Large-scale Foreign Investments in African Agriculture

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Evaluating household welfare effects of outgrower schemes, agro-industry employment and spillovers in Malawi and Tanzania

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In memory of my dearest friend and brother Jost

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Zusammenfassung

Die steigenden Nachfrage nach landwirtschaftlichen Ressourcen zur Produktion von Nahrungsmitteln und anderen Gütern seit Mitte der 2000er hat zu einem starken Anstieg ausländischer Direktinvestitionen in die Agrar- und Ernährungswirtschaft in Entwicklungsländern geführt (Cotula et al, 2009; Deininger et al., 2010). Eine zentrale Rolle nimmt dabei Subsahara Afrika (SSA) ein, wo ein bedeutsamer Anteil der großflächigen Agrarinvestitionen in den vergangenen Jahren zu beobachten ist (Deininger et al., 2010; Schoeneveld, 2014). So gab es laut Schoeneveld (2014) zwischen 2005 und 2013 in 37 afrikanischen Staaten 563 großflächige Landakquisitionen, die nahezu 23 Millionen Hektar umfassten. Die Entwicklung dieser Flächen zur Produktion von Biokraftstoffen war dabei zunächst der Hauptmotor (FAO, 2009) – nach ersten Schätzungen waren 78% der verhandelten Flächen für Energiepflanzen wie Jatropha oder Zuckerrohr vorgesehen (Anseeuw et al., 2012). Eine erhöhte Nahrungsnachfrage, u.a. aus Regionen des mittleren Ostens und Asiens, verstärkte in jüngeren Jahren das Interesse, Grundnahrungsmittel (u.a. Reis und Mais) in Großbetrieben in SSA zu produzieren. Obwohl viele dieser Investitionen, vor allem die zur Produktion von Biokraftstoffen, nicht oder noch nicht umgesetzt wurden (Maltsoglou et al, 2013; Singh et al, 2014.), lässt sich ein langfristiger Trend hin zu einer zunehmenden Bedeutung von Großbetrieben und großflächigen Agrarinvestitionen in SSA erwarten (Gibbon 2011; Deininger und Byerlee, 2012).

Die möglichen Auswirkungen dieser Investitionen sind jedoch stark umstritten (Cotula et al., 2009; Deininger et al, 2011). Einerseits weisen insbesondere Nichtregierungsorganisationen und Medien auf die sozialen und ökologischen Risiken dieser Investitionen hin. Dabei wird besonders vor großflächigem Landraub gewarnt, der mit dem Verlust der Lebensgrundlagen lokaler Bevölkerungsgruppen einhergehen würde. Anderseits betonen oftmals Regierungen und internationale Organisationen die sich durch diese Investitionen ergebenden Chancen für wirtschaftliche Entwicklung und Armutsbekämpfung, z.B. durch die erhöhte Arbeitsnachfrage in der Agrar- und Ernährungswirtschaft, durch den verbesserten Zugang von Kleinbauern zu hochpreisigen Märkten und zu modernem Knowhow und Technologien. Biokraftstoffinvestitionen können darüber hinaus zu einer verbesserten Energiesicherheit und Deviseneinsparungen beitragen, was insbesondere für nicht-ölproduzierende Binnenstaaten von großer Relevanz ist (Mitchell, 2011).

In vergangenen Jahren wurden auf internationaler Ebene Richtlinien für verantwortungsvolle Agrarinvestitionen ins Leben gerufen (siehe z.B. Committee for Food Security, 2014). Die Art des Investitionsmodells wird dabei in der Regel als ein wichtiger Parameter angesehen,

der die sozioökonomischen Auswirkungen stark beeinflusst (Vermeulen & Cotula 2010; Deininger et al 2011). Insbesondere werden Modelle, die Kleinbauern in Wertschöpfungsketten als Produzenten integrieren, wie z.B. Vertragsanbau, oftmals als effektive Ansätze gesehen, um die armutsreduzierende Wirkungen dieser Investitionen zu vergrößern (Vermeulen und Cotula 2010; Smalley, 2013).

Trotz der politischen Relevanz großflächiger Agrarinvestitionen in SSA gibt es bisher kaum empirische Studien über deren sozioökonomischen Auswirkungen. Empirische Evidenzen sind jedoch Voraussetzung für die Bewertung und Steuerung solcher Investitionen. Die Hauptmotivation der vorliegenden Arbeit ist es daher, einen Beitrag zu dieser Evidenz zu liefern.

Erste Simulationen über mögliche Auswirkungen solcher Investitionen von Arndt et al. (2010) in Mosambik und Baumgartner et al. (2015) in Äthiopien zeigen die Potentiale für Beschäftigung und Einkommen auf, aber betonen jeweils auch die besonderen Chancen alternativer Modelle wie Vertragsanbau für eine breitenwirksame Gestaltung dieser Investitionen. Deininger et al. (2015) nutzen in einer jüngeren Studie tatsächliche Ex-post-Daten über Groß- und angrenzende Kleinbetriebe in Mosambik, um Spillover-Effekte zu messen. Die Autoren finden tatsächliche positive Effekte, die sich in der Übernahme verbesserter Inputs und Anbaumethoden der Kleinbauern ausdrücken. Die Autoren stellen jedoch auch negative Wirkungen auf das persönliche Wohlbefinden der Bauern fest.

Ex-post Studien in SSA über tatsächliche Auswirkungen großflächiger Agrarinvestitionen über direkte Teilnahmekanäle, wie z.B. den Arbeitsmarkt oder Vertragsanbau, existieren nur wenige. Bestehende Studien zu Arbeitsmarkteffekten beziehen sich vielmehr auf weniger landintensive hochpreisige Exportketten, wie z.B. den Obstbau und Gemüseanbau. Studien hierzu weisen einerseits auf die geringe Qualität und Bezahlung von Arbeitsplätzen hin (z.B. Barrientos und Kitzinger, 2004; Barrientos et al., 2005). Andererseits stellen z.B. Maertens et al. (2011) im Senegal in einer haushaltsökonomischen Wirkungsanalyse in Gemüseexportketten insbesondere für ärmere Haushalte positive Einkommenseffekte fest. Studien zu Vertragsanbau in der afrikanischen Landwirtschaft kommen zu sehr unterschiedlichen Ergebnissen hinsichtlich ihrer Wohlfahrtseffekte. So wird vor der Gefahr der Ausbeutung von Bauern in diesen oftmals monopsonen Marktstrukturen oder aber der Ausgrenzung ärmerer Bauerngruppen gewarnt (Little und Watts, 1994; Porter und Phillips-Howard, 1997). Evaluationsstudien zu Einkommenseffekten mit Kontrollgruppenvergleichen kommen wiederum meistens zu positiven Ergebnissen für Vertragsbauern (z.B. Bolwig et al, 2009; Bellemare 2012; Väth und Kirk, 2014).

Das übergeordnete Ziel dieser Arbeit ist es, einen Beitrag zum besseren Verständnis der möglichen Auswirkungen ausländischer Direktinvestitionen in die afrikanische Agrar- und Ernährungswirtschaft für die Wohlfahrt ländlicher Bevölkerungsgruppen zu leisten. Konkret verfolgt die Arbeit das Ziel, die Auswirkungen ausländischer Direktinvestitionen auf Haushaltseinkommen und Einkommensarmut zu messen, insbesondere über die Wirkungskanäle (1) Vertragsanbau, (2) Lohnarbeit in der Landwirtschaft und im verarbeitenden Gewerbe und (3) Spillover-Effekte im Rahmen von Technologietransfer-Projekten. Die Ziele werden im Rahmen von drei Artikeln (Kapitel 2-4) bearbeitet, die jeweils Fallstudienuntersuchungen von Investitionen in Malawi und Tansania im Zucker- und Reissektor darstellen.

Der erste Artikel (Kapitel 2) untersucht die direkten sozioökonomischen Wirkungen einer Zucker- und Ethanol-Investition in Dwangwa, Malawi (Herrmann und Grote, 2015). Der Artikel vergleicht individuelle Vertragsbauern, gruppenbasierte Bewässerungssysteme und Plantagenbeschäftigung mit Kontrollgruppen hinsichtlich ihrer Einkommens- und Armutssituation. Der Artikel basiert auf Haushaltsdaten, die 2010 und 2011 in Zielgruppen- und Kontrolldörfern von 225 Vertragsbauern, 60 Plantagenarbeitern und 328 Kontrollgruppenhaushalten erhoben wurden. Zur Überwindung von Selektionsverzerrungs- und Endogenitätsproblemen wurde ein Treatment-Effects Modell geschätzt sowie Propensity Score Matching (PSM) und zahlreiche Robustheitsprüfungen eingesetzt. Die Ergebnisse zeigen u.a., dass Einkommensarmut unter Vertragsbauern im Vergleich zur Kontrollgruppe deutlich geringer ist, während Plantagenarbeiter nur mit Blick auf die extreme Armutsgrenze besser dastehen. Das lässt vermuten, dass Plantagenbeschäftigung in erster Linie ein Beitrag zur Reduzierung extremer Armut sein kann. Qualitative Interviews bestätigen die Ergebnisse, verweisen jedoch auf Risiken von Konflikten im Rahmen der großflächigen Erweiterungen von Bewässerungsprojekten und der Vertragsgestaltungen, was die armutsmindernden Potenziale dieser Investitionen untergräbt.

Der zweite Artikel (Kapitel 3) untersucht Wohlfahrtseffekte auf Haushaltsebene zweier großflächiger Agrarinvestitionen in Tansania. Die beiden Investitionen befinden sich in Kilombero, einer Hauptregion zur Förderung von Agrarinvestitionen im Rahmen des Südlichen Agrarentwicklungskorridors Tansanias (SAGCOT) (SAGCOT, 2011). Die beiden untersuchten Investitionen, Kilombero Sugar Company Limited und Kilombero Plantation

Limited, werden aufgrund ihrer Integration von lokalen Bevölkerungsgruppen als Vorbilder für zukünftige Investitionen gesehen. Die verwendete Stichprobe stammt von Haushaltsbefragungen aus 2013 mit insgesamt 516 Interviews, darunter Zuckerrohr-Vertragsbauern, Reis- und Zuckerarbeiter und Nichtteilnehmer. Während die Studie positive Wirkungen der Investitionen hinsichtlich der untersuchten Kanäle Vertragsanbau und Lohnarbeit bestätigt, sind große Unterschiede zwischen Kanälen und Subsektoren festzustellen. Vertragsbauern profitieren am meisten, jedoch Land-reiche mehr als Land-arme. Zuckerarbeiter erwirtschaften größere Gewinne als Arbeiter in der Reis-Investition, wobei in beiden Fällen Ressourcen-ärmere Haushalte zu profitieren scheinen. Die Studie zeigt somit positivere Auswirkungen von Investitionen auf, die Vertragsbauern integrieren, jedoch betont zudem die Chancen der Lohnarbeit insbesondere für Ressourcen-arme Haushalte. Der Artikel betont die Notwendigkeit, Hindernisse für Ressourcen-arme Vertragsbauern zu reduzieren. Insbesondere lassen qualitative Interviews eine wachsende Gefahr des Verdrängungsprozesses kleinerer Bauern durch lokale Eliten vermuten.

Artikel drei (Kapitel 4) misst technologische Spillover-Effekte von großflächigen Agrarinvestitionen. Hierzu wird ein öffentlich-privates Projekt zwischen Kilombero Plantation Limited und USAID analysiert, das eine Erhöhung der Reisproduktion im Kleinbauernsektor durch Förderung verbesserter Verfahren, Hochertragssorten und Dünger zum Ziel hat. Die Stichprobe besteht aus 144 am Projekt teilnehmenden Reisbauern, 152 nicht-teilnehmenden Haushalten und 61 Fabrik- bzw. Plantagenarbeitern. Der Artikel schätzt Treatment Effects Modelle, Einfachregressionsmodelle und PSM, um Ertrags- und Einkommenseffekte zu analysieren. Während Reisertrags- und Einkommenseffekte auf Haushaltsebene relativ gering sind, zeigt eine ergänzende disaggregierte Analyse einzelner Parzellen signifikante Effekte. Lohnbeschäftigung im Rahmen der Investition ist auch mit höherem Pro-Kopf-Einkommen verbunden, welches jedoch geringer ist als die Spillovereffekte. Die Studie zeigt somit die Potentiale derartiger Technologietransfer-Projekte auf, weist jedoch auch auf einige Hindernisse für eine weitere Verbreitung der Technologien hin, wie z.B. Finanzierung und Arbeitskräftemangel.

Die Gesamtheit dieser Arbeit versucht fünf konkrete Beiträge zur Literatur zu leisten. Erstens handelt es sich um eine der wenigen empirischen ex-post Analysen, die mit Haushaltsdaten und Kontrollgruppenvergleichen Auswirkungen großflächiger Agrarinvestitionen in SSA untersucht. Die unterschiedlichen Artikel bauen somit auf oben erwähnte Simulationen von Arndt et al. (2010) und Baumgartner et al. (2015) mit tatsächlichen Ex-post-Daten auf. Die untersuchten Teilsektoren und Länder sind dabei von besonderer Relevanz. Zucker und Reis gehören zu den in den derzeitigen Agrargroßprojekten und -investition zentralen Agrarrohstoffen (Landmatrix Datenbank, 2015). Tansania ist zudem eins der drei Hauptziele für Agrarinvestitionen innerhalb SSAs, neben Äthiopien und Mosambik (ebd.).

Zweitens handelt es sich speziell bei der Fallstudie Malawi (Kapitel 2) um eine der wenigen empirischen Analysen über die möglichen sozioökonomischen Auswirkungen einer zukünftigen möglichen agroindustriellen Biokraftstoffproduktion in SSA. Malawi ist das einzige Land SSAs, das seit 1982 kontinuierlich in industriellem Maßstab Ethanol-Biokraftstoff basierend auf Zuckerrohr-Melasse produziert (Amigun et al., 2011). Ethanol basierend auf Zuckerrohr wird derzeit als vielversprechendster und kostengünstigster Biokraftstoff für SSA gesehen, insbesondere für erdölimportierende Binnenstaaten (Johnson und Seebaluck 2012; Mitchell 2011).

