBM is that so few treatment farmers saved grain to replant improved varieties the following year. If access to certified seed of improved varieties was so difficult, why did fewer than half the treatment group (38%) recycle grain? The answer given was that seed was needed for home consumption. This may reflect the strategic role that pigeonpea plays in the food system. Households usually run out of maize in July or August, which is when improved varieties of pigeonpea are harvested. This allows households to substitute pigeonpea as a main meal in place of maize. *Makata* – pigeonpea cooked in the pod – and *makaka* – pigeonpea cooked with dried cassava – are popular ways to conserve the household's dwindling maize supply (Orr et al., 1999). Chronic food insecurity helps explain why recycling seed was less common than expected. For households experiencing hunger, the next meal was more important than next year.

Access to certified seed has accelerated the commercialisation of pigeonpea. The RBM increased the share of growers selling pigeonpea by 24%, the volume of pigeonpea sold by 16 kg per household, and income from pigeonpea sales by MWK 4,741 (US$ 5) per household. Faster commercialisation was achieved through increasing production by an average of 64 kg/household, thanks to a combination of expanding the area planted (0.4 acres) and higher yields (29 kg/acre). Importantly, this increase in commercialisation was achieved without any reduction in the income from the sale of cereal crops (maize, rice or sorghum) or other crops. This was because pigeonpea was mostly planted as an intercrop that did not take land away from other crops. Even more importantly, perhaps, commercialisation did not come at the expense of household food security. Indeed, home consumption of pigeonpea rose by 49 kg/household. Thus, the bulk of the increase in the production of pigeonpea (77%) was consumed by the household. Most of the protein in Malawian diets comes not from animal products but from grain legumes. As the major grain legume in southern Malawi, pigeonpea was the main source of protein for the sample households. Thus, higher production must have had a positive impact on nutrition, including nutrition for under-five children.[8] On balance, therefore, the RBM had a greater impact on home consumption and nutrition than on commercialisation and cash income.

A second assumption of the RBM was that collective marketing would result in higher prices for growers. In November 2018 the Sukhamphete cooperative sold its stock of pigeonpea to the ADMARC depot in Mulanje, for a reported price of MWK 230/kg compared to a price of only MWK 120-150/kg on the local market. However, we found no significant difference in average producer prices received by the treatment and control groups (

8 Pigeonpea is cooked in a variety of ways suitable for children, as *makata* (cooked with the pods removed) or as *chipere* (*dhal*) (cooked after removing the seed coat) (Orr et al., 1999).

Table 8). One explanation is that the treatment group did not sell their pigeonpea through the cooperative. According to the management committee, most participants repaid only the required amount of grain to the cooperative and sold most of their grain individually. Since the market price after harvest in 2017-18 did not even cover the break-even price of MWK 120-160/kg (Weber and Tiba, 2017), growers chose not to sell. Some (35%) sold no pigeonpea at all. Others (65%) waited for prices to rise. Once ADMARC offered to buy pigeonpea at 230 MWK/kg, growers were willing to sell. The ADMARC depot in Temani EPA is situated close to both the treatment and control villages. The identical prices received by both the treatment and control groups suggest that this is where most of them sold their pigeonpea.

A major challenge for the pigeonpea value chain is that price volatility gives buyers no incentive to arrange forward contracts. This became abundantly clear when we interviewed processing companies:

> 'There is no forward contracting because of the uncertainty over the Indian harvest and therefore the market price we can offer. Also, there is the risk of farmers side-selling if they get a better offer. Where is the guarantee that we will get it? Everybody wants to play safe. Also, 'Whom should we approach? Forward contracting works only with cooperatives that can aggregate the crop. We need at least 200 tons to make forward contracting viable.' (HMS Food and Grains Limited). (Orr et al., 2017: 13).

In the absence of forward contracts, growers are exposed to unpredictable prices and policies. In September 2018 the government announced that ADMARC would buy 23,000 t of pigeonpea.[9] But since this decision was made well after harvest when most pigeonpea had already been sold it was criticised as benefitting traders rather than growers.[10] Political considerations may have played a role since the government faced upcoming elections in May 2019. In this context, the risk of economic opportunism by local traders is high. Without a stable market, the value chain for pigeonpea makes commercialisation is a risky strategy for smallholders.

