Adoption and impact assessment of improved wheat technology on households´ wheat production in the Sudan

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ABSTRACT

Wheat is considered as one of the main cereals in the Sudan and the government considered domestic wheat production as a priority. The objective of this study was to analyze adoption and estimate its impacts on wheat yield as a major farm level impact for Support to Agricultural Research for Development on Strategic Commodities project (SARD-SC) implemented during the period from 2012-2016 in the Sudan. In order to estimate the determinants of adoption and to correct the self selectivity bias in the project participation, the two- step Heckman model was used which estimated a probit regression equation in the first step and corrected the bias through including the inverse Mill's ratio (IMR). To estimate the impact on wheat yield, the endogenous switching regression (ESR) model was used to estimate the average treatment effects resulting from the use of improved wheat varieties. The ESR model is potent in terms of correcting heterogeneity arising both from observed and non-observed household characteristics. The results showed that farmers' participation in hosting demonstration plots, attending field days and training through farmers field schools within the SARD-SC project had significantly enhanced adoption of the recommended wheat package in Sudan. The coefficient of the IMR indicated that the non-observable factors such as farmers' skills and motivations significantly decreased the area allocated for wheat and the use of Heckman's model had corrected the bias arising from such factors. The estimated ESR model showed that adoption of the package increased wheat yield by 1.98 ton/ha and farmers participation with SARD-SC project significantly increased the probability to adopt improved varieties. It is concluded that the strategy of intervention by the SARD-SC project to enhance wheat production in the Sudan enhanced both adoption of the recommended package and increased wheat productivity. It is recommended to implement the SARD-SC technology transfer strategy in establishing innovation platforms with the participation of various stakeholders to increase adoption of the recommended wheat package and improve yield for enhanced food security in the Sudan.

INTRODUCTION

Wheat is one of the main cereal crops consumed in the Sudan. The government considered domestic wheat production as a priority in the national food security planning. The Sudan wheat situation is characterized by rapid growth in consumption, continuous and variable deficit between domestic need and local production. SARD-SC project was launched to improve food security, alleviate poverty and increase income through enhanced productivity of selected major food crops with specific objectives to increase wheat productivity and production on a sustainable basis.

Few studies were conducted to analyze adoption and assess the impact of agricultural technologies in the Sudan. The impact of improved agricultural production technologies is strongly linked to adoption of these technologies. Abdelaziz and Ishtiag (2013) used logistic regression analysis to study adoption of faba bean and wheat production technologies in the River Nile and Northern States under International Fund for Africa Development (IFAD) funded project in the Sudan. They found that participation in demonstration plots and field days had significantly affected farmer's decision to adopt improved wheat varieties. They concluded that farmers who participated in IFAD project were more likely to adopt improved wheat varieties than those who did not participate.

Fageer *et al* (2013) identified sources of inefficiency in wheat production in the Northern State of the Sudan and found that the average technical efficiency of farmers in the sample was 77% implying that it is possible to increase wheat production in the study area by 23% using the same level of inputs. They reported that farmers' training, education and effective extension programs were found to be the most important factors influencing technical efficiency. They concluded that the average potential gain from the adoption of recommended package using that level of inputs was 1.47 ton/ha.

Ali Chebil *et al* (2015) focused on a metafrontier analysis of wheat farms in four different regions of the Sudan using non-parametric data envelopment analysis method to assess technical efficiency and technological gaps among regions. They found that the average technical efficiencies with respect to group frontiers for Gezira, Kassala, Northern, and River Nile were: 0.52, 0.61, 0.48, and 0.41, respectively. The corresponding average technological ratios were .0.82, 0.50, 0.75 and 0.92, respectively.

The main challenge of impact evaluation studies is the establishment of counterfactual situation for comparison. A number of quasi-experimental methods were developed for rigorous impact evaluation including endogenous switching regression (ESR) which is employed in this study. The objective of this study was to analyze adoption of improved wheat technology, which was disseminated by SARD-SC project level in the Sudan during the period 2012-2016 and estimate its impacts on wheat yield at the farm in the major wheat producing areas.

METHODOLOGY

The study area: Six regional sites were selected as the intervention sites, where innovation platforms were established, namely, Khor Argo from the Northern State, Abu Seleim from the River Nile State, Demiat and Debeira (in New Halfa Agricultural Corporation) from Kassala State and Wad Elbur and Bassatna (in the Gezira Scheme) from Gezira State in central Sudan.