Drittens trägt die Arbeit zu einem besseren Verständnis der Auswirkungen alternativer Geschäftsmodelle großflächiger Agrarinvestitionen in SSA bei. Insbesondere die Analyse der Einkommens- und Armutswirkungen von Lohnbeschäftigung ist von zentraler Bedeutung zum Verständnis großflächiger Agrarinvestitionen, da dies der zentrale Kanal ist, durch den ländliche Bevölkerungsgruppen direkt an diesen Investitionen partizipieren. Die Studienergebnisse ergänzen die Erkenntnisse von Maertens et al. (2011) zu Arbeitsmärkten im Gemüseexportsektor Senegals. Zudem ergänzt die Arbeit die bestehende empirische Literatur zu Vertragsanbau in SSA durch Analyse für großflächige Agrarinvestitionen relevanter Subsektoren sowie Investitionsmodelle, die Plantagen und Vertragsanbau koppeln (Outgrower-Estate-Modelle). Diese werden oftmals als innovative Lösung angesehen, um betriebswirtschaftliche und entwicklungspolitische Ziele in Einklang zu bringen. Diese Arbeit ergänzt Arbeiten von Väth und Kirk (2014, 2015) zu Palmölinvestitionen in Ghana. Viertens, trägt sie zu einem besseren komparativen Verständnis der Vorteile unterschiedlicher Investitionsmodelle bei, insbesondere des Plantagen- und Vertragsanbaus, und ergänzt somit Maertens und Swinnens (2009) Arbeit im Senegal. Schließlich trägt die Arbeit zu einem besseren Verständnis von Spillover-Effekten großflächiger Agrarinvestitionen bei. Die Arbeit ergänzt somit die landesweite Analyse von Deininger et al. (2015) zu Mosambik, mit empirischen Erkenntnissen zu einem konkreten Beispiel eines Technologietransferprojekts.

Stichworte: Großflächige Agrarinvestitionen, Ausländische Direktinvestitionen, Großbetriebe, Vertragsanbau, landwirtschaftliche Beschäftigung, Technologie-Spillover, Tansania, Malawi

Abstract

The rising demand for agricultural crops for food and non-food uses has led to a surge of foreign investors attempting to acquire agricultural land in developing countries since the mid-2000s (Cotula et al., 2009; Deininger et al., 2010). Sub-Saharan Africa (SSA) has received a major share of such large-scale agricultural investments (LSAIs) (Deininger et al., 2010; Schoeneveld, 2014). Growing biofuel demand was an initial major driver, with early data suggesting 78% of land under negotiation earmarked for biofuel crops, such as jatropha, sugarcane or oil palms (Anseeuw et al., 2012). In addition, foreign investors started to acquire lands in SSA for staple food production. Many investments, especially those targeting biofuels, have been abandoned or have not yet materialized (Maltsoglou et al., 2013; Singh et al., 2014). However, the broad trend of an increasing area under large-scale farming in SSA is likely to continue in the future (Gibbon, 2011; Deininger and Byerlee, 2012).

The potential implications of LSAIs have been highly controversial (Cotula et al., 2009). On the one hand, there are widespread concerns voiced by non-governmental organizations and the media of substantial social and ecological risks (Cotula et al., 2009; FAO, 2009; Deininger et al., 2011). On the other hand, governments and International Organizations often argue in favour of the potential of LSAIs to contribute to economic development and poverty reduction, for example, by providing jobs in agriculture and agro-processing or enabling small-scale farmers to access high-value markets, modern knowledge and technologies. Especially investments in biofuels may also lead to greater energy security and import substitution, which is particularly relevant for non-oil producing land-locked countries (Mitchell, 2011).

At the international level, policy guidelines have been developed in recent years to encourage responsible agricultural investments (Committee on Food Security – CFS, 2014). The type of investment model is considered a crucial parameter in this context for influencing the development impacts of LSAIs, with models creating linkages with smallholder farmers, such as contract farming or outgrower schemes, often seen as most effective (Deininger et al., 2011; Vermeulen and Cotula, 2010).

In spite of the relevance for development and for policy making, there is little empirical evidence yet of the welfare effects of LSAIs in general and specific investment models in particular. Contributing to this evidence is the main motivation for this thesis. Recent ex-ante simulations by Arndt et al. (2010) in Mozambique and Baumgartner et al. (2015) in Ethiopia have suggested potential positive welfare effects, particularly of investments involving

outgrower systems. Deininger et al. (2015) use country-wide survey data of large-scale and small-scale farmers in Mozambique to study actual effects. The authors found positive spillover effects, with small-scale farmers surrounding such large-scale farmers adopting improved input and methods. Yet, they also find negative impacts on subjective well-being. There are hardly any ex-post evaluations of actual impacts of LSAIs in SSA through direct participation channels, such as the labor market or contract farming/outgrower schemes.

Existing evidence on labor market effects mainly comes from the high-value horticulture exports sector in SSA. This literature, on the one hand, criticises the low quality of jobs and low wages created (Barrientos and Kitzinger, 2004; Barrientos et al., 2005), whereas on the other hand, the only existing econometric study of household welfare effects by Maertens et al. (2011) in Senegal finds positive income effects from participation, with benefits especially occurring to poorer households. Empirical studies on contract farming or outgrower schemes in SSA come to rather mixed conclusions regarding the welfare effects. Some studies note the risk of exploitation of farmers and the exclusionary processes, whereas impact evaluations that use control-group comparisons, mostly find positive household welfare effects for farmers integrated in such supply chains (e.g., Bolwig et al., 2009; Maertens and Swinnen, 2009; Bellemare, 2012; Vaeth and Kirk, 2014).

The overall objective of this thesis is to contribute to a better understanding of the potential implications of LSAIs for rural households' welfare in SSA. Specifically, the objectives are to measure income and poverty effects of LSAIs through different institutional arrangements, namely (1) product market linkages through outgrower schemes, (2) labor market linkages through estate and factory employment, and (3) spillover effects as part of technology transfer projects. The thesis approaches these objectives via three articles (Chapters 2-4) drawing on case studies of LSAIs in Malawi and Tanzania in the sugar and rice sub-sectors.

The first article (Chapter 2) explores the direct socio-economic impacts of a sugar and ethanol investment in Dwangwa, Malawi (Herrmann and Grote, 2015). The article compares participation through individual rainfed outgrower schemes, group-based irrigation outgrower schemes, and estate employment with a control group in terms of income and poverty status. The article uses cross-section data collected in 2010 and 2011 in treatment and control villages, including 225 outgrowers, 60 estate workers, and 328 non-participating households. To account for selection bias and endogeneity problems a Treatment Effects Model, Propensity Score Matching (PSM), and numerous of robustness checks are used. The results show significant positive income differences between participants in either supply-chain set-up and the respective control group. Income poverty is significantly lower among outgrowers relative to the control group, but for the case of estate workers differences are only significant for the extreme poverty line, which suggests estate employment to primarily reduce extreme poverty. Although qualitative interviews confirmed these results, they allude to risks of social conflicts in the outgrower scheme expansions and lack of transparency in their operations, likely undermining their poverty-reducing potentials.

The second article (Chapter 3) investigates household welfare effects of two LSAIs in Tanzania, comparing labor and outgrower models. The two LSAIs operate in Kilombero Valley of Morogoro Region, which is a priority cluster for attracting agribusiness investments under the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) (SAGCOT, 2011). The investments analyzed, namely Kilombero Sugar Company Limited and Kilombero Plantation Limited, are considered best-practice cases for future investments under SAGCOT. The sample comes from surveys conducted in 2013 with 516 households, comprising sugarcane outgrowers, rice and sugar agro-industry workers and non-participants. The results confirm positive effects through the analyzed impact channels, but find large differences between arrangements and subsectors. Outgrowers benefit the most, yet land-rich more so than land-poor. Sugar workers experience larger gains than workers in the rice investment, though in both investments land-poor workers seem to benefit. Hence, the study suggests large direct benefits for participation in outgrower schemes, but also potentials of agro-industry wage employment for the land-poor to escape extreme poverty. The article also underlines the need to address constraints particularly of land-poor outgrowers. Qualitative interviews, for example, pointed to risks for this group due to elite capture by wealthier outgrowers.

Article three (Chapter 4) evaluates spillover effects of LSAIs. The article studies a Public-Private Partnership technology transfer project between Kilombero Plantation Limited and USAID, which aims at improving rice production of farmers surrounding the investment by promoting improved methods, high-yielding varieties and fertilizer (SAGCOT, 2013). The sample comprises 144 farmers participating in the project, 61 factory and plantation workers, and 152 non-participants from the 10 project villages. The article combines plot- and household-level analyses and uses a treatment effects model, ordinary least squares regressions and PSM to analyze yield and income effects. Although only slightly higher yield and income effects are observed at the household level, by adding plot-specific analysis to account for partial adoption, effects from adoption are substantial. Labor market participation is also associated with higher per capita incomes, but is lower than the effects of the smallholder rice project. The results suggest that participation in such investments have potentials to contribute to income improvements. Yet particularly projects that increase the productive capacity of surrounding areas, such as smallholder intensification projects or contract farming, are likely to yield greater welfare benefits of such investments.

The thesis attempts to make five major contributions to the literature. Firstly, this thesis is one of the few empirical studies using micro-level survey data to investigate impacts of LSAIs in SSA. It thereby adds actual ex-post evidence to simulations by Arndt et al. (2010) and Baumgartner's et al. (2015) referred to before. The sub-sectors and countries analyzed are interesting in this context as both are among the most targeted in LSAIs, with Tanzania among the main destinations for LSAIs in SSA (Land Matrix Database, 2015).

Secondly, the thesis is among the few to analyze the socio-economic effects of a nascent biofuel industry in SSA. Malawi has been the only country in SSA to continuously produce biofuel-ethanol on an industrial scale since 1982 (Amigun et al., 2011). Sugarcane-to-ethanol is considered to be the most promising, lowest-cost biofuel option at the moment in SSA, particularly for landlocked countries (Mitchell, 2011; Johnson and Seebaluck, 2012).

Thirdly, the thesis contributes to a better understanding of the welfare effects of different business models for LSAIs in SSA. Especially, investigating income and poverty effects of wage employment is crucial to understanding the overall implications of LSAIs given that this is the major channel through which the rural poor are integrated in LSAIs. The study results complement the evidence on high-value horticultural export crops (Maertens et al., 2011) with insights on LSAIs. In addition, the thesis contributes to the literature on contract farming/outgrower schemes in SSA, with an analysis of subsectors relevant for LSAIs and models combining plantation and contract farming approaches (outgrower-estate-models), often considered solutions to combine goals of competitiveness with inclusiveness. The thesis adds to recent work done by Vaeth and Kirk (2015) on similar palm oil investments in Ghana.

Fourthly, the thesis adds to an understanding of the relative benefits of different institutional arrangements for LSAIs, adding to Maertens' and Swinnen's (2009) work in Senegal. Measuring these welfare differences is important to understand socioeconomic implications of changes in the production of these subsectors. At the same time, the type of institutional arrangement may be an important parameter that governments could influence, for example, by making investment permits or land leases conditional on contract farming arrangements.

Finally, the thesis contributes to a better understanding of spill-over effects of LSAIs. The work complements Deininger et al.'s (2015) study in Mozambique, by providing micro-level evidence and insights into a specific technology transfer model for LSAIs in Tanzania.

Keywords: large-scale agricultural investments, foreign direct investments, smallholder farmers, Tanzania, Malawi, outgrowers; agro-industry employment; spillovers; sugarcane; rice

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List of Abbreviations

AfDB	African Development Bank
ATT	Average Treatment Effect on the Treated
BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research)
BRN	Big Results Now
CGIAR	Consultative Group on International Agricultural Research
DIE	Deutsches Institut für Entwicklungspolitik / German Development Institute
DSC	Dwangwa Sugar Company
e.g.	for example
Eds.	Editors
et al.	et alii
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics
FFS	Farmer Field Schools
GDP	Gross Domestic Product
GoM	Government of Malawi
GoT	Government of Republic of Tanzania
GR	Green Revolution
ha	hectare
HH	Household
Ibid.	ibida
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
IFPRI	International Food Policy Research Institute
IMR	Inverse Mill's Ratio

kg	kilogram
KPL	Kilombero Plantation Limited
KSCL	Kilombero Sugar Company Limited
LMGO	Land Matrix Global Observatory
LSAIs	Large-scale agricultural investments
OLS	Ordinary Least Squares
PSM	Propensity Score Matching
RAI	Responsible agricultural investments
RUBADA	Rufiji Basin Development Authority
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SBT	Sugarboard of Tanzania
SRI	Sustainable Rice Intensification
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TEM	Heckman Treatment Effects Model
TSH	Tanzanian Shillings
USAID	United States Agency for International Development

1 Synthesis

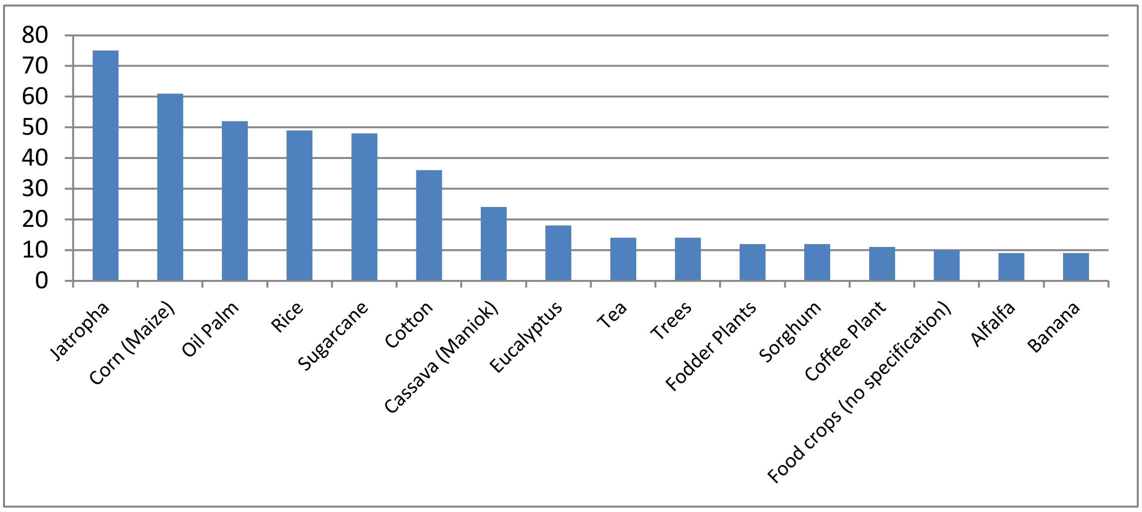
1.1 Background and problem statement

After decades of neglecting the agricultural sector, the rising demand for agricultural crops for food and non-food uses, such as biofuels, has led to a surge of foreign investors attempting to acquire agricultural land in developing countries since the mid-2000s (Cotula et al., 2009; Deininger et al., 2010). Between 2008 and 2009 alone, an estimated 46.6 million hectares of land were under negotiation globally according to Deininger et al. (2010). Sub-Saharan Africa (SSA) has received a major share of such large-scale agricultural investments (LSAIs) (ibid.), with recent estimates by Schoeneveld (2014), for example, showing 563 large-scale land deals between 2005 and 2013 in 37 countries of SSA, covering nearly 23 million hectares.