The policy decision to buy through ADMARC nullified any potential impact the RBM might have had through collective marketing. The ADMARC price of MWK 230/kg was well above the price found on local markets. Hence, there was no financial gain from collective action. However, this does not rule out such gains in the future. ADMARC offered no price premium for improved varieties. But private processors are willing both to buy in bulk and to pay a premium for white or bold grains:

> HMS Food and Trading checks the quality of pigeonpea at the factory gate. They just pay attention to colour, nothing else. White pigeonpea gets a 6–7% price premium, not more. Sometimes they will grade using other criteria, but this is an additional cost. They might pay a premium for bold grains, since this is preferred for toor dhal by Indian consumers in the UK. They will reject loads with lots of unfilled grains. This is a problem with white varieties, which mature earlier. Because farmers want to get peak prices, they harvest too early, so there are many unfilled grains (Orr et al., 2017: 18).

This suggests that collective marketing of the crop after harvest can benefit smallholders in the pigeonpea value chain. In Year 1 the RBM generated 16 tons of grain. While this is not enough for a forward contract, it may be enough to attract a bulk purchase from a large processing company.

Our findings have wider implications. DFID's conceptual framework for agriculture sees the commercialisation of smallholder agriculture as a strategy for poverty reduction (DFID, 2015). New technology can increase output from limited land. Armed with this technology, smallholders can take advantage of new market opportunities. Improved varieties of pigeonpea are a textbook example of such a technology. They are not just higher yielding. Breeders also designed these varieties to meet the needs of the market. Bold grains, white colour, ease of de-hulling – these were traits that processors and consumers wanted. Other varieties lacked these traits. Why then have improved varieties not had a greater impact on poverty?

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9 Minister Mussa says Admarc to buy pigeonpeas from smallholder farmers. Nyasa Times, 19 September 2018. https://www.nyasatimes.com/minister-mussa-says-admarc-to-buy-pigeon-peas-from-smallholder-farmers/

10 Committee says pigeonpea prices disadvantage farmers. The Nation, 18 September 2018. https://mwnation.com/committee-says-pigeon-pea-prices-disadvantage-farmers/

One explanation is that smallholders are unaware of these varieties. Among the control group in our sample, only half (53%) had ever heard about or planted Mwaiwathualimi or Chitedze 1. This market failure has been blamed on a privatised seed delivery system which is unprofitable for self-pollinated crops. Yet farmers also grew Mthawajuni, an unknown variety that has spread from farmer-to-farmer without official approval or involvement by private seed companies.[11] Yet in 2008 twice as many farmers knew about Mthawajuni as about improved varieties (Simtowe et. al., 2010). Clearly, lack of knowledge or access to seed cannot be the full explanation for the low adoption of improved varieties.

A second explanation is that growers lack incentives to plant improved varieties. In theory, these varieties should attract a price premium. Mwaiwathualimi has large, cream-coloured seeds that produce the yellow *toor dhal* favoured by Indian consumers, unlike the seeds of the variety Mthawajuni which are small and red-speckled (Orr et. al., 2017). Yet in local markets prices were determined not by attributes like colour or size of grain but by weight. This reduced the financial incentive to grow improved varieties. However, improved varieties also enjoyed higher yields, which would increase the volume and value of sales. Moreover, not all pigeonpea was sold. Higher yields also meant more pigeonpea for families to eat. The twin benefits to household income and food security suggest that growers did not lack incentives to adopt improved varieties.

A third explanation is that, even if growers adopted improved varieties, the small amount they sold means that the impact of commercialisation on poverty was limited. The average volume of pigeonpea sold by the treatment group was 42 kg/household and the average income from sales was MWK 9,886 or just over US$ 10 (

11 The provenance of Mthawajuni is unknown, but it may be an advanced line that 'escaped' from a research trial. Mthawajuni is a medium-duration variety (of 150–200 days) that owes its popularity to early maturity (the name Mthawajuni in Chichewa means 'escapes cold'), high grain yield and thick, bushy stems that make it a valuable source of fuelwood. (Orr et al., 2015)

Table 8) True, this was not a maximum. Three in four of the treatment households claimed they had enough land to plant more pigeonpea. At present, therefore, land is not a limiting factor, at least when pigeonpea is intercropped.[12] But expanding production will not necessarily result in higher sales. One third of the treatment group sold no pigeonpea at all, while the average share of production that was sold was only 35% (

12 In Mozambique, the recent surge in pigeonpea production was achieved by expanding the area planted, thanks to a 'bandwagon effect' as more farmers started growing the crop. By 2010 Mozambique had overtaken Malawi as an exporter of pigeonpea (Walker et. al., 2015).