Sampling frame, sample size and sampling procedure: The sample was designed to include both participant and non-participant household farmers in the four producing States at six innovation platforms. Primary data were collected from a total sample of 544 households, 253 participants or beneficiaries and 291 non-participants or non-beneficiaries (Table 1). Random sampling was used for non-participant farmers at the six innovation platforms. For the baseline survey, the following equation was applied: Sample size (N) = $Z^2.P\ (1-P)$

where: Z value = 1.96 for 95% confidence level.

P = Percentage picking a choice expressed as decimal (0.5 used for sample size needed).

Confidence interval was expressed as decimal (e.g.0.04 = ± 4).

Table 1. Sample size.

Item	Dongola	Gezira	Kassala	River Nile	Total
Participant	54	95	75	29	253
Non-participant	50	84	86	71	291
Total	104	179	161	100	544

Method of data collection: A field survey was carried out in the main wheat producing areas in the Sudan using a well prepared structured questionnaire to collect primary data through direct interviews with respondents. The data collected included information such as wheat production in 2015-2016, application of the recommended package and share of income from wheat in total agricultural income.

Model used to analyze adoption

The Heckman model: The two-step Heckman model (Heckman, 1979) which models farmers' decisions to adopt the recommended package and the intensity of adoption in terms of area of improved wheat as described by the decision and outcome equations. The reason behind using Heckman model is for its robustness and flexibility to model specifications and presence of available procedures to correct heteroskedasticity. Moreover, it can also estimate treatment effects, which are closer to experimental results.

Adoption decisions can be modelled in a set of two equations, namely, the selection equation and the outcome equation. In the selection equation, the treatment is a binary indicator of adoption whereas in the second equation (usually called the outcome equation), a continuous variable (the outcome variable) capturing the measured values of the extent to which the technology package components are used is regressed on a subset of observable factors which affect adoption decision.

In the selection equation the treatment T is a binary indicator of adoption which takes the value of 1 when adoption is observed and 0 if it is not observed:

$$\mathrm{T}_{it}(\mathrm{Z}_{\mathrm{it}}, \mathrm{U}_{\mathrm{it}}, \varepsilon_{\mathrm{it}}) = \begin{cases} 1, if\, E\pi^*(\mathrm{Z}_{\mathrm{it}}: \mathrm{T}_{it} = 1) - E\pi^*(\mathrm{Z}_{\mathrm{it}}, U_{it}: \mathrm{T}_{it} = 0) > 0 \\ 0,\ \text{Otherwise} \end{cases} \quad (1)$$

where, E is the expectation operator and $\pi^*$is a general utility function making the expected utility that is to be maximized conditional on observable and unobservable factors. ε_i an error term which is independently and identically distributed; *i* and *t* indicate individual farmers and time.

Adoption of a specific technology, such as a new crop variety, can often be thought of as binary, even if the farmer does not fully adopt the technology package by making self-selected adjustments to inputs and farm management practices. Shahidur *et al* (2004) stated that the farmer in response to crop variety adoption endogenously adjusts management and input use, which is dichotomous. When ε_{it} is zero, adoption takes place only if maximized expected utility with the new technology exceeds maximized expected utility with the old technology. In the second equation, a continuous variable (the outcome variable) capturing the measured values of the extent to which the technology package components are used is regressed on a subset of observable factors which affect adoption decision. Suppose that y_{it} is the outcome that is used as a measure of utility. The outcome variable is a function of observed and unobserved variables and u_{it} which is an error term where:

$$y_{it} = \begin{cases} x_{it}\beta + u_{it}, & if\ T_{it} > 0 \\ 0, & if\ T_{it} \leq 0 \end{cases} \quad (2)$$

The estimated coefficients of the outcome variable (β) indicate the direction and magnitude of effect of different covariates on the outcome variable.The Heckman model holds under the following assumptions:

1. Both error terms are normally distributed with mean 0, variances and correlation

$$(\varepsilon, u) \sim N(0,0,\sigma 2\varepsilon, \sigma 2u, \rho\varepsilon u) \quad (3)$$

2. The error terms are independent of both sets of explanatory variables (X and Z).

$$(\varepsilon, u) \perp\!\!\!\perp (X, Z) \quad (4)$$

The variables used to estimate the two-step Heckman model included the following:

1. For selection equation, the dependent variable was adoption of the improved varieties. The independent dummy variables were seed type, participant in demonstration, participant in field days and education. Other variables are distance to input market, distance to output market, production relation, seed production, head age and total loss.
2. For outcome equation, area under improved varieties was the dependent variable. The independent dummy variables were participation in demonstration, access to seeds, use of recommended number of irrigations and use of clean seeds. Another variable was distance to microfinance.
3. For estimation of the endogenous switching regression, the variables used were age, experience, number of years of formal education, income from wheat sale, wheat area, total farm area, seed rate, extension visits and percentage of sold wheat to total wheat production. Other dummy variables were sowing date, market oriented production (i.e. if farmer sold his product or not), land ownership, know wheat package, self-finance, access to seeds, hosting demonstration and attendance of field days.

Model used to analyze impacts

The endogenous switching regression: The endogenous switching model can be written in the reduced form as follows (Mare and Winship, 1987).

$$Z_i^* = \sum_k \pi_k X_{ki} + \varepsilon_{1i} \quad (5)$$
$$Y_{0i} = \sum_k \beta_{0k} X_{ki} + \varepsilon_{2i} \quad (6)$$
$$Y_{1i} = \sum_k \beta_{1k} X_{ki} + \varepsilon_{3i} \quad (7)$$

where,
i Denotes farmer's id (i=1… n).
Z_i is a dichotomous variable equals 1 for participation and 0 for non- participation with a latent tendency Z_i^* that indexes the likelihood for participation.
Y_i is the outcome variable that takes two values Y_0 and Y_1 for participation and non – participation pertaining to the same individual, i.
X_{ki} is the on the kth measured independent variable (k = 1,…,k).
β_{0k} and β_{1k} are parameters to be estimated.
ε_{2i} and ε_{3i}denote stochastic disturbances.
The interest of this model centers on the expected difference between the two outcomes namely $E(\mathrm{Y}_1)$ - E (Y_0).

Although two outcomes are hypothesized for each individual, in reality, only one outcome is observed and the other outcome is a counterfactual. The objective of studying treatment effects call for the knowledge of counterfactual outcomes for both participants and non – participants. Comparison of the coefficients across equations 3 and 4 yields the treatment effects conditional on the covariates (Mare and Winship, 1987).

The endogenous switching regression is used to estimate the average treatment effects (ATE) and the average treatment of the untreated group (ATU) resulting from the use of improved wheat varieties.

Cronbach's Alpha

Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability.Theoretically, Cronbach's alpha results should give a number from 0 to 1. The general rule of thumb is that a Cronbach's alpha of 0.70 and above is good, 0.80 and above is better, and 0.90 and above is best.Cronbach's alpha does has some limitations: Scores that have a low number of items associated with them tend to have lower reliability, and sample size can also influence the results for better or worse. However, it is still a widely used measure (Institute for Digital Research and Education, 2016).

Cronbach's alpha can be written as a function of the number of test items and the average inter-correlation among the items. Below, for conceptual purposes, is the formula for the Cronbach's alpha:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Where,
N is equal to the number of items, c-bar is the average inter-item covariance among the items and v-bar equals the average variance.

Chronbach´s alpha measure was applied for two items in this study, mainly the participation of farmers adopting the technology and those who were not adopting. Also, the kind of participation whether demonstration plots using full package or participation in seed production or no participation.

RESULTS AND DISCUSSION

Results of the Heckman selection model indicated that, farmers who were hosting demonstration plots and those who participated in the field days were more likely to adopt improved wheat varieties. The results reflected how farmers became well aware of the demonstration plots which were practiced under the supervision of wheat research scientists. The significant and positive coefficient of the age of the household head showed that, elder farmers had the tendency to adopt improved variety. The age showed that the main activity of most or all of the elder farmers was agricultural production. Education was significant, but negative contrary to what was expected and hypothesized (Table 2). That might be due to the involvement of educated farmers in other jobs or trades. Also, the amount of seed loss had significant negative coefficient. The high amount of seed loss was mainly due to late harvesting.

Table 2 Heckman selection equation, dependent variable using improved varieties (dummy).