Most of these LSAIs have targeted the production of biofuel or food crops (Figure 1). Growing biofuel demand was an initial major driver, with early data suggesting 78% of land under negotiation earmarked for energy or mixed crops, such as jatropha, sugarcane or oil palms (Anseeuw et al., 2012). The production and use of liquid biofuels had been heavily promoted since the early 2000s mainly in industrialized countries as a strategy to address climate change and energy security concerns (Doornbosch and Steenblik, 2007). Although SSA countries continued to play a minor role in global biofuel production (Maltsoglou et al., 2013), a number of countries were considered to have substantial production potential, thanks to favorable climatic conditions and large areas of underutilized land (e.g. Smeets et al., 2007; Watson and Purchase, 2012). Consequently, many countries developed strategies and policies to foster domestic biofuel industries and attract foreign investments (Jumbe et al., 2009). In addition, foreign investors started to increasingly acquire lands in SSA for staple food production, partly as a response to increased food demand in parts of Asia and the Middle East.

Many LSAIs, especially those targeting biofuels, have been abandoned or have not yet materialized, often because of unviable business plans, lack of capital, changing biofuel legislations or bureaucratic hurdles (Maltsoglou et al., 2013; Singh et al., 2014). However, the broad trend of an increasing area under large-scale farming in SSA is likely to continue in the future (Gibbon, 2011; Deininger and Byerlee, 2012).

Table 1: Number of large-scale land deals in Sub-Saharan Africa (by crop)



Source: Land Matrix data base (2015)

The potential implications of LSAIs have been highly controversial (Cotula et al., 2009; Deininger et al., 2011). On the one hand, there are widespread concerns mainly voiced by non-governmental organizations (NGOs) and the media of substantial social and ecological risks. Such concerns are reinforced by research showing that LSAIs have so far often targeted countries or regions with weak governance systems and poor protection of local people's land rights (Arezki et al., 2015, Osabuohien, 2014). In addition, a number of case studies confirm these risks and show that LSAIs often had lower benefits than expected and resulted in local conflicts for land ('land grabbing') (e.g., Nhantumbo & Salomao, 2010; Borras et al., 2011a; Borras et al., 2011b).

On the other hand, governments and International Organizations often argue in favor of the potential of LSAIs to contribute to economic development and poverty reduction, for example, by providing jobs in agriculture and agro-processing or enabling small-scale farmers to access high-value markets, modern knowledge and technologies. In addition, they may contribute to overall economic development via investments in schools and hospitals as part of Corporate Social Responsibility (CSR) commitments (Deininger and Byerlee, 2012) or by increasing tax revenues. Especially investments in biofuels may also lead to greater energy security and import substitution, which is particularly relevant for non-oil producing land-locked countries (Mitchell, 2011).

At the international level, policy guidelines have been developed in recent years to encourage responsible agricultural investments (RAI) that contribute to poverty reduction and economic development, e.g., the RAI-Principles (Committee on Food Security – CFS, 2014). The type of investment model or supply chain set-up is considered a crucial element in this context for influencing the development impacts of LSAIs (ibid.; Vermeulen & Cotula, 2010). The literature discusses a variety of alternative models to large-scale land acquisitions, such as contract farming, nucleus-outgrower schemes, or joint ventures (Vermeulen and Cotula, 2010). Models that create linkages with smallholder farmers, such as contract farming or outgrower schemes,[1] are often considered most effective (Vermeulen and Cotula, 2010; Smalley, 2013).

In spite of the relevance for development and for policy making, there is little empirical evidence yet of the welfare effects of LSAIs in general and specific investment models in particular, which is the main motivation for this thesis. Recent ex-ante simulations by Arndt et al. (2010) in Mozambique and Baumgartner et al. (2015) in Ethiopia suggest potential positive welfare effects. Arndt et al. (2010), for example, assessed potential income implications of large-scale biofuel investments in Mozambique using a country-wide computable general equilibrium evaluation framework, exploring both sugarcane plantation-based expansion and jatropha outgrower investments. Although they predict overall income improvements, they predict outgrower-based models to be more pro-poor. Baumgartner et al. (2015) provides micro-level insights by simulating expansions of a large-scale rice investment in Ethiopia using a linear programming approach based on survey data. While they also predict overall positive employment effects, they also argue that investments partly based on outgrower systems to generate more inclusive results.

In a recent study, Deininger et al. (2015) use country-wide survey data of large-scale and small-scale farmers in Mozambique to assess actual spillover effects of large-scale farms. The authors find evidence of some positive spillovers, with surrounding farmers adopting some practices and accessing fertilizer and pesticides as used by large-scale farms. Yet they find also negative impacts on smallholder farmers' subjective well-being.

There are hardly any ex-post evaluations of actual impacts of LSAIs in SSA through direct participation channels, such as the labor market or contract farming/outgrower schemes. Existing evidence on labor market effects mainly emanates from the high-value horticulture exports sector in SSA. This literature, on the one hand, criticizes the low quality of jobs and

[1] In this article, the terms contract farming and outgrower schemes are used interchangeably. Eaton and Shepherd (2001, p.2) define contract farming "as an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices," often involving production support through advice and input provision.

low wages created (Barrientos and Kitzinger, 2004; Barrientos et al., 2005). On the other hand, the only existing econometric study of household welfare effects by Maertens et al. (2011) on tomato export chains in Senegal finds positive income effects from participation, with benefits especially occurring to poorer households. Empirical studies on contract farming or outgrower schemes in SSA come to rather mixed conclusions of their effects. Some studies, for example, note the risk of exploitation of farmers (e.g., Little and Watts, 1994) as well as their exclusionary processes (e.g., Porter and Phillips-Howard, 1997; Singh, 2002). In contrast, some impact evaluations in recent years that use control-group comparisons mostly find positive household welfare effects for farmers integrated in such supply chains (Warning and Key, 2002; Bolwig et al., 2009; Bellemare, 2012; Vaeth and Kirk, 2014). Vaeth and Kirk (2014) is the only study analyzing contract farming in sub-sectors most relevant for LSAIs, in this case palm oil in Ghana. There is hardly any study comparing different business models or investment channel using ex-post data, with an exception of Maertens' and Swinnen's (2009) study on contract farming and wage-labor participation in Senegal.

1.2 Research objectives

The overall objective of this thesis is to contribute to a better understanding of the potential implications of LSAIs for rural households' welfare in Sub-Saharan Africa.

Specifically, the objectives are to measure income and poverty effects of different impact channels and business models, namely (1) product market linkages through outgrower schemes, (2) labor market linkages through estate and factory employment, and (3) spillover effects as part of technology transfer projects.

The thesis approaches these objectives via three articles (Chapters 2-4) drawing on case studies of LSAIs in Malawi and Tanzania in the sugar and rice sub-sectors:

- *Article 1 evaluates a foreign direct investment (FDI) in Malawi's sugar sector on household income and income poverty via participating as estate workers and different outgrowers models.*
- *Article 2 studies income and poverty effects of LSAIs in Tanzania, by comparing two foreign investments in the sugar and rice sub-sectors via factory and estate worker channels and outgrowers schemes.*

- *Article 3 analyses plot- and household level yield and income spillover effects of the large-scale rice investment Tanzania and compares it to direct labor market effects.*

1.3 Case studies & data

Case studies

The thesis comprises three case studies of LSAIs in Malawi and Tanzania.

In Malawi, the analysis relies on a major sugar and ethanol producing cluster in the Central Region, with Dwangwa Sugar Company (DSC) at its core. DSC is under leadership of the British-South African sugar producer Illovo Ltd. and was established in 1979 through a sugar factory, a 6,000 ha estate on swamp land, and initially an integrated smallholder irrigation scheme. Later, an ethanol plant was constructed by another company. The investment was selected as case study because of the growing importance of different smallholder arrangements, which allows for a comparison of estate investments with smallholder-based arrangements. Since the 1990s, independent smallholders started to participate as rainfed outgrowers and since the 2000s, the Government of Malawi (GoM) started implementing large-scale smallholder irrigation schemes, financed by the African Development Bank (AfDB) and the European Union (EU).

In Tanzania, the analysis relies on two LSAIs in Kilombero Valley, Morogoro Region. Kilombero District of Morogoro Region is a priority cluster for attracting agribusiness investments under the Southern Agricultural Growth Corridor of Tanzania – SAGCOT (SAGCOT, 2011). Kilombero contains the largest low-altitude freshwater wetland of East Africa (Kangalawe & Liwenga, 2005) and is a major rice and sugarcane producing area of Tanzania. However, large-scale farming is not well developed (Nindi et al., 2001). Investments under SAGCOT were still in a preparatory phase when the survey started. The two investments analyzed in this thesis, namely Kilombero Sugar Company Limited (KSCL) and Kilombero Plantation Limited (KPL), existed already.

KSCL is the largest sugar producer in Tanzania, accounting for more than 60% of the country's sugar output (SBT, 2015). KSCL was established already in the 1960s and comprises two adjacent agricultural estates and sugar factories, as well as an alcohol distillery (Illovo, 2014). Employment is created for 870 permanent staff and 2,073 seasonal workers at peak periods (ibid.). The share of outgrowers increased substantially since the early 2000s, contributing to around 60% of total sugarcane production. Outgrowers are linked to KSCL through associations that have sugarcane supply agreements with KSCL. Harvesting and transportation is organized by the associations.

KPL is a large-scale rice investment established in 2008 as joint venture between the British company Agrica and RUBADA, a Tanzanian parastatal organization, on an almost 6,000 ha government property. The investment comprises an industrial rice mill, a large warehouse, and cleaning and drying facilities. At full operation, employment of 180 full-time and up to 300 seasonal workers is expected. As processes are highly mechanized, agricultural jobs are mainly in weeding. Although KPL buys at times rice from surrounding farmers, no real contract farming scheme had been yet established. However, in partnership with USAID, a smallholder rice intensification project was installed that aims at improving the rice production of 5,000 farmers in the area by promoting improved methods, high-yielding varieties, and fertilizer, with varieties and fertilizer also used by KPL (SAGCOT, 2013).

Data sets

Three household surveys were conducted as part of the articles for this thesis.

The first household survey and qualitative interviews were conducted between 2010 and 2011 around DSC in Malawi. The household survey includes a representative sample of sugarcane outgrowers, estate workers and non-participants in the villages surrounding DSC. The sample comprised 225 sugarcane outgrowers, 60 estate workers as well as 328 non-participating households from the outgrower villages and control villages.

The second household survey was conducted in 2013 in villages surrounding KPL. The survey comprised 357 households, 144 of which were small-scale rice farmers participating in the rice intensification project, 61 households who were factory or estate workers, and 152 non-participants. Project participants and non-participants were randomly selected from the 10 project villages. Agro-industry workers came from three KPL surrounding villages, but were interviewed at their work place.

The third survey was also conducted in 2013 with groups including sugarcane outgrowers, sugar factory and estate workers and non-participants in villages surrounding KSCL. Interviewees were selected through a two-stage stratified random sampling procedure. First, three wards were purposely selected because it was where most of the sugarcane growers came from. Households were selected from all villages within the three wards. Village population lists were used to categorize households according to the three groups (outgrowers, workers, non-participants) and participants were randomly selected accordingly.

1.4 Structure of the thesis and main conclusions

The thesis' specific objectives are addressed in three different articles, which are as follows:

The first article (Chapter 2) explores the direct socio-economic impacts of the sugar and ethanol investment in Malawi (Herrmann and Grote, 2015). The article compares participation through individual rainfed outgrower schemes, group-based irrigation outgrower schemes, and estate employment with a control group in terms of income and poverty status. The article uses the Malawian cross-section data collected in treatment and control villages of a total of 613 households (outgrowers, estate workers and non-participating households). In addition, focus group discussions and individual qualitative interviews are used to cross-check and understand underlying processes. To account for selection bias and endogeneity problems a Treatment Effects Model and Propensity Score Matching (PSM) and numerous robustness checks are used. The findings show significant positive income differences between participants in either supply-chain set-up and the respective counterfactual group. Income poverty is significantly lower among outgrowers relative to the counterfactual, but for the case of estate workers differences are only significant for the extreme poverty line, which suggests estate employment to primarily reduce extreme poverty. Although qualitative interviews confirmed these results, they allude to risks of social conflicts in the outgrower scheme expansions and lack of transparency in their operations, likely undermining their poverty-reducing potentials.

The second article (Chapter 3) investigates the household welfare effects of the two LSAIs in Tanzania in the two sub-sectors rice and sugar, comparing labor and outgrower models. It uses parts of the two surveys conducted in 2013 in Kilombero Valley. The sample used for this article comprises 516 households, including sugarcane outgrowers, rice and sugar agro-industry workers and non-participants. The results confirm positive effects through the analyzed impact channels, as found by Herrmann and Grote (2015). However, there are large differences between arrangements and subsectors. Outgrowers benefit the most, yet land-rich more so than land-poor. Sugar workers experience larger gains than workers in the rice investment, though in both investments land-poor workers seem to benefit. Hence, the study suggests large direct benefits for participation in outgrower schemes, but also potentials of agro-industry wage employment for the land-poor to escape extreme poverty. The article also underlines the need to address constraints of land-poor outgrowers in particular. Qualitative interviews pointed specifically to risks for land-poor outgrowers due to elite capture of outgrower services by wealthier outgrowers.

Article three (Chapter 4) analyzes spillover effects of LSAIs to small-scale farmers. Specifically, it evaluates the Public-Private Partnership project between KPL and USAID, involving training farmers through farmer-field schools and distributing improved technologies. In addition, it compares this spillover channel to the agro-industry wage labor channel. The article relies on part of the previous data set of agro-industry rice workers and non-participants as well as participants of the rice project. The sample size for this article is 357, comprising 144 farmers participating in the project, 61 factory and plantation workers, and 152 non-participants from the 10 project villages. The article combines plot- and household-level analyses and uses a treatment effects model, ordinary least squares regressions and PSM to analyze yield and income effects. Although only slightly higher yield and income effects are observed at the household level, by adding plot-specific analyses to account for partial adoption, effects from adoption are substantial. Labor market participation is also associated with higher per capita incomes, but is lower than the effects of the smallholder rice project. The results, among others, suggest that participation in such investments have potentials to contribute to income improvements. Yet particularly projects that increase the productive capacity of surrounding areas, such as smallholder intensification projects or contract farming, are likely to yield greater welfare benefits of such investments.