Table 8). For Malawi as a whole, the average share of pigeonpea sold is even less (27%) (Djanza et al., 2017). A combination of small farm size and chronic food insecurity limits the volume that smallholders can sell. But even if the treatment group had sold its entire harvest, the income would have been just US$ 30 per household.[13] At the margin, this income is significant but its contribution to poverty reduction is modest.

Finally, the impact of commercialisation on poverty is limited by price volatility. Unlike teff in Ethiopia, the price for pigeonpea is determined not by domestic demand but by demand in India. While this demand is growing, prices fluctuate depending on the harvest in India and government price policy. As we have seen, this makes buyers in Malawi wary of forward contracting. Transport costs in landlocked Malawi are also higher than its competitors in Tanzania and Mozambique, which reduces the price that buyers can offer. As a result, the value chain for pigeonpea in Malawi lacks the stable foundation needed for commercial growth. Sales rise when prices are high and home consumption rises when prices are low. This makes the commercialisation of pigeonpea a risky investment for smallholders. In this context, commercialisation becomes an opportunistic form of income generation rather than a planned strategy for graduating from poverty.

[13] The treatment group sold an average of 41.56 kg/household, earning an income of MWK 9.886/household (

Table 8). This gives an average price of MWK 237.87/kg. The total volume of production among the treatment group was 117.20 (Table 7). Multiplying total production by the average price gives a value of MWK 27,878/household. The exchange rate at the time of the household survey was MWK 956 = US$ 1, which gives a total income of US$ 29.

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6 Conclusion

The basic assumption of the RBM was that a farmer-managed seed system based on a revolving seed fund would accelerate the adoption of improved varieties and increase the commercialisation of pigeonpea by resource-poor farmers. This evaluation was conducted to test social inclusion and the impact on commercialisation.

The results are mixed. On the one hand, the RBM is socially inclusive. Among the participants, the likelihood of being poor and the share of households living below either national or international poverty lines were the same for both RBM participants and non-participants. We conclude that the RBM and the cooperative system have proved an effective channel for delivering certified seed to resource-poor farmers. This has resulted in greater awareness of improved varieties, greater access to certified seed, and higher adoption. The RBM has also increased the commercialisation of pigeonpea. The RBM has increased the number of sellers, the average volume of sales, and the income from sales. However, many RBM participants did not sell any pigeonpea, and most additional production was consumed rather than sold. Commercialisation was still 'thin', and production for the market was confined to a minority, with 50% of sellers accounting for almost 80% of sales. Consequently, the impact of the RBM on commercialisation has been limited.

In conclusion, the value chain for pigeonpea holds a general lesson about smallholder commercialisation. A strategy of commercialisation is problematic when it is based on staple food crops. On the one hand, commercialisation based on these crops is more inclusive, because these crops are also grown by poorer farmers. The RBM tested by this project is a case in point. The RBM was not only socially inclusive but it accelerated the commercialisation of pigeonpea, in terms of both the number of sellers and the quantity sold. Nevertheless, the impact of commercialisation on poverty reduction was less than expected. The same factors that made the commercialisation of a staple food crop socially inclusive simultaneously imposed limits on the scale of commercialisation. Among poorer farmers the production of pigeonpea is constrained by small farm size while the amount they can offer for sale is limited by food insecurity and the need to prioritise home consumption. As with teff in Ethiopia, another staple food crop, it is hard to combine the twin objectives of social inclusion and poverty reduction through commercialisation. On the other hand, by successfully combining social inclusion with higher household food security the RBM has benefitted poorer smallholders.