	Coef.	Std. Err.	z	P>|z|	[95% conf. interval]	
Demonstration plots	0.7399716	.3442216	2.15	0.032	.0653097	1.414633
Field days	0.878512	.2001817	4.39	0.000	.4861632	1.270861
Distance to inputs market	0.0029548	.0082755	0.36	0.721	-.013265	.0191745
Distance to output market	-0.0007924	.0073222	-0.11	0.914	- .0151437	.0135588
Education	-0.3048794	.1221822	-2.50	0.013	-.544352	-.0654067+6
Seed source	0.0737404	.1499125	0. 49	0.623	-.2200827	.3675634
Head age	0.0260085	.005947	4.37	0.000	.0143525	.0376645
Production relation	0.0873066	.1858486	0. 47	0.639	-.2769498	.4515631
Amount of seed loss	-0.0178373	.0061991	-2.88	0.004	-.0299874	-.0056873
Constant	-0.1909621	.3824839	-0.50	0.618	-.9406169	.5586926
Pseudo R square	0.21					

Table 3 Heckman outcome equation. Dependent variable, was area under improved varieties (ha).

	Coef.	Std. Err.	z	P>|z|	[95% conf. interval]	
Education	.3657243	.3006965	1.22	0.225	-.2258888	.9573374
Head sex	-.7988693	.9887549	-0.81	0.420	-2.74422	1.146482
Head age	.0102623	.0146903	0.70	0.485	-.0186405	.0391652
Family size	.0132952	.0492286	0.27	0.787	-.0835608	.1101512
Production relation	-3.15398	.5159288	-6.11	0.000	-4.169058	-2.138903
Distance to inputs market	-.0034465	.0165281	-0.21	0.835	-.0359652	.0290722
Distance to output market	.0092336	.0099771	0.93	0.355	-.0103961	.0288634
Distance to microfinance office	-.0134785	.0184939	-0.73	0.467	-.0498648	.0229079
Total loss	.0108421	.0223345	0.49	0.628	-.0331005	.0547847
Number of irrigations	.2666638	.1135586	2.35	0.019	.0432399	.4900877
Demonstration plots	.4069141	.3963367	1.03	0.305	-.3728688	1.186697
Variety select field day (VSF)	.5945977	.409464	1.45	0.147	-.2110127	1.400208
Need credit	.2412144	.4352092	0.55	0.580	-.6150491	1.097478
Training	-.2767115	.3923532	-0.71	0.481	-1.048657	.495234
Using clean seed	-.474385	1.280934	-0.37	0.711	-2.994592	2.045822
Urea price	0093104	.0123165	0.76	0.450	-.0149219	.0335428
Using DAP	-.0004973	.0012244	-0.41	0.685	-.0029062	.0019116
Seed type	.9988036	.9657008	1.03	0.302	-.9011892	2.898796
IMR	-9.224025	1.074309	-8.59	0.000	-11.3377	-7.110349
Constant	2.155469	4.193683	0.51	0.608	-6.095499	10.40644

The coefficient of the inverse Mill's ratio in the outcome equation is negative and significant indicating that the non- observable factors that determine variety selection (from selection equation) significantly decreased the area allocated for wheat production implying the existence of bias due to self selection which is corrected by the Heckman's two steps model. Also, the coefficient of the production relation is negative and significant, meaning that shared cropping or rent farmers are more likely to adopt the recommended package relative to farmers with private land ownership (Table 3).

The estimates of decision and regime equations of the endogenous switching regression are presented in Table 4(a, b). The ESR estimates of wheat yield show that, hosting demonstration plots, participation in field days and attending training significantly increased the likelihood of improved variety adoption. The ESR model results further showed that, adoption of improved wheat varieties had significant and positive effects on yield. The average treatment effect on treated group (farm households that adopted improved wheat varieties) was found to be about 1.98 tons per ha. This means that, households who actually adopted the improved varieties yielded 1.98 tons/ha more than those who did not adopt.

The Heckman selection estimates are presented in Table 5.When rho is positive, this indicates that unobservables are positively correlated with one another. When rho is negative, this indicates that unobservables are negatively correlated with one another. At the very bottom of table 4 of the regression output for Heckman selection model examining yield, we have estimates for the following:

The adjusted standard error for the yield equation regression is given by sigma and the correlation coefficient between the unobservables is given by rho.

Table 4(a) Estimates and yield determinants using the ESR model.