Table 2: List of papers included in the dissertation

Chapter	Authors	Title	Published in / Submitted to / Presented at
2	Herrmann, R., Grote, U. (2015)	Large-scale Agro-Industrial Investments and Rural Poverty: Evidence from Sugarcane in Malawi.	Published in: Journal of African Economies, 24 (5): 645-676.
			Accepted paper for presentation at the PEGNet Conference 2012, Dakar, Senegal, September 6-7, 2012.
			Accepted paper for presentation at the 14th World Bank Land & Poverty Conference, 2013, Washington D.C., April 8-11, 2013.
			Accepted paper for presentation at Tropentag 2011, Bonn, October 5-7, 2011.
3	Herrmann, R.	Large-scale agricultural investments and smallholder welfare: a comparison of wage labor and outgrower channels in Tanzania.	Submitted Paper at the Journal "World Development".
			Accepted paper for presentation at the 2014 Global Land Project / Open Science Meeting, Berlin, March 19- 21, 2014.
			Accepted paper for presentation at the 15th World Bank Land & Poverty Conference, 2014, Washington D.C., March 24-27, 2014.
			Accepted paper for presentation at the Tropentag 2015, Berlin, October 5-7, 2015.
			Accepted paper for presentation at the CSAE Conference 2016:

			Economic Development in Africa, Center for Studies of African Economies, Oxford, March 20-22, 2016.
4	Herrmann, R.	Technology spillovers and labor market effects of a large-scale rice investment in Tanzania.	Submitted paper to the Journal "Agricultural Economics".
			Accepted paper for presentation at the 17th World Bank Land & Poverty Conference, 2016, Washington D.C., March 14-18, 2016.

1.5 Contributions to the literature

The thesis attempts to make five major contributions to the literature about the welfare implications of LSAIs in SSA.

Firstly, this thesis is one of the few empirical studies using micro-level survey data to investigate ex-post impacts of LSAIs in SSA. It thereby adds to recent ex-ante analyses by Arndt et al. (2010) on biofuel crops in Mozambique and Baumgartner's et al. (2015) on rice in Ethiopia. The sub-sectors and countries analyzed in this thesis are interesting cases. Both, rice and sugarcane are among the most relevant sub-sectors targeted in LSAI proposals in SSA (Land Matrix Database, 2015), as a consequence of rising demand from within and from outside SSA (Larson et al. 2010; Johnson & Seebaluck, 2012). Tanzania has been among the main destinations for LSAIs in SSA, apart from Mozambique and Ethiopia (Land Matrix Database, 2015). Whereas biofuel production has been an initial driver for LSAIs in Tanzania (Locher & Sulle, 2013), recent policy programs have been launched to attract large agribusiness investments more broadly, namely the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) and Big Results Now (BRN) (GoT, 2013; GoT, 2015). Rice and sugar are priority subsectors in SAGCOT and BRN (SAGCOT, 2011; GoT, 2015). The rice and sugar investments analyzed in this thesis are located within the SAGCOT corridor and are considered best-practice investments. The thesis is the first empirical evaluation of their socio-economic effects. Although Malawi has not been a major recipient of LSAIs given its small land-locked nature, it has been one of the lowest-cost producers globally (LMC, 2005). Between 2010 and 2013, sugarcane yields averaged 107 tons per hectare, only topped by Peru, Egypt and Senegal (FAOSTAT, 2015). The sugarcane-based industries are supported as one of three pillars under the new National Export Strategy (NES, 2014).

Secondly, the thesis is among the first to analyze the socio-economic effects of a nascent large-scale biofuel industry in SSA. Malawi has been the only country in SSA that has continuously produced biofuel-ethanol based on sugarcane-molasses on an industrial scale since 1982 (Amigun et al., 2011; Maltsoglou et al., 2013). Sugarcane-based ethanol is currently the main source for biofuel production in SSA (Amigun et al., 2011) and is considered to be the most promising, lowest-cost biofuel feedstock, particularly for landlocked countries (Mitchell, 2011; Johnson and Seebaluck, 2012). The case is therefore particularly suitable for a study of the potential effects of an expanding biofuel industry in SSA.

Thirdly, the thesis contributes to the understanding of the welfare effects of different business models an impact channels for LSAIs in SSA. In this context, the thesis investigates the impact of factory and plantation/estate wage employment as part of LSAIs on household income and poverty, which is crucial to understand the overall implications of LSAIs given that the labor market is likely to be the major channel through which the rural poor are integrated in LSAIs. This study contributes to closing the gap on empirical evidence on their welfare implications by evaluating income and poverty effects of participation in factory or estate employment of LSAIs. It thereby complements existing evidence on high-value horticultural export crops (Maertens et al., 2011) with insights on rice and sugar sub-sectors. In addition, the thesis contributes to an understanding of the welfare impacts of outgrower schemes within LSAIs by studying sugarcane schemes in Malawi and Tanzania. The thesis therefore adds to the literature on contract farming in high-value crops in SSA, by focusing on outgrower schemes in a sub-sector relevant in LSAI, similar Vaeth's and Kirk's (2015) research on palm oil in Ghana. Sugarcane production in SSA is particularly interesting as it commonly relies on large estates (Yamba et al., 2008), but with small-scale farmers also often integrated through outgrower schemes to complement estate production (*outgrower-nucleus estate*) (ISO, 2008). Land Matrix data reveals, for example, that 25% of sugarcane investments intend to integrate such contract farming arrangements (Land Matrix, 2015). Governments see outgrower schemes often as main instrument to increase the inclusiveness of LSAIs, e.g. SAGCOT in Tanzania and Malawi's NES (GoT, 2015; GoM, 2014). Their welfare implications are unclear as these supply chains present extreme forms of monopsonic relationship with a single processor usually sourcing from a large number of farmers that have no alternative market outlets, making them highly depend (Sivramkrishna and Jyotishi, 2008; White, 1997). Yet, smallholders could also benefit from the buyer's monopsonic position as the buyer may invest in the suppliers' production capacity due to the lower risk of side-selling (Glover, 1990). In addition, sugar farmers may also benefit from highly protected sugar markets and sale of other by-products (e.g. molasses for ethanol production in Malawi).

Fourthly, the thesis adds to an understanding of the relative benefits of different institutional arrangements for LSAIs, adding to Maertens' and Swinnen's (2009) comparative study on alternative supply chain set-ups in horticultural export chains in Senegal. Understanding differences in welfare effects of different institutional arrangements, is of high relevance given the importance often attached to the institutional arrangement to influence the development outcomes of such investments. Moreover, the type of institutional arrangements is a potential parameter for governments to influence, for example, by making investment permits or land leases conditional on contract farming arrangements.

Finally, the thesis contributes to an understanding of spill-over effects of LSAIs. The study therefore complements and adds to Deininger et al.'s (2015) study in Mozambique by providing micro-level evidence from a specific investment in rice in Tanzania. It provides insights into a particular Public-Private Partnership (PPP) project to transfer knowledge and rice technology (high-yielding varieties, fertilizer) to the smallholder sector.

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Note: The contribution of the authors to the submitted articles is as follows: The data collection, literature review, all calculations and drafting the texts have been done by Herrmann unless noted otherwise. The contribution of Grote in chapter 2 can be defined as: overall supervision, providing suggestions and guidance on methods, results and general contents; as well as thorough editing.

2 Large-scale agro-industrial investments and rural poverty: evidence from sugarcane in Malawi

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3 Large-scale agricultural investments and smallholder welfare: a comparison of wage labor and outgrower channels in Tanzania

Abstract

This article evaluates household welfare effects of large-scale agricultural investments in Tanzania, one of the main recipients of such investments in Africa. Specifically, the article compares households participating in sugar and rice investments through outgrower schemes or as agro-industry worker with non-participants in terms of household income and income poverty. Building on primary household data, it is one of the first studies to empirically analyze ex-post impacts of large-scale agricultural investments in Africa. The analysis draws on cross-section survey data of 516 households collected in Kilombero District, a priority cluster for the Southern Agricultural Growth Corridor of Tanzania (SAGCOT). The results suggest overall positive effects of the investments on the participants. However, there are large differences between arrangements and subsectors. Outgrowers benefit the most, yet land-rich more so than land-poor. Agro-industry workers in the sugar investment experience larger gains than those in the rice investment, though in both investments land-poor workers seem to benefit. Hence, the study suggests large direct benefits of outgrower schemes and potentials of agro-industry wage employment for the land-poor to escape extreme poverty. Yet, it also stresses particularly the need to address the constraints of land-poor outgrowers. Qualitative interviews, for example, pointed to growing risks for land-poor outgrowers in the context of rising elite capture by larger outgrowers.

Keywords: large-scale agricultural investments, socio-economic impacts, outgrowers, agro-industry employment, Tanzania

3.1 Introduction

The biofuels boom and sharply rising global food prices since the mid-2000s have led to a massive surge in foreign investors attempting to acquire agricultural lands in developing countries (Deininger et al., 2011). Sub-Saharan Africa (SSA) has received a major share of such large-scale agricultural investment (LSAI) proposals (Cotula et al., 2009). Recent estimates by Schoeneveld (2014) suggest 563 large-scale land deals between 2005 and 2013 in 37 countries, covering nearly 23 million hectares. However, past experiences with LSAIs in SSA provide plenty of examples of failures of such investments (Collier and Dercon, 2009; Deininger and Byerlee, 2012; Tyler and Dixie, 2013) and many of these new LSAIs have also been abandoned, especially those targeting biofuels (Maltsoglou et al., 2013; Singh et al., 2014), or have not yet materialized (Land Matrix Global Observatory – LMGO, 2015). Still, the share of large-scale farming and investments in SSA is likely to rise in future, given the technological innovations to manage large farms, growing demand for standardized products and governments' motivations to expand into uncultivated areas (Deininger and Byerlee, 2012).

The potential implications of LSAIs have been highly controversial. On the one hand, there are widespread concerns of substantial social and ecological risks of such investments that threaten the very livelihoods of poor farming households (Cotula et al., 2009; Hall, 2011; Global Land Grabbing Conference, 2011). Previous experiences in SSA also show that LSAIs were often associated with substantial social conflicts with negative long-term repercussions (Deininger and Byerlee, 2012). A recent econometric analysis of Arezki et al. (2015) also finds that LSAIs have so far often targeted countries with weak governance systems and protection of poor people's land rights, reinforcing such concerns. On the other hand, LSAIs may contribute to economic development and poverty reduction by generating rural employment, enabling local farmers to access high-value markets, modern knowledge and technologies or by contributing to investments in infrastructure, schools, and hospitals as part of Corporate Social Responsibility commitments or through tax revenues (Deininger et al., 2011; Deininger and Byerlee, 2012). At the international level, policy guidelines have been developed in recent years to encourage such responsible agricultural investments that contribute to poverty reduction and economic development (e.g., Committee on Food Security – CFS, 2014). The type of institutional arrangement is considered an important parameter in this context (Vermeulen & Cotula, 2010), with arrangements that create linkages with smallholder farmers, such as contract farming or outgrower schemes,[2] often considered most effective (Arndt et al., 2010; Deininger et al., 2011).

In spite of the relevance for development and policy making, there is still a paucity of empirical evidence on the welfare and poverty effects of LSAIs (Deininger and Byerlee, 2012; Oya, 2013a). Studies have so far used ex-ante simulations to measure potential impacts,

[2] Eaton and Shepherd (2001, p.2) define contract farming "as an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices," often involving production support through advice and input provision. In this article, the terms contract farming and outgrower schemes are used interchangeably.

with Arndt et al. (2010) simulating large-scale biofuel expansions through jatropha or sugarcane production in Mozambique and Baumgartner et al. (2015) assessing the expansion of a rice investment in Ethiopia. Both studies suggest positive welfare effects, but more pro-poor effects if smallholders are integrated in the supply-chains. Deininger et al. (2015) have recently used survey data of large-scale and small-scale farmers in Mozambique to study spillover effects. The authors find evidence of some spillovers to small-scale farmers in terms of adoption of farming practices, fertilizer and pesticides, but also negative impacts on farmers' subjective well-being.

However, hardly any empirical evidence exists on the actual impacts through the most relevant direct channels of LSAIs, i.e. labor market linkages via plantations and large-scale farming or product market linkages via outgrower schemes. Studies on labor market effects have so far focused on less land-intensive high-value horticulture export sectors in SSA, which often have viewed these jobs critically because of their low quality and low wages (e.g., Barrientos and Kitzinger, 2004; Barrientos et al., 2005).The only study applying a more rigorous approach using a control-group comparison (Maertens et al., 2011, on horticulture exports in Senegal), however, finds positive welfare effects, with benefits especially occurring to poorer households. The existing literature on contract farming comes to rather mixed conclusions of their effects. On the one hand, authors have noted the risk of exploitation of farmers (e.g., Little and Watts, 1994) and exclusionary processes (e.g., Porter and Phillips-Howard, 1997; Singh, 2002). On the other hand, more recent impact evaluations mostly find positive household welfare effects for contract farmers (Warning and Key, 2002; Bolwig et al., 2009; Maertens and Swinnen, 2009; Bellemare, 2012; Vaeth and Kirk, 2014; Herrmann and Grote, 2015). Vaeth and Kirk (2014) on palm oil in Ghana and Hermann and Grote (2015) on sugar in Malawi are the only two studies that analyze contract farming as part of a LSAI. In addition, only two studies exist that compare the effectiveness of different institutional arrangements, which are Maertens and Swinnen (2009) and Hermann and Grote (2015), who assess contract farming and wage employment in Senegal and Malawi, respectively.

The aim of this study is to contribute to the literature on the welfare effects of LSAIs by evaluating the household income and income poverty implications of outgrower schemes and estate/plantation and factory employment in large-scale rice and sugar investments in Tanzania. The analysis is based on cross-section data of sugarcane outgrowers, agro-industry workers (sugar and rice) and non-participants in villages surrounding two LSAIs in Kilombero District, Morogoro Region. The article is among the first that attempts to measure actual ex-post impacts of LSAIs in SSA, thus, contributing to filling the literature gap identified by Deininger and Byerlee (2012) and Oya (2013a). Moreover, it attempts to contribute to a better understanding of the heterogeneous effects of LSAIs because of differences in sub-sectors and institutional arrangements.

Rice and sugar in Tanzania are very interesting cases. Demand for rice and sugar has been increasing within and outside the region amid rising incomes and urbanization (Larson et al. 2010; Johnson & Seebaluck, 2012). Both subsectors have been among the main targeted crops under LSAI proposals in SSA (LMGO, 2015), with Tanzania among the top three recipient countries, apart from Ethiopia and Mozambique (ibid.). Sugar and rice are considered priority sub-sectors in Tanzania's national strategies to develop commercial agriculture (Southern Agricultural Growth Corridor of Tanzania - SAGCOT, 2011; Government of Tanzania - GoT, 2013). The case study area is within SAGCOT, a major public–private partnership initiative to attract agribusiness investments. The two investments have been referred to as role models for future SAGCOT investments (SAGCOT, 2011).