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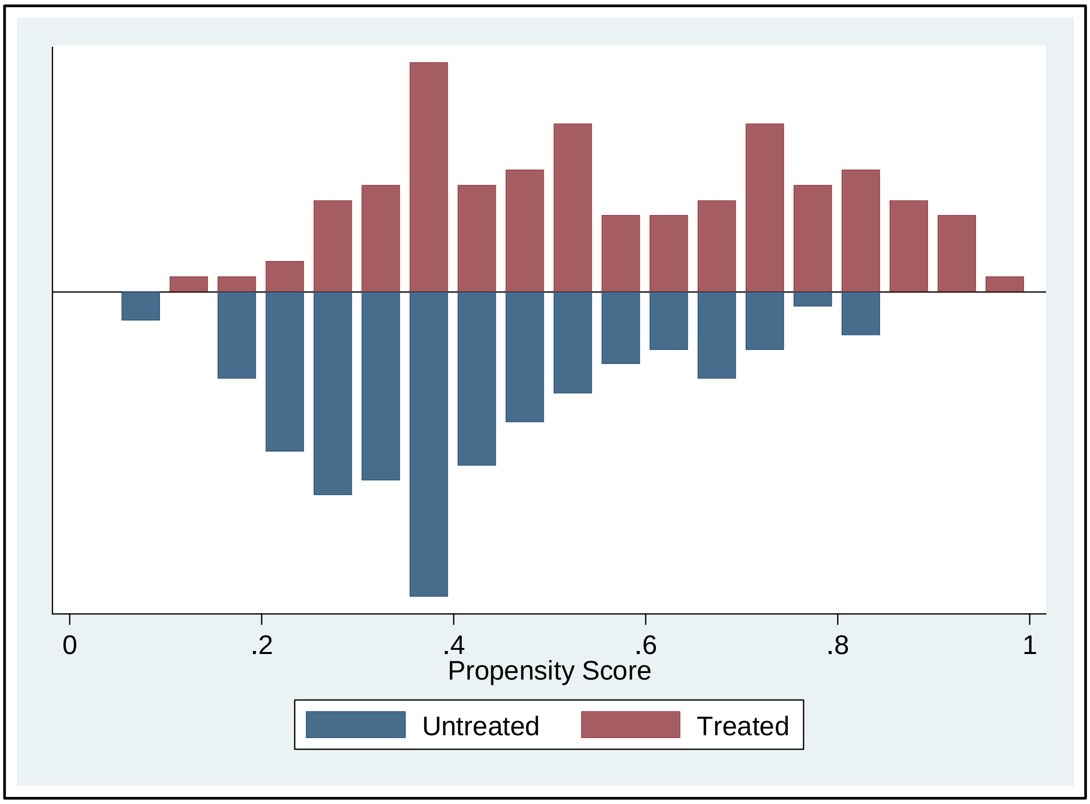
Appendix 1. Testing results for Propensity Score Matching

Balance

Figure 4 shows the distribution of propensity scores obtained using kernel matching. The histogram shows different densities for RBM participants (treated) and non-participants (Untreated). This implies that many households would not be good matches as the density of propensity scores of potential controls occurs at low propensity scores while than of treatment households are at high propensity scores.

Figure 4: Distribution of propensity scores for treatment (treated) and control (untreated) groups



Source: SRMS Household Survey 2018-19

Table 18 compares the mean values of the independent variables in the logit regression for both treatment and control groups after matching using kernel matching. The t-test shows that, for the matched sample, the mean values of the independent variables do not differ significantly between the two groups (t-values < 2). The mean bias for the matched sample is 5.7%, which is close to the recommended value of 5% (Grilli and Rampichini, 2011). This implies that kernel PSM using kernel matching has reduced selection bias due to these variables and that the matched treatment and control households have the same propensity for selection into treatment. The estimated Rubin's R (the ratio of treated to (matched) non-treated variances of the propensity score index) value is 1.01 which is within the standard value of (0.5, 2).