Yield (regime 0)	Coef.	Std. err.	z	P>|z|	95% conf. interval	
Family size	0.1067919	.0206893	5.16	0.000	.0662415	.1473422
Main-market distance	0.0006498	.0036864	0.18	0.860	-.0065753	.0078749
Age	-0.0038869	.0061246	-0.63	0.526	-.0158909	.0081171
Wheat area	-0.000201	.0211979	-0.01	0.992	-.0417481	.0413462
Production relations	0.1767273	.2012523	0.88	0.380	-.2177199	.5711744
Education	-0.1208247	.118475	-1.02	0.308	-.3530314	.111382
Input market distance	-0.0438134	.0157149	-2.79	0.005	-.0746141	-.0130127
Output market distance	0.0523121	.0162539	3.22	0.001	.0204551	.0841691
Total loss	-0.0188903	.0058962	-3.20	0.001	-.0304466	-.007334
Seed source	0.0416947	.2008436	0.21	0.836	-.3519514	.4353408
Cons	0.2969685	.5337625	0.56	0.578	-.7491868	1.343124

Table 4(b) Estimates and yield determinants using the ESR model.

Yield (regime1)	Coef.	Std. Err.	z	P>|z|	95% conf. interval	
Family size	-0.0437729	.01631	-2.68	0.007	-.0757398	-.0118059
Main market distance	0.0016041	.0035321	0.45	0.650	-.0053187	.008527
Age	0.0003755	.0046417	0.08	0.936	-.008722	.009473
Wheat area	-0.0153116	.0124782	-1.23	0.220	-.0397685	.0091453
Production relations	-0.567	.1616758	-3.51	0.000	-.8838787	-.2501212
Education	-0.0194757	.0939105	-0.21	0.836	-.203537	.1645855
Input market distance	-0.0005955	.0049735	-0.12	0.905	-.0103434	.0091523
Output market distance	0.0036541	.0036703	1.00	0.319	-.0035396	.0108478
Total loss	-0.0126675	.0070539	-1.80	0.073	-.0264928	.0011578
Seed source	0.0894293	.1019148	0.88	0.380	-.1103201	.2891787
Cons	4.054199	.3343949	12.12	0.000	3.398797	4.709601

Table 5. Heckman selection estimates.

Yield (regime 0)	Coef.	Std. Err.	z	P>|z|	95% conf. interval	
Demo plots	1.375211	.2553549	5.39	0.000	.8747247	1.875697
Field days	0.9832869	.2309938	4.26	0.000	.5305474	1.436026
Training	0.5683121	.154698	3.67	0.000	.2651095	.8715147
Cons	0.5408725	.0751383	7.20	0.000	.3936041	.6881409
/lns0	0.0153199	.119747	0.13	0.898	-.2193799	.2500198
/lns1	0.2776063	.0418728	6.63	0.000	.1955371	.3596755
/r0	-1.208179	.2573432	-4.69	0.000	-1.712563	-.7037959
/r1	-1.320359	.2030016	-6.50	0.000	-1.718235	-.9224827
Sigma0	1.015438	.1215957			.8030166	1.284051
Sigma1	1.319966	.0552707			1.215964	1.432864
Rho0	-0.8361325	.07743			-.9369612	-.6067717
Rho1	-0.8668731	.0504522			-.9376501	-.7270698

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Cronbach′s alpha results

According to Cronbach′s alpha measure, the following results were obtained from the four states under the study (Table 6).

Table 6 Cronbach′s alpha reliability test.

State	No. of farmers	No. of items●	Cronbach's alpha
Dongola	104	2	0.912
Gezira	179	2	0.868
Kassala	161	2	0.899
River Nile	100	2	0.887

● For scale reliability, the items used were ; participants and non-participants; and kind of participation

The model was alpha. Based on the above results, the measure was reliable and acceptable. This indicated that the items were closely related.

CONCLUSION AND IMPLICATIONS

The study analyzed determinants of adoption of improved wheat technology and assessed its impact on crop yield using survey data collected in 2016 from a sample of about 558 farmer households in four agro-ecological zones in the Sudan. The study applied Heckman two steps and endogenous switching regression models to analyze adoption and impact of improved wheat technology. Results showed that, farmers who were hosting demonstrations and attending field days were more likely to adopt improved wheat technology. The study indicated that adoption of improved wheat technology significantly increased yield of wheat. These results showed that, the strategy of intervention by the SARD-SC project to boost wheat production in the Sudan enhanced both adoption of the recommended package and increased wheat productivity. The use of improved seeds in particular together with the improved management practices, and training of farmers and transfer knowledge to them, led to enhancement of adoption and higher yield of wheat. The participation of different stakeholders along the value chain of wheat through establishment of innovation platforms, which contributed to creation of enabling policy environment and institutions including credit and finance, were all means to promote adoption of improved agricultural technologies. Cronbach's alpha measure showed best reliabilty and closed relation among items under investigation.