The article is structured as follows. Section 2 discusses the literature. Section 3 describes the context of agro-industry investments in Tanzania. Section 4 explains the data source and methodology, before Section 5 presents and discusses descriptive and econometric results. Section 7 concludes.

3.2 Literature review

This chapter summarizes existing literature on the effects of contract farming or outgrower schemes and employment linked to LSAIs. Contract farming may help smallholder farmers overcome their previous lack of access to credit, quality inputs, high-value output markets or know-how (Barrett et al., 2012). Input market access, for example, can be facilitated if either (a) farmers use their output-contracts as collateral, (b) the output-contracts have inbuilt credit schemes (e.g., tri-partite arrangements with commercial banks) or (c) cash earnings are sufficient to buy inputs (Grosh, 1994; Govereh et al., 1999). As a result of improved access to quality inputs, extension, and high-value output markets, producer prices and/or quantity may increase, leading to overall higher incomes. Yet negative welfare effects may also arise due to increased exposure to production and marketing risks from adopting a new crop and accessing previously unknown markets (Eaton and Shepherd, 2001; Simmons et al., 2005). Most problematic may be situations in which farmers face a single buyer, and relationship-specific investments are undertaken, potentially locking them in (Sivramkrishna & Jyotishi, 2008). Sugar, for instance, is an extreme case of monopsonic market relations, where usually a single processor sources from a large number of outgrowers with no alternative market outlet. Side-selling is made difficult due to the bulkiness and perishability of the crop, as well as legislation, which often creates regional monopolies.[3] At the same time, outgrowers may benefit from the processor's output market security if it creates incentives for the processor to invest in the outgrowers, as side-selling risks are reduced (Glover, 1990; Tiffen & Mortimore, 1990). Some recent studies find positive participation effects of contract farming in terms of household welfare (Warning & Key, 2002; Miyata et al., 2009; Bellemare, 2012), although there are a few exceptions (Simmons et al., 2005; Narayanan, 2014).

The direct welfare effects of participating as wage laborers in LSAIs are more uncertain. As agricultural wage employment usually involves high monitoring costs, hired labor has usually been used for only simple tasks involving low wages (Otsuka & Yamano, 2006; Oya, 2013). Agricultural wage employment is therefore often argued to be performed by those households lacking the ability to engage in high-rewarding non-farm or on-farm jobs (Davis et al., 2010). Consequently, although it may be an important coping strategy against shocks, it is usually believed to add little to lift the poor out of poverty (Otsuka & Yamano, 2006; Oya, 2013). There is some indication, however, that jobs in large-scale investments may have more significant effects, especially if foreign capital is involved, as in the cases analyzed here. Foreign firms may bring in capital, new ideas and technologies, thereby increasing worker productivity (Harrison, 1994). Paying higher wages may also be a strategy to increase efficiency or to retain productive workers (efficiency-wage hypothesis) (Akerlof & Yellen, 1986), or be a result of exposure to global consumer scrutiny (Oya, 2013). Te Velde & Morrissey (2003), for example, found in manufacturing industries in SSA that foreign firms tend to pay higher wages than domestic firms. Some studies on agro-industries in SSA regarding foreign-owned firms (Cramer et al., 2008, for Mozambique) or food exports (Maertens & Swinnen, 2009; McCulloch & Ota, 2002) also provide some positive evidence to this hypothesis.

3.3 Large-scale agricultural investments in Tanzania

3.3.1 Context of LSAIs in Tanzania

Agro-industry investments involving large-scale land acquisitions have been a matter of considerable debate throughout SSA (Gibbon, 2011).[4] Prior to independence, large-scale foreign estates that produced export crops were strongly promoted by governments in

[3] The Tanzanian Sugar Board Act of 2001, for example, effectively creates regional monopsonies by prohibiting the establishment of different sugar factories within a certain area (Nkonya and Barreiro-Hurle, 2014).
[4] Yet, this is in spite of their relative low importance. Gibbon (2011), for example, estimates that on average only 5%–7.5% of all cultivated land in Sub-Saharan Africa has been under plantations or large-scale farming.

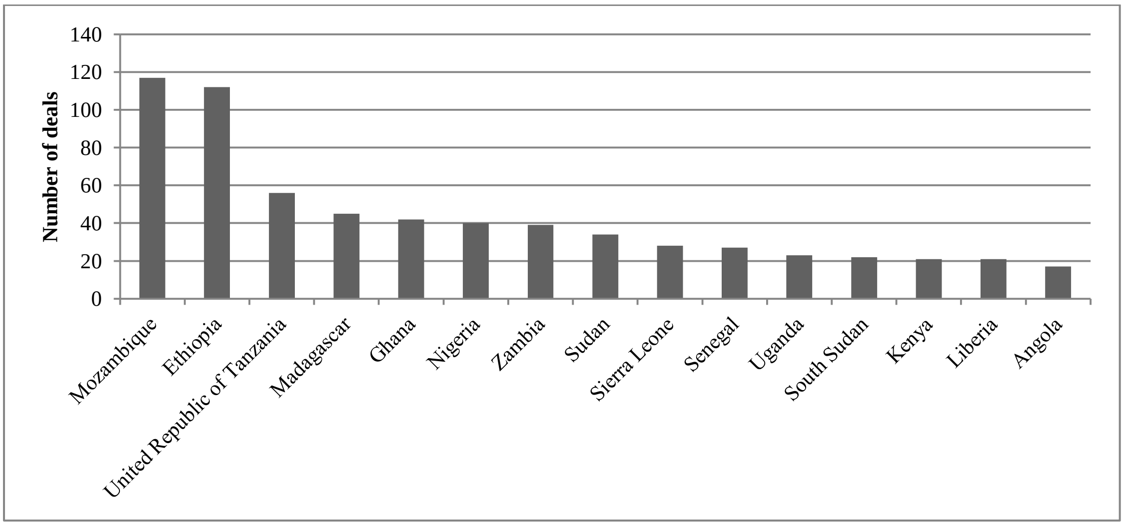
Tanzania and elsewhere, leaving the small-scale sector often with little support (ibid.; Rweyemamu, 1973). Yet smallholder cash-crop production flourished in some regions (ibid.; Mrema & Ndikumana 2013) and received widespread state support after independence, e.g., through cooperative development (Maghimbi, 2010) or outgrower programs linked to agro-industry investments (e.g., World Bank, 1994). After the state-led period in the 1990s, policies focused again on promoting commercial private investments as an engine for agricultural growth,[5] though recognizing small-scale farmers' role in poverty reduction (e.g., National Growth and Poverty Reduction Strategies – MKUKUTA I and II).

Since the mid-2000s, Tanzania has experienced a rapid increase in biofuel and other agricultural investment proposals and has become one of the main destinations in Africa for LSAIs (Figure 1). By 2008, an estimated 4 million hectares had been under negotiation for biofuel projects alone (Sulle & Nelson, 2009). Most biofuel investments, however, have failed (Locher & Sulle, 2013), while numerous studies reported conflicts with local communities (e.g., Action Aid 2009, HAKIARDHI, 2014, Daley & Scott, 2011). Although the area under negotiation declined thereafter, an estimated 1 million hectares was still negotiated in 2012, though focusing now on food crops and forestry products (Locher & Sulle, 2013). In this context, recent major investment promotion initiatives in Tanzania were formulated to attract LSAIs. The Southern Agricultural Growth Corridor of Tanzania (SAGCOT), for example, was established in 2010 at the World Economic Forum on Africa as an international public–private partnership to mobilize agribusiness investments throughout the southern transport corridor (SAGCOT, 2011). In addition, Big Results Now (BRN) was adopted in 2012 as a government initiative, complementing SAGCOT, to accelerate investments in agriculture, with the specific aim of establishing 25 large-scale commercial farming deals (GoT, 2013; GoT, 2015).

Controversies around early biofuel investments have led to proposals for regulatory changes, such as Biofuels Guidelines that put a ceiling on land purchases in biofuels and incentives for implementing outgrower schemes (GoT, 2010). Amendments had previously been made to the Land Act to involve local communities, allowing for joint ventures between villages and private investors (Sulle & Nelson, 2009). SAGCOT and BRN have also adopted inclusive business models in their blueprints by focusing on outgrower schemes or collective farming arrangements (block farms) (GoT, 2015).

[5] The Investment Promotion Act of 1996 provided investment incentives and led to the establishment of the Tanzanian Investment Center (TIC), which is mandated to actively promote large-scale agricultural investment (TIC, 2015).

Figure 1: Number of large-scale land deals in Sub-Saharan Africa (2014)



Source: LMGO (2015)

3.3.2 Development of sugar and rice sub-sectors

Sugar and rice are priority subsectors in SAGCOT and BRN (SAGCOT, 2011; GoT, 2015). Despite the potential for sugar production (FAO, 2010; SAGOCT, 2011), the industry has lacked competitiveness, with exports making up less than 5% of production (FAOSTAT, 2015), similar to other producing countries (LMC, 2004). The first factory and estate investments occurred in the 1930s and expanded after independence, involving state-supported outgrower schemes (World Bank, 1994). Parastatal ownership after 1967 led to the financial problems of the industry (ibid.) and eventual government divesture in 1998 (Sugar Board of Tanzania - SBT, 2015). After privatization, production increased sharply by 16% annually between 2000 and 2005, while imports declined (FAOSTAT, 2015).[6] Outgrower area more than doubled to 20,000 ha between 2000 and 2012 (35% of total area) (ibid.), which is in contrast to many other countries, where outgrowers have played a minor role (LMC, 2004). Since mid-2000s, output growth has slowed to around 2% annually (FAOSTAT, 2015), resulting in imports more than tripling and reaching more than 40% of total supply (ibid.). Low factory efficiency and low farm yields are major production constraints (Nkonya & Barreiro-Hurle, 2012). Yet, operating under full capacity would not be sufficient to meet demand (Smalley et al, 2014). Consequently new investments are given high political priority (SAGCOT, 2011).

[6] Despite sharp employment cuts (e.g. Holt Norris & Worby, 2012), 14,000 continued to be directly employed during peak seasons (2011/12) (SBT, 2015).

Rice has become an important staple in SSA, with demand increasingly being met by imports from outside the region (Larson et al., 2010). In contrast to the rest of SSA, imports to Tanzania have declined as production increased annually by 6% between 2000 and 2012, making it the largest producer in East Africa (FAOSTAT, 2015). Production is dominated by smallholder farmers; more than 1.1 million households are estimated to produce rice in Tanzania (GoT, 2012a). Large commercial farms have played a minor role (GoT, 2012b). Tanzania has become a marginal exporter of rice (FAOSTAT, 2015) and could even become a major exporter to the entire region (SAGCOT, 2011). Yet, current trade policies and low rice productivity have constrained exports (Barreiro-Hurle, 2012).[7] A National Rice Sector Development Strategy was therefore formulated to increase technology adoption (ibid.), while large-scale rice investments are also being increasingly promoted (SAGCOT, 2011, BRN, 2013).

3.3.3 Large-scale agricultural investments in the Kilombero Valley

Kilombero District of Morogoro Region has been identified as a priority cluster for investments under SAGCOT (SAGCOT, 2011). Kilombero contains the largest low-altitude freshwater wetland of East Africa (Kangalawe & Liwenga, 2005) and provides soil and climatic conditions highly suitable for production of a variety of crops (Beck, 1964), for some of which yields are the highest in the region (GoT, 2012c).[8] Kilombero is also the largest rice producer in Morogoro (ibid.). Agriculture is the main income source, which is largely conducted by small-scale farmers, most of whom produce rice and maize (ibid.). Poor infrastructure and other factors have constrained diversification into high-value crops. Still, the area has experienced strong in-migration by farmers in previous decades (Kangalawe & Liwenga, 2005; Nindi et al., 2001). Large-scale farming is not well developed, except for some teak, sugarcane and rice estates (Nindi et al., 2001). Investments under SAGCOT were still in a preparatory phase when the survey started. The two investments analyzed – Kilombero Sugar Company Limited (KSCL) and Kilombero Plantation Limited (KPL) – existed already, but are considered best-practice cases for investments under SAGCOT (SACGOT, 2013).

Kilombero Sugar Company Limited (KSCL)

KSCL was established in the 1960s as the first major commercial project in Kilombero, with a concession of more than 10,000 hectares and state-promoted outgrower schemes (Beck,

[7] FAOSTAT data suggests that while Tanzania is the 28th most important rice producer in the world, it is only in 99th place in terms of rice yields (2010–13 averages) (FAOSTAT, 2015)

[8] At the same time, the Kilombero Valley is surrounded by sites of great biodiversity value that constrain overall agricultural expansion (Nindi et al., 2001).

1964). After near collapse during nationalization (Smalley et al., 2014), it was acquired in 1998 by British–South African Illovo and ED&F Man, with GoT retaining a 25% share (SBT, 2015).

KSCL is the largest sugar producer in Tanzania, accounting for more than 60% of the country's sugar output (SBT, 2015). KSCL comprises two adjacent agricultural estates and sugar factories, as well as an alcohol distillery (Illovo, 2014). Employment is created for 870 permanent staff and 2,073 seasonal workers at peak periods (ibid.).[9] In addition, more than 10,000, mostly small-scale, farmers are integrated through outgrower schemes. As estate expansion is limited due to land constraints, production increase has relied on estate yield improvements through irrigation (ibid.), as well as outgrower expansions on customary land, which more than tripled to nearly 12,000 hectares of rainfed land in 2011/12 (60% of total sugarcane area) (SBT, 2015). Outgrowers are linked to KSCL through associations that have sugarcane supply agreements with KSCL. Harvesting and transportation is organized by the associations. Farmers buy certified seed cane through associations, some additionally purchase fertilizer and other inputs. Outgrower yields are very low, averaging 35–40 tons per hectare compared to 80-ton estate yields (Illovo, 2014). Recent government and donor support has aimed at raising outgrower yields by promoting block farms (European Commission – EC, 2012; GoT, 2013).