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Table 18: Significance tests for matched sample with kernel matching

Variable	Mean Treated	Mean Control	%bias	t-test t	t-test p>|t|	V(T)/V(C)
genderhh	.25	.19537	13.4	0.98	0.328	.
agehh	47.607	48.462	-6.7	-0.48	0.630	0.71
educhh	5.2411	5.1807	1.8	0.14	0.891	1.04
depratio	1.1472	1.0824	7.0	0.53	0.599	0.68*
povescore	40.375	38.758	13.7	1.05	0.296	1.12
farmsize	2.3638	2.2752	8.1	0.58	0.564	1.85*
coupon	.23214	.22412	1.9	0.14	0.887	.
maize	6.7321	6.9949	-7.5	-0.49	0.621	1.10

* if variance ratio outside [0.69; 1.45]

Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
0.011	3.51	0.898	7.5	7.3	25.0	1.77	33

* if B>25%, R outside [0.5; 2]

Source: SRMS Household Survey 2018-19

Sensitivity analysis

Treatment effects are sensitive to variables that influence selection into treatment but which are unobserved. Sensitivity analysis is used to measure the influence of these unobserved variables. The analysis was made using Rosenbaum bounds, which uses the sensitivity parameter gamma (Γ) to measure the log odds of being assigned to the treatment group due to unobserved factors. Gamma = 1 corresponds to the random assignment of treatments in experimental data, i.e. the absence of selection bias due to unobserved factors. Gamma = 1.1 measures the effect of a 10% change in the log odds of selection into treatment due to the influence of unobserved factors. The significance of the change in log odds is tested by the *p*-value of the upper bound at the 0.05 confidence level.

Rosenbaum bounds is appropriate only for continuous variables. Sensitivity analysis was carried out on the 9 continuous variables in Table 17. Table 19 reports the results. Based on the assumption that the treatment effect is over-estimated, the relevant statistic is the upper Rosenbaum bound (sig+). For example, the result for pigeonpea production (ppharvest) shows that even when Γ = 1.5, i.e. an increase of 50% in the log odds of selection into treatment, the *p*-value of the upper bound significance level (sig+) does not change but remains at 0. Hence, we can reject the null hypothesis of no treatment effect.

Table 19 shows that the *p*-value of the upper bound significance level (sig+) does not exceed 0 between Γ = 1.1 and Γ = 1.5. We therefore reject the null hypothesis of hidden bias on the treatment effects for the continuous variables in Table 17.

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Table 19: Sensitivity analysis of treatment effects

Rosenbaum bounds for ppharvest (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	70	70	61.5	80
1.1	0	0	67.5	75	57.5	82.5
1.2	0	0	64	75	55	87
1.3	0	0	62.5	77.5	51	87.5
1.4	0	0	60	80	50	90
1.5	0	0	57	82.5	49	92.5

```
* gamma  - log odds of differential assignment due to unobserved factors
  sig+   - upper bound significance level
  sig-   - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+    - upper bound confidence interval (a=  .95)
  CI-    - lower bound confidence interval (a=  .95)
```

Rosenbaum bounds for pparea (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	1.5	1.5	1.5	1.625
1.1	0	0	1.5	1.5	1.5	1.75
1.2	0	0	1.5	1.625	1.5	1.75
1.3	0	0	1.5	1.625	1.375	1.75
1.4	0	0	1.5	1.75	1.25	1.75
1.5	0	0	1.5	1.75	1.25	1.875

```
* gamma  - log odds of differential assignment due to unobserved factors
  sig+   - upper bound significance level
  sig-   - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+    - upper bound confidence interval (a=  .95)
  CI-    - lower bound confidence interval (a=  .95)
```

Rosenbaum bounds for ppyield (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	42.165	42.165	37.5	47.5
1.1	0	0	40	43.75	36	50
1.2	0	0	38.75	45	35	50.4
1.3	0	0	37.5	47	33.11	52.5
1.4	0	0	36.9725	48.46	32.265	54.545
1.5	0	0	35.73	50	30.88	55.555

```
* gamma  - log odds of differential assignment due to unobserved factors
  sig+   - upper bound significance level
  sig-   - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+    - upper bound confidence interval (a=  .95)
  CI-    - lower bound confidence interval (a=  .95)
```

Rosenbaum bounds for ppcons (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	25.5	25.5	22.5	35
1.1	0	0	25	28	20	37.5
1.2	0	0	25	30.15	17	42
1.3	0	0	22.5	34.5	15	47
1.4	0	0	22	37	15	50
1.5	0	0	20	38.075	12.5	50

* gamma - log odds of differential assignment due to unobserved factor
  sig+ - upper bound significance level
  sig- - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+ - upper bound confidence interval (a= .95)
  CI- - lower bound confidence interval (a= .95)