REFERENCES

Abdelaziz, A.H. and I. F. Abdalla. 2013. Adoption of faba bean and wheat production technologies in the River Nile and Northern States under IFAD-funded Project in Sudan. Sudan Journal of Agricultural Research 21: 87-104.

Ali, C., A. A. Hashim, A. O. Hassan, I.F. Abdalla, I. Tahir, S. Assefa, and O. Yameogo 2016. Journal of Agricultural Science 8(2): 179-186.

Fageer, E. A., B. Dhehibi, A. Mazid, A. A. Hussein and A.A. Hassan 2013: The Impacts of an improved technology package on production. efficiency: The case of wheat farms in the Northern State of Sudan. American-Eurasian Journal. Agricultural of Environmental Science 13 (8): 1114-1123.

Heckman, J.J. 1979. The common structure of statistical models of truncation, sample selection, and limited dependent variables and a simple estimator for such model. Annals of Economic and Social Measurement 5: 475-492.

Shahidur, R. K., G. B. Koolwal and A. Hussain. 2010. Handbook on impact evaluation: Quantitative methods and practices. World Bank.

Institute for Digital Research and Education 2016. https://stats.idre.ucla.edu/wp content/uploads/2016/02/alpha.sav. What does Cronbach's alpha mean?

Mare, R.D. and C. Winship. 1987. Endogenous Switching Regression Models for the Causes and Effects of Discrete Variables. In J. S. Long (ed.) : Common Problems/Proper Solutions : Avoiding Errors in Quantitative Research Pp. 132-160. Newbury Park, CA ; (cited in Rasheed Ph D thesis).

تبني تقانات القمح واثرها على انتاج مزارعي القمح بالسودان

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[2]المركز العالمي للبحوث الزراعية في المناطق الجافة (ICARDA)

الخلاصة

محصول القمح من أهم محاصيل الغلال المستهلكة في السودان وتعطي الحكومة أولوية للإنتاج المحلى . هدفت هذه الدراسة لتحليل درجة تبنى الحزم التقنية المحسنة والمجازة وتقدير أثرها على إنتاجية القمح باعتبارها اهم اثر على المستوى المزرعي لمشروع بنك التنمية الافريقي لدعم السلع الغذائية في السودان(SARD-SC) خلال الفترة من 2012 الى 2016. لتقدير محددات التبني ولتصحيح الاختيار الشخصي المتحيز للمشاركين في المشروع تم استخدام نموذج two – step Heckman لمعرفة مقدرات معادلة الانحدار في المرحلة الأولى وتم إضافة Inverse Mill Ratio لتصحيح التحيز في المرحلة الثانية للانحدار الخطى لمساحة الأصناف المحسنة. لتقدير الأثر على إنتاجية القمح تم استخدام نموذج الانحدار endogenous switching regression لمعرفة أثر متوسط المعالجة الناتجة من استخدام الأصناف المحسنة للقمح. أوضحت النتائج أن المزارعين المشاركين في الحقول الإيضاحية والحضور في أيام الحقل والمتدربين في مدارس المزارعين ضمن نشاطات مشروع SARD-SC تحسنت درجة التبني لحزمة أنتاج القمح الموصى بها في السودان لديهم وبدرجة معنوية. أوضحت مقدرات IMR أن العوامل غير المتاحة مثل مهارات المزارعين والحوافز أدت إلى نقصان المساحة المتحولة لزراعة القمح وبدرجة معنوية كما أدى استخدام نموذج Heckman لتصحيح التحيز الناتج من هذه العوامل. أوضحت مقدرات ESR أن تبنى الحزم التقنية قد زاد من إنتاجية القمح بمقدار 1.98 طن/هكتار وأن المزارعين المشاركين بمشروع SARD SC قد زادوا احتمال تبنى الأصناف المحسنة بدرجة معنوية . أثبتت نتائج هذه الدراسة أن تدخل مشروع SARD-SC أدى إلى تحسين درجة تبنى الحزم الموصى بها لإنتاج القمح بالسودان وبالتالي تحسين الإنتاجية . لذلك أوصت الدراسة بإنشاء المزيد من منصات الابتكار بمختلف مناطق إنتاج القمح بناءً على أنشطة مشروع SARD SC لاستيعاب مزيداً من مزارعي القمح في السودان وذلك لتحسين الأمن الغذائي في السودان.