Kilombero Plantation Limited (KPL)

KPL is a recent rice joint venture between the British company Agrica and RUBADA, a Tanzanian parastatal organization mandated to promote agricultural investments in the Rufiji Basin. In 2008, Agrica purchased a 5,818-ha government property called Mngeta Rice Farm, which began as a Tanzanian–North Korean joint venture in 1986, but which was liquidated in 1993 (KPL, 2009). KPL established an industrial rice mill, a large warehouse, and cleaning and drying facilities (SAGCOT, 2013). At full operation, 20,000 tons of milled rice are expected to be produced, making it Tanzania's largest rice producer (KPL, 2009; SAGCOT, 2013), with employment of 180 full-time and up to 300 seasonal workers (ibid.). As processes are highly mechanized, agricultural jobs are mainly in weeding, with other jobs in processing, warehousing and support services. At the time of the survey, KPL had, at times, bought rice from smallholders, but no real contract farming scheme had been yet established. However, in partnership with USAID, a smallholder rice intensification project was installed, aimed at improving the rice production of 5,000 farm households in the area (SAGCOT, 2013).

[9] Most workers are employed on the estate and within the factories, many of whom are cane cutters involved in the manual sugarcane harvesting during the 9–10-month-long harvesting season. Other estate jobs include fertilizer application, truck driving, or gap filling.

3.4 Data and methodology

Data

The article is based on structured interviews from surveys conducted between April and June 2013 in villages surrounding KSCL and KPL, which focused on three groups: KSCL outgrowers, workers at KSCL and KPL (factory and estate) and non-participating households. Non-participants are not involved in sugarcane production, but focus on maize and rice farming as well as non-farm activities (e.g. local brewery, trade or casual wage labor).

In the sugar survey, interviewees were selected through a two-stage stratified random sampling procedure. First, three wards (group villages) (Ruhembe, Mkula, and Sanje), were purposely selected because it was where most of the sugarcane growers lived according to information provided by KSCL extension officers. Ruhembe includes all the villages that sell sugarcane to the northern sugar factory (K2), except for those sugarcane growers living in urban areas. The households living in urban areas, who are usually non-farm business operators with sufficient capital to acquire sugarcane plots, were not included in the sample and only interviewed through qualitative interviews. The other two wards are the main sugarcane-producing areas selling to the southern factory (K1). Almost all sugar agro-industry workers that live around the estates and factories, and are not migrant workers, come from these wards. Households were selected from all villages within the three wards. Village population lists were used to categorize households according to the three groups (outgrowers, workers, non-participants) and participants were randomly selected accordingly.

The agro-industry workers in the rice survey live in three villages directly surrounding KPL. As it was difficult to identify workers within the villages, sampling and interviews were conducted at the work place. Non-participants were sampled as control groups from within 10 villages surrounding the investment, based on population lists. The overall sample for this article comprises 209 and 307 households for the rice and sugar survey respectively.[10]

Methodological issues

In order to understand the direct household welfare effects, this study estimates the average treatment effect of the treated (ATT), which is the average outcome difference between participation, $E[Y(1) | D = 1]$, and the situation had the participant not participated, $E[Y(1) | D = 0]$:

$$ATT = E[Y_{1i} - Y_{0i} | D_i = 1] = E[Y_{1i} | D_i = 1] - E[Y_{0i} | D_i = 1].$$

[10] Due to missing data and outliers in the income section, seven households of the rice investment survey and five households of the sugar investment survey had to be discarded.

To overcome the problem that the outcome in absence of participation is unobservable (Heckman et al., 1997), randomly assigning households into treatment and control groups would allow both groups to be statistically equivalent except for participation, so that $E[Y(0)|Z,D=1] = E[Y(0)|Z,D=0]$. Yet, participation is rarely random in observational studies and, instead, participants and non-participants usually differ before treatment, which may lead to over- or underestimating the true treatment effect (selection bias). Such a selection bias may arise from (a) project placement and selection decisions by the company as well as (b) households' self-selection into the respective channel. Companies, for instance, may prefer working with better-off farmers to reduce transaction costs (Barrett et al., 2012). Households may decide to participate, depending on their expected returns, risks and their capacity to participate. In the literature on agricultural market access or contract farming (e.g. Benfica, 2006; Barrett et al., 2012; Bellemare, 2012), participation is often influenced by the initial physical, educational and financial asset base, entrepreneurial ability, social networks, risk aversion or technical skills (Barrett et al., 2012). For the case of agro-industry wage employment, the non-farm diversification literature also indicates that initial wealth status influences household-level diversification opportunities (Ellis, 2000). Poorer households may therefore rather self-select into the rural labor market due to their low agricultural earning potentials.

In the sugarcane outgrower case studied, participation has been relatively open. Smallholder outgrower participation first increased strongly at the end of 1970s. The company promoted sugarcane growing among all farmers in surrounding villages and provided infrastructure support as well as financial and agricultural assistance (Smalley et al., 2014). However, during the 1980s and 1990s most outgrowers quit (ibid.). Given the objective to increase sugar self-sufficiency after privatization, smallholders were encouraged again in the early 2000s to join through a number of public–private partnerships, involving outgrower infrastructure rehabilitation, technical assistance, micro-finance, and bulk input supply, making it easier for farmers to participate (see Befeki, 2006; Smalley et al., 2014). In addition, KSCL encouraged participation by improving factory efficiency and more transparent payment systems (ibid.). Low rewards from alternative crops also led many farmers to join sugarcane outgrower schemes (ibid.). The Sugar Industry Act of 2001 governs outgrower participation, requiring outgrowers to join an outgrower association and to register with the Sugar Board of Tanzania. There are no additional requirements, except for having land available and start-up capital to acquire inputs, as well as paying a small association fee (Smalley & Sulle, 2014), which are therefore hypothesized to be the main entry barriers.

Likewise, interviews with non-participants still revealed that lack of capital (85%), land (72%), and sufficient family labor (24%) were perceived to be the main factors impeding participation.

In the case of agro-industry workers, the participation process and barriers are not as clear. As far as sugar investment is concerned, during the early years of the investment, employment of migrant laborers was common (World Bank 1994), many of whom later on stayed in the region and acquired farm land (Smalley & Sulle, 2014). With privatization, many workers quit their jobs at the estates due to declining salaries and fewer additional benefits, but were replaced by other workers on seasonal contracts with lower wages (ibid.). Although it may suggest that households lacking alternative income sources would mainly work in these jobs, qualitative interviews still suggested an overall very high demand among households for this work, which is understandable, especially given the high youth underemployment. In the rice case, qualitative interviews suggested that participants and non-participants view employment on the estates as inferior to other jobs. Yet, demand for factory as well as estate jobs is also very high. Some even noted the need to pay bribes to access these jobs.

Evaluation approach

In order to address potential selection bias, the article uses propensity score matching (PSM) (Rosenbaum & Rubin, 1983; Caliendo & Kopeinig, 2008). PSM compares outcome means of participants and non-participants with similar propensity scores, i.e. their probability of participating $P(D_i=1 \mid Z)$ given a vector of household characteristics Z. Using a probit model, the treatment effect is derived for those participants and non-participants overlapping in propensity scores using different matching algorithms.

PSM's validity depends on two major assumptions (ibid.): First, all factors influencing participation and outcomes can be accounted for (selection of observables). Second, there is sufficient similarity of participants and non-participants (overlap condition). Selection on observable characteristics only, however, is highly unlikely in practice. PSM is therefore considered a second-best approach to randomized experiments or difference-in-difference methods (Barrett et al., 2012) and estimates have to be seen as suggestive rather than conclusive. To ensure comparability, only units within a common support area in terms of propensity scores are matched. A number of tests are performed to check whether the distribution of variables in the group of participants and non-participants is balanced (Caliendo and Kopeinig, 2008). The probit model control variables are based on the discussions in the previous section. Human capital variables of the household head (age, gender and educational level) were included, which are likely to affect a household's capacity to overcome access barriers to outgrower schemes or to access agro-industry jobs. The household size (male and female working members, number of dependants) may determine whether the household can take up labor-intensive on-farm jobs or join the labor market. Land ownership is an important physical capital when adopting a new crop and is used as a wealth proxy. Membership of local organizations and migratory background (place of birth of household head) are further included as social-capital variables.

Endogeneity may be a problem in the model due to reverse causality for some variables (land, assets, and liquidity constraints). The outgrower model therefore includes lagged formulations for some variables (land ownership, livestock) through retrospective questions about the situation in 2003.[11] The 67 outgrowers who had already participated before that time were excluded for the main model. Some potentially endogenous variables for which baseline information is missing (especially credit access) were excluded. The probit models were then estimated for outgrower or worker villages only, respectively, to derive estimates for households assumed to have an actual chance to participate. The model results were then extrapolated to estimate propensity scores for the entire group of non-participants (see e.g. Bernard et al., 2008, for a similar approach). Lagged explanatory variables, however, may introduce further endogeneity problems through recall bias (Raphael, 1987) and unobserved heterogeneity (Bellemare et al., 2015). Therefore, further robustness tests are conducted by re-estimating the model without using lagged variables.[12] Although there still may be difficulties measuring confounders (e.g., risk perception, entrepreneurial behavior or social capital), different robustness tests were used to check model results, including re-estimation of the models with alternative sub-samples and using alternative model formulations. In addition, Rosenbaum-bounds were estimated to test how strong unobserved factors would need to be in order to alter the inferences drawn from the model (Rosenbaum, 2005). In order to cross-check the quantitative information, qualitative information was integrated in the analysis from group discussions and qualitative questions in the questionnaires.

3.5 Descriptive results

Sample characteristics

The relevancy of LSAIs for rural poverty reduction depends on the entry barriers, particularly for poorer household groups. Table 1 therefore compares household characteristics of the groups analyzed in the study: (1) agro-industry workers in the rice and sugar sectors, which

[11] See Maertens & Swinnen (2009) and Maertens et al. (2011), who follow a similar approach.
[12] Yet these problems cannot be completely avoided in this article.

are households with at least one member employed at the estate or factory of KPL or KSCL in 2011–12; (2) outgrowers, which are sugarcane farmers selling to KSCL; (3) groups of non-participants living in the vicinity of KPL and KSCL, but neither involved in group (1) or (2).[13] Sugarcane outgrowers are significantly better equipped in terms of human and physical capital than non-participants: they have larger areas of land, are better educated and own more livestock and other assets than non-participants. Land ownership among outgrowers averages 4.8 acres, almost twice the area owned by workers and non-participants, but still small compared to mean farm sizes in Tanzania and other land-abundant countries in SSA (e.g., Jayne et al., 2014). Moreover, outgrowers are on average older than non-participants, which may suggest difficulties experienced by younger households in accessing land, or other factors preventing them from participating. Agro-industry workers in both sub-sectors tend to have younger heads and fewer household members than non-participants. In terms of land ownership, workers are similar to non-participants in the sugarcane survey, but have significantly less land than non-participants in the rice survey. Credit access is low among all groups, but significantly higher for outgrowers (38% have access to credit) than for the other groups (8%–10%), which may suggest some benefits from participating in outgrower schemes in terms of lower credit-access barriers.

The importance of participating as a worker or outgrower in the LSAIs for overall household income varies between groups. Agro-industry workers in the rice survey continue to rely largely on agricultural income sources, but with wage income already making up 44%. Agro-industry workers in the sugar survey generate 64% of overall income from wages. Sugarcane outgrowers instead specialize in agriculture, from which they derive nearly 80% of their income.

Table 1: Characteristics of outgrowers, agro-industry workers and non-participants

	Rice sample		**Sugar sample**		
	Agro-industry worker (N=61)	**Non-participants (N=148)**	**Outgrowers (N=144)**	**Agro-industry worker (N=63)**	**Non-participants (N=100)**
Average age of household (hh) head (yrs.)	38.8*	42.02	49.2***	39.8*	42.4
Female hh head (Female = 1)	7%	7%	8%**	5%***	18%
Hh head with some primary education	75%	89%	88%	92%	86%
Hh head with at least secondary	59%	47%	48%***	28%	28%

[13] In the sugar survey, only four of the households sampled were both outgrowers and agro-industry workers.

education					
Number of hh members	4.3*	4.8	4.8***	4.7	4.4
No. of women in hh > 16 years	1.19	1.29	1.56***	1.33	1.26
No. of men in hh > 16 years	1.43	1.38	1.39**	1.18	1.15
Dependants	1.7**	2.3	1.81	1.78	1.91
Farming household (binary)	98.4%	99.5%	100%	90%	98%
Average land holding (acre)	2.2***	3.6	4.82***	2.5	2.66
Total asset ownership (PCA)	1.38*	1.43	1.20***	0.97	0.95
Livestock (log of TLU)	0.33	0.22	0.31***	0.16	0.13
Credit access	9%	10%	38%***	10%	9%
Access to non-farm self-employment	33%**	46%	33%	25%	38%
Access to wage employment	100%	30%	36%	100%	62%
Organizational membership	41%	39%	94%***	38%	27%
Hh head born in the village	54%	44%	57%**	67%	67%
<u>*Income shares:*</u>					
Total agricultural income	45%***	74%	79%***	27%***	54%
Total hh wage income	44%***	5%	6%***	64%***	24%
Other non-agricultural income	11%***	21%	15%**	9%***	21%

Notes: Agro-industry workers are households of which at least one member has worked in 2011/12 at the estate or factory of KPL or KSCL. Outgrowers are households producing sugarcane and selling it to KSCL. Non-participants are households neither involved as agro-industry workers nor outgrower schemes. The significance tests are t-tests comparing the participant (outgrowers or agro-industry workers) with the non-participant groups: *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. Source: Author's calculations, Kilombero survey rice & sugar

Gross margin, wage and household income comparisons

Participation as agro-industry wage laborer or outgrower is hypothesized to directly influence wages or agricultural incomes (intermediate outcomes) respectively. Yet, in order to capture intra-household substitution and spillover effects – not captured by crop gross margins or wages – and to compare welfare effects for different groups, the article focuses on annual per capita household income as the main impact indicator. Household income is the sum of marketed, subsistence and in-kind farm and non-farm income. In addition, income poverty is calculated following the National Bureau of Statistics' methodology for the national poverty line, but using income instead of expenditure data.[14] Table 2 reports intermediate outcomes for the outgrow channel in terms of technology use and gross margins of sugarcane

[14] Total household income is converted in adult-equivalent scales (HBS, 2007) and compared to the Tanzanian national basic needs poverty line of Tsh 36,482 per adult equivalent per month in 2011/12 (NPS 2012/13).

outgrowers compared to the most common alternative crops, rice and maize. Sugarcane gross margins are calculated as the difference between sugarcane revenues and all field and off-field production costs. Initial investment costs are converted to annual figures. Rice and maize gross revenue is the total production valued at market prices received by the households for the sold produce. Although adoption of sugarcane is associated with higher costs, overall income from sugarcane production per acre still exceeds the alternatives by a factor of three. Participation in the sugarcane outgrower scheme is also associated with a higher adoption rate of fertilizer (80%) and pesticides (65%), most of which is financed through own savings (90%).