Rosenbaum bounds for ppsold (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	25	25	25	27.5
1.1	0	0	25	25	20	32.5
1.2	0	0	25	25.5	17	37.5
1.3	0	0	25	27.5	12.5	37.5
1.4	0	0	24.85	30	12.5	42.5
1.5	0	0	20	33.5	12.5	50

* gamma - log odds of differential assignment due to unobserved factors
  sig+ - upper bound significance level
  sig- - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+ - upper bound confidence interval (a= .95)
  CI- - lower bound confidence interval (a= .95)

Rosenbaum bounds for ppinc (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	5750	5750	4000	6500
1.1	0	0	5400	5750	3750	6800
1.2	0	0	4990	6015	3250	7250
1.3	0	0	4250	6325	3000	7990
1.4	0	0	4000	6542	2500	8625
1.5	0	0	3750	6900	2300	9200

* gamma - log odds of differential assignment due to unobserved factors
  sig+ - upper bound significance level
  sig- - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+ - upper bound confidence interval (a= .95)
  CI- - lower bound confidence interval (a= .95)

Rosenbaum bounds for firewsav (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	4500	4500	4500	6300
1.1	0	0	4500	5000	4500	6900
1.2	0	0	4500	5000	4500	7200
1.3	0	0	4500	5600	4500	7600
1.4	0	0	4500	6600	4500	7600
1.5	0	0	4500	6900	4500	8000

* gamma - log odds of differential assignment due to unobserved factors
sig+ - upper bound significance level
sig- - lower bound significance level
t-hat+ - upper bound Hodges-Lehmann point estimate
t-hat- - lower bound Hodges-Lehmann point estimate
CI+ - upper bound confidence interval (a= .95)
CI- - lower bound confidence interval (a= .95)

Rosenbaum bounds for cerinc (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	2500	2500	-2.7e-07	3500
1.1	1.1e-16	0	375	3000	-2.7e-07	4000
1.2	1.9e-15	0	-2.7e-07	3000	-2.7e-07	5000
1.3	2.1e-14	0	-2.7e-07	3500	-2.7e-07	5000
1.4	1.7e-13	0	-2.7e-07	3750	-2.7e-07	5000
1.5	1.0e-12	0	-2.7e-07	4000	-2.7e-07	6250

* gamma - log odds of differential assignment due to unobserved factors
sig+ - upper bound significance level
sig- - lower bound significance level
t-hat+ - upper bound Hodges-Lehmann point estimate
t-hat- - lower bound Hodges-Lehmann point estimate
CI+ - upper bound confidence interval (a= .95)
CI- - lower bound confidence interval (a= .95)

Rosenbaum bounds for othcropinc (N = 240 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	4000	4000	2850	5000
1.1	0	0	3500	4750	2500	5000
1.2	0	0	3250	4999.5	2500	5299.5
1.3	0	0	3000	5000	2260	6000
1.4	0	0	2650	5000	2000	6545
1.5	0	0	2500	5000	2000	7000

* gamma - log odds of differential assignment due to unobserved factors
sig+ - upper bound significance level
sig- - lower bound significance level
t-hat+ - upper bound Hodges-Lehmann point estimate
t-hat- - lower bound Hodges-Lehmann point estimate
CI+ - upper bound confidence interval (a= .95)
CI- - lower bound confidence interval (a= .95)

Source: SRMS Household Survey 2018-19

Appendix 2. Seed Supply Survey, 2018-2019

This Appendix analyses four components of the RBM in the two-year period 2017-18 and 2018-19: the repayment rate of pigeonpea grain; the re-cycling of certified seed received in 2017-18; the diffusion of improved varieties from farmer-to-farmer; and farmers' views on the design of the RBM. The analysis is based on the experience of the 120 households in the treatment group.

Repayment rates

The RBM is only sustainable if farmers are willing to repay harvested grain in exchange for C1 seed. Table 20 shows the repayment rates among the treatment farmers sampled in the household survey in 2018-19. Among the 120 farmers in this sample, 116 (97%) reported they had received C1 seed of Mwaiwathualimi or Chitedze 1 in the previous crop year (2017-18). Of the 101 farmers who received Mwaiwathualimi, 95 (94%) reported that they had repaid grain to the cooperative, while for Chitedze 1, 103 (95%) of those who received seed reported that they had repaid grain.

The original design for the RBM was for recipients to receive 2 kg of improved seed for each variety, and to return 4 kg of grain of each variety after harvest, thus returning a total of 8 kg (Weber and Tiba, 2017). However, because the number to receive seed was increased from 200 to 253, households received less than this (OPM 2018a). Table 20 shows that on average, farmers received 1.1 kg and 1.5 kg of certified seed of Mwaiwathualimi and Chitedze 1, respectively. The average quantity repaid was 2 kg and 2.5 kg of Mwaiwathualimi and Chitedze 1, respectively. On average, therefore, farmers repaid double for Mwaiwathualimi and 60% for Chitedze 1. In total, over 85% of farmers who received certified seed in 2017-18 reported repaying the agreed amount. Of the 28 farmers who repaid nothing, the main reason given was the low yield of pigeonpea (23 farmers or 82%).

The RBM was designed to distribute certified seed to a new cohort of farmers each year. However, 110 (92%) of the treatment group reported that they had received seed in both 2017-18 and 2018-19. The cooperative management informed us that some of the grain repaid in 2017-18 was not sold but re-distributed to farmers who had received seed the previous year for planting in 2018-19.

Table 20: Repayment rates, 2018-19, for treatment group (n=120)

Variable	Number	Percentage
Household member of cooperative? (Yes)	97	80.8
Household member of cooperative? (No)	23	19.2
Average years membership?	3.64	
Own shares in cooperative? (Yes)	94	96.9
Average number of shares	1.82	
Received Mwaiwathualimi seed in 2017-18? (Yes)	101	84.2
Received Chitedze 1 seed in 2017-18? (Yes)	109	90.8
Received Mwaiwathualimi OR Chitedze 1 certified pigeonpea seed in 2017-18? (Yes)	116	96.7
Received seed in BOTH years (2017-18 and 2018-19)?	110	91.7
Quantity Mwaiwathualimi seed received in 2017 (kg)	1.09	
Quantity Chitedze 1 seed received in 2017 (kg)	1.53	
If you received Mwaiwathualimi seed in 2017, did you repay any grain? (Yes)	95	79.2

If you received Chitedze 1 seed in 2017, did you repay any grain? (Yes)	103	85.8
How much Mwaiwathualimi grain did you repay? (kg)	1.96	
How much Chitedze 1 grain did you repay? (kg)	2.50	
Did you repay the agreed amount of Mwaiwathualimi grain to the cooperative? (Yes)	85	70.8
Did you repay the agreed amount of Chitedze 1 grain to the cooperative? (Yes)	87	72.5
If you did not repay, what was the reason?		
Yield of pigeonpea was too low	23	82.1
Amount to be repaid was too high	0	0
Other	5	17.9

Source: SRMS Household survey, 2019.

Recycling improved seed

Pigeonpea is self-pollinated, so seeds can be recycled for up to three years without significant loss of yield. We assumed that farmers who received certified (C1) pigeonpea seed in Year 1 (2017-18) would recycle this seed and plant C2 pigeonpea seed in Year 2 (2018-19). To evaluate the performance of recycled C2 improved seed, we asked farmers who replanted C1 seed questions about crop performance.

Table 21 shows crop production and management for those who planted C2 seed, i.e. those who replanted certified seed received in 2017-18. Of the 120 farmers in the treatment group, only 53 (44%) reported replanting this grain as seed in 2018-19. Of these 53 farmers, 45 (85%) reported they had saved grain for recycling. Thus, eight farmers (15%) who recycled grain obtained this from other sources. Of the 67 farmers who did not recycle grain as seed, the most common reason given (25 farmers or 37%) was that they had used all their harvested grain for home consumption.

The C2 grain performed well as seed. We have answers for 47 (89%) of the 53 farmers who recycled seed. Only 8 farmers (17%) reported that germination or yield was "poor". Twenty-seven farmers (57%) even reported that the yield of recycled seed was *higher* than the yield of certified seed in the previous season.