Table 2: Technology adoption and gross margin analysis (sugar survey)

	Sugarcane production (N=144)	Rice production (N=262)	Maize production (N=107)
Area allocated to crop (acre)	2.67	2.0	1.18
Fertilizer use (binary)	78%	30%	3%
Pesticide use (binary)	65%	46%	1%
Labor hiring for weeding (binary)	66%	51%	14%
Total production (t)	62.3	1.6	0.8
Total yields (t / acre)	21.1	0.85	1.57
Percentage sold (%)	100%	38%	16%
Value of gross revenue per acre	1,424,295	537,999	360,448
Total costs per acre	467,249	161,344	47,027
Value of net revenue per acre	953,561	361,256	299,082
Block farm profits (per acre)*	951,711		
Total value of net revenue	2,826,091	672,236	346,077

Notes: The rice and maize production figures include both sugarcane and non-sugarcane farmers. *49 of the interviewed sugar cane farmers reported receiving additional income from having plots in the collective farming schemes (block farms). Source: Author’s calculations, Kilombero survey sugar

Table 3 compares agro-industry wage workers with households reported to work in other wage jobs, most of which (85% in the sugar cane survey) is casual wage employment in the smallholder sector (rice and maize). Around 50% of workers mentioned working for other farmers. In the sugar survey, 35% specified working for sugarcane outgrower farmers, an indication of potential indirect effects of the investment. Nearly 80% of sugar workers are seasonally employed; the rest are divided into casual and permanent staff. On average, employment is for 9 months per year, which is also the length of the harvesting season. Thus, although most employment is seasonal, it still covers three-quarters of the year, mainly during the dry season. In the rice survey, workers were employed for an average of 7 months, but this may overestimate the situation, as factory workers were oversampled. Agricultural work in the rice industry, instead, is mainly through short-term casual contracts. Average daily wages do not differ significantly between the agro-industry and local sectors, which may come as a surprise, but which could also suggest that the higher agro-industry wages exert upward pressure on local wages. But given that annual employment duration is almost twice as high in the agro-industry compared to local jobs, monthly wages and annual incomes differ by factor two and three compared to local jobs in the two sectors respectively.

Table 3: Agro-industry vs. other agricultural wage employment (median values)

Variables	Rice investment		Sugar investment	
	Agro-industry employment	**Other agric. wage labor**	**Agro-industry employment**	**Other agric. wage labor**
Years working in this job	2	6	4	10
Number of months per year	7	3	10	4
Number of days per month	25	11	26	12
Number of person days per year	162	31	243	56
Average income per month in Tsh	90,500	45,000	151,233	50,000
Average income per day in Tsh	3,673	4,000	5,833	5,000
Annual income from this job in Tsh	612,500	142,500	1,440,000	205,000
Total number of observations	61	74	63	132

Notes: Most of the wages in the agro-industry are paid bi-weekly or monthly. We therefore used the self-reported information on average number of days to calculate daily wages. The exchange rate in 31 December 2011 was 1580 Tanzanian Shilling to USD. Source: Author’s calculations, Kilombero survey rice & sugar

Table 4 shows that differences in wage and crop income are also reflected in household income differences. Sugarcane outgrowers have the highest per capita incomes, which is more than twice the income of non-participants. Incomes of agro-industry workers are also higher than that of non-participants in both surveys, but differences are small in the rice survey. On the one hand, this is because per-capita average incomes of agro-industry workers in the two investments differ slightly, i.e. sugar workers have 20% higher incomes than rice workers on average. On the other hand, non-participants seem to be better-off in the vicinity of the rice investment site, compared to non-participants around the sugar investment (18% richer). Relative differences in the two investments compared to the respective groups of non-participants are therefore substantial – 76% in sugar and 24% in rice. Average poverty rates of all participant groups are also significantly lower than that of non-participants.

Table 4: Total household income and income poverty comparisons

	Rice		Sugar		
	Agro-industry employment	**Non-participants**	**Sugarcane outgrowers**	**Agro-industry employment**	**Non-participants**
Total agricultural income	1,291,891	1,697,674	3,520,426	1,010,704	930,294
Total hh wage income	966,137	108,116	271,672	1,575,381	346,110
Other non-agricultural income	464,019	586,925	776,745	705,812	544,602
Total household income	2,722,046	2,416,484	4,568,842	3,291,897	1,811,621
Per capita hh income	811,145	651,974	1,217,941	974,790	552,779
Below food poverty line	15%	34%	6%	6%	43%
Below basic poverty line	20%	48%	23%	18%	53%
Observations	61	148	144	63	100

Source: Author's calculations, Kilombero survey rice & sugar

3.6 Econometric results of household welfare effects

3.6.1 Probit model and balancing tests

Table 5 shows the probit model results to derive the propensity scores. In the rice wage-labor case, education, number of male household members in working age, total number of dependants and land ownership are significantly associated with participation. The correlation with household members and land ownership is expected: households with less land but sufficient family labor rely more often on wage labor. The significant education coefficient may be linked to the fact that many younger, even educated, families may lack land and therefore have to rely on wage employment. But better-educated families may also more easily get a job at the company as they may be expected to be better workers.

In both sugar sector models, land is not a significant predictor of participation. Although the variable may suffer from measurement problems more than other variables, it could suggest that the outgrower schemes have lower land-based entry barriers than qualitative interviews suggested (see Section 4).[15] Yet, more educated households as well as male-headed households have a higher likelihood of participating. For agro-industry wage employment, participation is negatively correlated with the age of the household head, but positively with

[15] Qualitative observations also partly confirmed this result. Moreover, most sugarcane outgrowers in the interviewed villages own relatively small plots, whereas the large sugarcane farmers usually come from outside the villages in urban settlements surrounding the factories and are not part of the survey, as mentioned above.

group membership, which could suggest the importance of social capital. The main intention for estimating the models is, however, to balance the differences in observable characteristics between the groups.

Table 5: Probit model

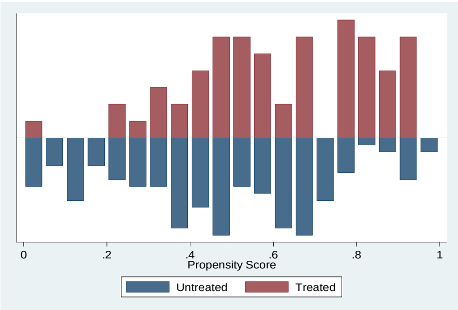
	Rice investment (worker)	Sugar investment (worker)	Sugar investment (outgrower)
	Coeff	Coeff	Coeff
Age head (years)	0.004 (0.015)	-0.041** (0.018)	0.001 (0.013)
Female-headed household (1=yes)			-0.866*** (0.276)
Education head (1=at least secondary)	0.739*** (0.085)	0.182 (0.210)	0.583*** (0.153)
Male working members (number)	0.293** (0.120)	0.240 (0.262)	-0.132 (0.163)
Female working members (number)	-0.236 (0.225)	0.187* (0.113)	0.007 (0.186)
Dependents (number)	0.179** (0.083)	-0.011 (0.124)	-0.085 (0.141)
Land ownership (acre) (log)*	-1.537*** (0.261)	-0.200 (0.229)	0.125 (0.154)
Group membership*	0.073 (0.227)	0.509* (0.268)	0.113 (0.352)
Born in village (1=yes)	-0.287 (0.247)	-0.284 (0.401)	0.225 (0.305)
Village fixed effects	No	No	Yes
Constant	0.887 (0.739)	1.341** (0.632)	0.274 (0.431)
Observations	115	134	175
Pseudo R^2	0.21	0.08	0.16
Sensitivity	66.04	58.73	65.33
Specificity	82.26	59.15	73.00
Correctly classified	74.78	58.96	69.71

Notes: a) lagged variables using retrospective questions for the outgrower model about the situation in 2002-3. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. Participants in the probit models comprise only households living in the same villages: 61 workers and 54 non-participants in the rice model, 63 workers and 71 non-participants in the sugar worker model, and 75 outgrowers and 100 non-participants in the outgrower model. Source: Author's calculations, Kilombero survey rice & sugar

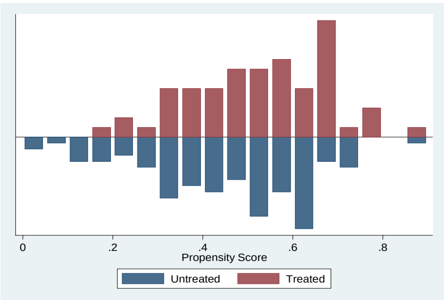
Results of the balancing quality checks are reported in Figure 2 and Tables 6 and A1. Figure 2 shows the histograms of the predicted propensity scores of treated and control groups. For the sugar outgrower and worker models they are within a similar range, whereas treated and control groups differ more in the rice case, though substantial overlap in the propensity scores remains. In all channels, the common support area includes most of the participating households, which is important for the matched participant sample to be representative of the initial sample (Blundell & Dias, 2000).[16] The mean comparisons of the model covariates (Table A1) suggest good balancing for all the three models. There is, however, some heterogeneity between different measures and matching algorithms – kernel (KM), radius (RM) and nearest neighbor matching (NNM)[17] – when comparing the pseudo-R2 and likelihood ratio tests as well as absolute mean and median bias test before and after matching (Table 5). Good matches (cf., Caliendo & Kopeinig, 2008) are reached with KM and RM, whereas NNM leads to weaker matches, especially in the rice worker case, which requires some caution when interpreting the results.[18]

Figure 2: Propensity score distribution

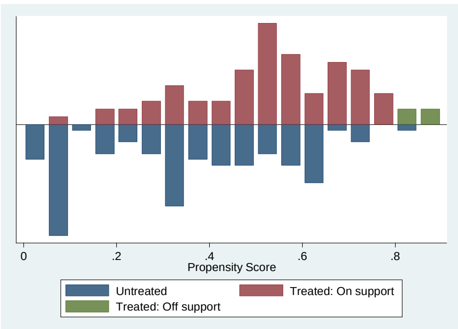
Propensity score distribution – Rice worker comparison



PS distribution – Sugar worker comparison



PS distribution – Sugar outgrower comparison



Source: Author's calculations, Kilombero survey rice & sugar

[16] Only seven adopters are lost in total when applying the common support condition (3 rice workers and 4 sugar outgrowers)

[17] The default 0.06 bandwidth is used for the KM and 0.1 calipers for the RM, while five nearest neighbors are used with the NNM.

18 Caliendo & Kopeinig (2008) argue that a bias reduction below 5% is usually seen as sufficient.

Table 6: Matching quality – summary measures

		Sample	Pseudo R2	LR chi2	p>chi2	MeanBias	MedBias
Sugar (outgrower)							
	NNM	Raw	0.161	38.56	0.001	19.0	16.7
		Matched	0.03	5.95	0.981	9.4	8.7
	KM	Raw	0.161	38.56	0.001	19.0	16.7
		Matched	0.014	2.82	1.000	6.3	6.4
	RM	Raw	0.161	38.56	0.001	19.0	16.7
		Matched	0.005	0.93	1.000	2.8	2.3
Sugar (worker)							
Model 5	NNM	Raw	0.088	16.39	0.037	16.1	10.6
		Matched	0.039	5.07	0.750	11.5	9.9
	KM	Raw	0.088	16.39	0.037	16.1	10.6
		Matched	0.02	2.69	0.952	9.7	8.7
	RM	Raw	0.088	16.39	0.037	16.1	10.6
		Matched	0.02	2.73	0.950	8.1	6.1
Rice (worker)							
Model 4	NNM	Raw	0.196	31.15	0.000	27.5	22.7
		Matched	0.126	10.5	0.232	19.4	17.7
	KM	Raw	0.196	31.15	0.000	27.5	22.7
		Matched	0.074	6.21	0.623	16.8	13.8
	RM	Raw	0.196	31.15	0.000	27.5	22.7
		Matched	0.053	4.56	0.804	13.5	14.2

Source: Author's calculations, Kilombero survey rice & sugar

3.6.2 Matching results

The estimation results for the ATT of the different channels are reported in Tables 7a and 7b, including the different PSM matching algorithms compared to ordinary least squares (OLS). ATTs are estimated for agricultural income, total household income, per-capita household income and basic needs poverty. For all the analyzed cases, OLS results are similar to PSM, yet with some differences in the size of the ATTs. For the case of sugarcane outgrowers (Table 7a), the models predict ATTs for agricultural income of 1.3 million to 1.5 million Tanzanian Shilling (Tsh), which are between 150% to 215%. In terms of total household income and per-capita income, outgrowers' ATTs are also between 120% (2.2–2.5 million Tsh) and 151% (530–590,000 Tsh), respectively. Income poverty is around 40% lower compared to the control group.

For the agro-industry employment cases (Table 7b), results differ between both sectors. Participation in the rice investment as worker is associated with lower agricultural incomes compared to the counterfactual situation, which suggest some negative household-level substitution effects, while the ATT is positive in the sugar case; yet in both cases the ATT is not statistically significant. In terms of per capita household income, participation as agro-industry worker in the sugar sector is associated with ATTs of 84% and 99% (450–490,000 Tsh), which are lower than in the outgrower case, but still very substantial. For the case of rice workers, ATTs for total household income are positive, although the models fail to predict statistically significant ATTs, but do so for per-capita income of around 50%. Differences between sectors may reflect different lengths of harvesting seasons as well as the differences in control groups' income level, as discussed in Section 4. Yet, while average income differences may be lower, around the poverty line differences are significant in both cases: income poverty is 24% to 28% lower in the rice case and 40% lower in the sugar labor channel. This result may suggest that while participation in the rice investments may not contribute to large income improvements, it could provide protection against extreme poverty.

The estimated income difference in the outgrower scheme is largely in line with most other studies attempting to quantify the impact of contract farming. However, other studies find significantly lower participation effects of 30% to 50% (e.g. Warning and Key, 2001; Rao and Qaim, 2011; Bellemare, 2012). Such differences may result from the fact that these studies focus on crops also produced locally by non-participating farmers. In this study, contracting is interlinked with introducing a new crop into a region not well integrated into high-value markets, which potentially results in much larger income differences between the common alternative income strategies (cf. the case of poultry in Simmons et al. 2005; tomatoes in Maertens and Swinnen, 2009). For the labor market cases, the significant and high positive household incomes for sugar industry workers are in line with previously cited studies in the horticultural export sector (McCulloch and Ota, 2002; Maertens and Swinnen, 2009).