Table 21: Crop management and production for C2 seed

Variable	Number	Percentage
Replant recycled seed this season? Yes No	 53 67	 44.2 55.8
Receive any recycled seed from cooperative? (Yes)	20	16.7
Save any Mwaiwathualimi grain to recycle as seed? (Yes)	38	31.7
Save any Chitedze 1grain to recycle as seed? (Yes)	29	24.2
Save any Mwaiwathualimi OR Chitedze 1 grain to recycle as seed? (Yes)	45	37.5
If NO, what was the reason?		
Yield was not high enough	2	1.7
Used all grain for home consumption	44	36.7
Quality of grain was not good enough for seed	21	17.5

Do not like the variety	6	5.0
Other	2	1.7

Source: SRMS Household survey, 2019.

The RBM was expected to increase access to improved seed indirectly through farmer-to-farmer diffusion. Of the 249 treatment farmers who received certified seed in 2017-18, 65% planned to share some harvested grain (C2 seed) with other family members, while 60% planned to share with neighbours or non-family members. Family members would be given seed as a gift or repaid in grain, while neighbours or non-family members would receive it through sales. These numbers led us to expect a rapid diffusion of improved pigeonpea seed through informal channels in Year 2 (OPM 2018a). However, the household survey in 2018-19 revealed that the actual rate of diffusion was lower (Table 22). Of the 120 treatment farmers who received certified seed in 2017-18, only 32 (27%) gave or sold seed to family members while 27 (23%) gave or sold seed to other farmers. The average quantity given or sold (3 to 6 kg) was enough to plant 1-2 acres of intercropped pigeonpea. Nevertheless, the RBM did increase access to C2 seed among non-treatment households.

Table 22: Diffusion of C2 seed in 2018-19

Variable	Number	Percent	Qty (kg)
Saved or received seed for re-planting in 2018-19? (Yes)	53	44	
Used for planting own field	46	38	3.11
Gave/sold to family members	32	27	5.61
Gave/sold to other farmers	27	23	4.98

Source: SRMS Household survey, 2019.

Finally, we tested the assumptions of the RBM by asking treatment farmers directly for their opinions. The questions used a five-point Likert scale. The results presented in Table 23 combine the answers for agree/totally agree and for disagree/totally disagree. The results show that a large majority of farmers believed that improved pigeonpea varieties performed better than other varieties, with higher yields, earlier maturity and greater resistance to pests and diseases (Table 23). All 120 treatment farmers agreed that the RBM had improved access to certified seed while 98% agreed that it had reduced the risk of buying poor quality seed. All 120 treatment farmers agreed that selling seed collectively gave higher prices than selling individually. Finally, the majority did not agree that the repayment rate for the RBM was too high. We conclude that the design of the RBM – combining the supply of certified seed with collective marketing – addressed two systemic risks facing growers in the value chain for pigeonpea.

Table 23: Views of Treatment Group on the Replicable Business Model (n=120)

Statement	Totally disagree + disagree	Agree + totally agree	Neutral	Sig.-level ($P > 0.000$)*
Mwaiwathualimi/Chitedze 1 reduces the risk of crop loss from drought because it matures earlier than other varieties	11 (9.2)	109 (90.8)	0 (0.00)	120 (100.0)
Mwaiwathualimi/Chitedze 1 is more resistant to pests and diseases than other varieties	7 (5.8)	113 (94.2)	0 (0.0)	120 (100.0)
In a normal year, Mwaiwathualimi/Chitedze 1 gives a higher yield than other varieties	5 (4.2)	115 (95.8)	0 (0.0)	120 (100.0)

Getting certified seed from the cooperative has increased the availability of Mwaiwathualimi/Chitedze 1 seed	0 (0.0)	120 (100.0)	0 (0.0)	120 (100.0)
Getting certified Mwaiwathualimi/Chitedze 1 seed from the cooperative has reduced the risk of buying poor quality seed	2 (1.7)	118 (98.3)	0 (0.0)	120 (100.0)
I can trust the quality of Mwaiwathualimi/Chitedze 1 seed that I get from the cooperative	0 (0.0)	120 (100.0)	0 (0.0)	120 (100.0)
I get a higher price when I sell pigeonpea through the cooperative	0 (0.0)	120 (100.0)	0 (0.0)	120 (100.0)
The quantity of Mwaiwathualimi/Chitedze 1 grain that I must repay to the cooperative is too high	118 (98.3)	2 (1.7)	0 (0.0)	120 (100.0)

Source: SRMS Household survey, 2019.

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