Table 7a: ATT: sugarcane outgrower scheme

	OLS		NNM		KM		RM	
	ATT (SE)	**%diff**	**ATT (SE)**	**%diff**	**ATT (SE)**	**%diff**	**ATT (SE)**	**%diff**
Agricultural income (in `000 Tsh)	1,352*** (244)	146%	1,650*** (288)	216%	1,629*** (301)	210%	1,627*** (110)	209%

Total hh income (in `000 Tsh)	2,200*** (377)	122%	2,521*** (460)	153%	2,494*** (485)	149%	2,505*** (461)	151%
Per capita hh income (in `000 Tsh)	528** (93)	116%	596*** (106)	147%	593*** (107)	146%	595*** (110)	147%
Basic needs poverty	-0.400***	-40%	-0.397*** (0.094)	-40%	-0.406*** (0.099)	-41%	-0.400*** (0.099)	-40%

Notes: *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. The OLS models comprise the entire group of participants and non-participants from all villages (209, 163, and 175 in the rice worker, sugar worker, and outgrower model, respectively). The PSM models comprise all households within the common support are from all villages (209, 163, and 171 in the rice workers, sugar worker and outgrower model, respectively). Source: Author's calculations, Kilombero survey rice & sugar

Table 7b: ATT: agro-industry wage employment

	Rice sector							
	OLS		**NNM**		**KM**		**RM**	
	Coeff (SE)	**%diff**	**Coeff (SE)**	**%diff**	**Coeff (SE)**	**%diff**	**Coeff (SE)**	**%diff**
Agricultural income (in `000 Tsh)	149 (204)	9%	-161 (190)	-12%	-128 (172)	-10%	-121 (175)	-9%
Total hh income (in `000 Tsh)	595* (302)	24%	502 (323)	25%	444 (291)	21%	470* (248)	23%
Per capita hh income (in `000 Tsh)	170** (70)	31%	265*** (85)	64%	240*** (77)	54%	232*** (77)	52%
Basic needs poverty	-0.30** (0.074)	-31%	-0.37*** (0.091)	-37%	-0.35*** (0.096)	-35%	-0.35*** (0.082)	-35%

	Sugar sector							
	OLS		**NNM**		**KM**		**RM**	
	Coeff (SE)	**%diff**	**Coeff (SE)**	**%diff**	**Coeff (SE)**	**%diff**	**Coeff (SE)**	**%diff**
Agricultural income (in `000 Tsh)	133 (223)	14%	244 (332)	24%	280 (322)	29%	267 (307)	27%
Total hh income (in `000 Tsh)	1,883*** (468)	104%	2,051 (575)	97%	2,189 (570)	109%	2,194 (561)	112%
Per capita hh income	449***	99%	455**	84%	493***	96%	495***	96%

(in `000 Tsh)	(118)		(179)		(136)		(122)	
Basic needs poverty	-0.403*** (0.091)	-40%	-0.416*** (0.085)	-42%	-0.397*** (0.077)	-40%	-0.401*** (0.076)	-40%

Notes: *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. The OLS models comprise the entire group of participants and non-participants from all villages (209, 163, and 175 in the rice worker, sugar worker, and outgrower model, respectively). The PSM models comprise all households within the common support are from all villages (209, 163, and 171 in the rice workers, sugar worker and outgrower model, respectively). Source: Author's calculations, Kilombero survey rice & sugar

3.6.3 Heterogeneity of effects

As average differences may hide heterogeneity within the group of participants, Table 8 presents income differences separately for land-poor (< 2 acres) and land-rich households (> 2 acre). The results suggest that participation in sugarcane outgrower schemes has a positive and significant effect on agricultural and per capita income for both land-poor and land-rich households, but significantly more for the latter group. Thus, whereas land-rich and land-poor outgrowers have significantly higher agricultural and per capita incomes than non-participants, larger sugarcane outgrowers seem to benefit more than land-poorer outgrowers. For sugar workers, differences in terms of per capita income are significant and positive for both groups. Although ATTs for land-poor workers are relatively lower than for land-rich households compared to the group of non-participants, it is still positive and significant. Yet, ATTs of agricultural incomes among land-poor workers is negative and significant, which may suggest negative effects on agricultural income, whereas the ATTs are positive for land-rich sugarcane workers. For the case of rice agro-industry workers, land-poorer households also have significantly lower agricultural production compared to non-participants, which is not the case for land-richer workers. Yet in per capita income terms land-poor rice workers are predicted to have higher per capita incomes relative to land-rich households.

Table 8: Heterogeneity of impacts (Kernel matching)

	Sugar cane outgrower scheme				
	Treated	**Untreated**	**ATT**	**SE**	**% change**
Agricultural income					
Land poor (<2 acres)	29	100	782,424***	240,570	101%
Land rich (>2 acres)	42	100	2,181,397***	382,767	269%
Per capita total income					

Land poor (<2 acres)	29	100	215,708**	112,393	64%
Land rich (>2 acres)	42	100	811,880***	143,507	201%

	Sugar agro-industry worker				
	Treated	**Untreated**	**ATT**	**SE**	**% change**
Agricultural income					
Land poor (<2 acres)	32	100	-477,421***	168,427	-50%
Land rich (>2 acres)	30	100	1,088,385*	566,834	109%
Per capita total income					
Land poor (<2 acres)	32	100	346,607**	138,292	66%
Land rich (>2 acres)	30	100	648,567***	219,626	129%

	Rice agro-industry worker				
	Treated	**Untreated**	**ATT**	**SE**	**% change**
Agricultural income					
Land poor (< 3 acre)	28	156	-328,928**	127,844	-29%
Land rich (>3 acres)	25	156	324,374	359,829	21%
Per capita total income					
Land poor (< 3 acre)	28	156	329,415***	99,674	84%
Land rich (>3 acres)	25	156	206,142	135,237	41%

Notes: *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. Source: Author's calculations, Kilombero survey rice & sugar

3.6.4 Robustness analysis

Table 9 presents a number of robustness tests for estimating the ATT for per capita income, by adjusting some key parameters: (i) restricting matching to treatment villages only (labor market models); (ii) estimating the logit model by using the entire non-participant sample (labor market models); (iii) estimating the logit model using different logit specifications (labor market model), (iv) estimating the logit model without using some variables that suffered from potential reverse causality (land ownership and group membership) and (v) replacing lagged with current values. The results highlight the robustness of the models for sugarcane outgrower and agro-industry labor; in the case of rice, the estimated differences are positive, though not statistically significant.

Table 9: Robustness checks (per capita household income)

		ATT	SE	Mean bias	Median bias
1) Agro-industry employment - Matching only with non-participants in treatment villages					
Rice sub-sector:					
	NNM	132,198	132,537	17.9	18.2
	KM	116,821	119,193	9.8	9.4
	RM	122,743	99,790	11.2	11.8
Sugar sub-sector:					
	NNM	667,194***	132,244	5.6	6.1
	KM	674,398***	128,787	4.1	4.6
	RM	671,216***	129,343	3.5	3.2
2) Agro-industry wage models: Propensity scores estimated from entire group of non-participants					
Rice sub-sector:					
	NNM	143,974	95,742	5.6	4.3
	KM	144,664	84,880	5.9	6.3
	RM	151,949*	78,449	5.0	5.4
Sugar sub-sector:					
	NNM	533,088***	131,436	4.8	4.3
	KM	543,926**	123,644	3	2
	RM	537,707***	129,685	2.4	2
3) Agro-industry wage models: Different specification of logit model					
Rice sub-sector:					
	NNM	98,658	104,591	8.8	6.5
	KM	111,765	103,760	4.4	3.3
	RM	124,038	98,138	4.4	4.2
Sugar sub-sector:					
	NNM	573,424***	457,561	6.2	5.6
	KM	602,466***	478,139	5.3	2.2
	RM	565,237***	484,577	3.4	3.1
4) Sugarcane outgrower - PS estimated w/o land and group membership variable					
	NNM	623,238***	110,184	7.7	6.1
	KM	627,076***	103,518	7.3	5.2
	RM	605,756***	105,503	6.9	5.7
5) Sugarcane outgrower - Different logit model (current land holding, livestock)					
	NNM	560,947***	462,830	6.4	6.6

KM	549,091***	461,074	6.3	5.1
RM	551,387***	447,970	4.9	4.0

Notes: *, **, and *** indicate significance at 10%, 5%, and 1%, respectively. Source: Author's calculations, Kilombero survey rice & sugar

In spite of the robustness checks, limitations in the data and model (small sample size, lack of baseline data, unobserved heterogeneity) preclude drawing clear causal inferences. Yet, a Rosenbaum-bounds test was also conducted to test the models' sensitivity to hidden bias, which suggested results for both sugarcane models to be very robust to hidden bias but less so for the rice investment.[19]

Qualitative interviews and group discussions also suggested a less clear picture of the potential effects. Only 39% mentioned being satisfied with the sugarcane income they generate. Reasons noted were high production costs as well as low or unstable market prices. Still, around 80% of outgrowers would recommend their children to go into sugarcane farming. Compared to others, 85% of outgrowers mentioned having slightly or much higher standards of living, whereas only 3% perceived it to be worse. Compared to before they joined, 74% noted a slight improvement, 2% a much better situation, whereas 19% felt a worsening situation. For agro-industry workers, when asked about their satisfaction regarding their labor contract, 51% of sugar workers replied that they were satisfied, whereas only 22% rice workers were satisfied. Yet, when comparing their well-being to others, 75% of sugar and 74% of rice workers felt their well-being to be higher and only 2% and 12% to be worse, respectively. Compared to before participating, 76% of sugar workers and 54% of rice workers noted an improvement, though only slightly. Still, most sugar and rice workers (67% and 75%, respectively) would not recommend their children to take up this job.

The qualitative interviews also pointed to further problems in the outgrower model that may undermine their poverty-reducing potential. Whereas power imbalances between sellers and buyers are considered major sources of conflict in the literature (e.g., Little & Watts, 1994), they seemed less relevant here. Instead, governance issues within the outgrower associations were more problematic, as larger outgrowers seem to influence service provision (harvesting, transport) leaving resource-poorer outgrowers with less access (elite capture). Often, these smaller outgrowers are not serviced for several seasons, causing some to abandon their land, which may eventually lead to greater land concentration among larger farmers. Institutional

[19] Results are not shown because of space limitations, but are available upon request.

innovations such as block farming (see Section 2), which could enhance smallholder competitiveness, seem to be not well supported by outgrower associations. Other factors are worsening extension support and input availability among smallholders, which keeps their yields low (cf. Smalley et al., 2014). In addition, waiving of import tariffs at times is making domestic producers more vulnerable to market shocks.

3.7 Conclusions

This article examined the effects of large-scale agricultural investments (LSAIs) on household welfare in Tanzania, one of the main recipients of LSAIs in Sub-Saharan Africa. Building on primary household-level data, it compared income levels and income poverty of households involved in different investment schemes - large-scale factory and estates investments in rice and sugar and outgrower schemes for smallholders in the sugar sector – with those not participating in these schemes.

The empirical analysis, conducted by means of propensity score matching accompanied by several robustness and sensitivity tests, suggests significant and strong positive effects from participating in sugarcane outgrower schemes as well as some positive results from participating in the agro-industry labor market. The positive results for the outgrower channel are broadly in line with other studies on contract farming and outgrower schemes (e.g. Rao and Qaim, 2009; Maertens and Swinnen, 2009; Vaeth and Kirk, 2014). However, land-rich outgrowers seem to benefit more than land-poor in absolute and relative terms. For agro-industry workers in the sugar investment, estimated income effects are slightly lower than for outgrower farmers, but still very large. For workers in the rice investment, predicted effects are significantly lower, but still positive and significant. In particular the results concerning the sugar industry contrast with commonly voiced concerns about this type of employment, but are in line with Maertens' et al. (2011) study on tomato exports in Senegal. The findings show that, in the context of few alternative market and employment opportunities, this type of employment is often an improvement compared to alternative vulnerable farming systems. The results, however, have to be seen as suggestive rather than conclusive evidence due to the data and model limitations, as is often the case in studies on contract farming (Bellemare, 2015). Qualitative interviews as part of this study support the general results, although they also pointed to a number of challenges, especially regarding the operation of outgrower schemes, which may constrain the investments' potential to reduce poverty.

In order to derive more general conclusions about the implications of the investments, however, further research would first need to account for a broader set of outcome variables to capture the multi-dimensionality of poverty (particularly nutrition, health, education). Well-implemented investments may also involve investments in schools and health facilities as part of their Corporate Social Responsibility approach, generating additional welfare benefits (Deininger and Byerlee, 2012), as was the situation for the cases analyzed. Secondly, indirect effects to the non-farm and small-scale farming sector influence their development impacts. Such investments may, for example, introduce new farming methods, inducing spillovers to small-scale farmers. In one of the investments studied a partnership with USAID was initiated to support small-scale rice intensification in the region. In addition, there may also be positive effects for the entire sub-sector, when large agribusiness firms may have more influence producer and processor benefiting policies. Lastly, industrial hubs might arise due to various inter-industrial linkages. In contrast to that, however, large-scale producers targeting the domestic market may push small-scale farmers and local processors out of market due to oversupply. Increasing land demand due to estate or outgrower expansions may also reduce land availability and cause local conflicts.

Lastly, case study results have to be seen as context specific and are only to a limited extent generalizable. The case studies revealed important differences between the investments and sub-sectors, but are not representative of the sub-sectors. The investments considered have been referred to as best-practice cases in Tanzania (SAGCOT, 2013). For the outgrower case studied, for example, participants benefited considerably from substantial public–private partnership support after privatization (see Section 5). In other cases, relationships between processors and outgrowers have been more contentious and schemes less inclusive. At Mtibwa Sugar, another sugar factory in the same region, for instance, conflicts as a result of pricing policies and continuous factory breakdowns leave large amounts of outgrower produce unprocessed (Nkonya et al., 2014), leading many farmers to quit participation (cf. SBT, 2015). Factory efficiency in terms of capacity utilizations, for instance, is as different as 54% (Mtibwa) and 87% (Kilombero) (ibid.). Outgrowers at Kilombero have also received higher prices than those at Mtibwa (38% difference) due to different pricing models, which in Kilombero includes, apart from sugar sales, molasses and biogas utilization (Nkonya & Barreiro-Hurle, 2012). Outgrowers at the investment studied make up also around 60% of the total sugarcane area. In other schemes, such as those in Malawi, Mozambique, Zimbabwe or Zambia, outgrowers often play only a marginal role in relation to the area and production of the estate, thus limiting the schemes poverty-reducing potentials and farmers negotiation power (Oya, 2012; Gibbon, 2011).

For the case of agro-industry employment, conclusions about the overall benefits are strongly influenced by the labor intensity of the investments as it determines the potential for creating direct and indirect effects. For sugarcane, the number of workers employed per 1,000 ha may range from only 150 for mechanical harvesting in Mozambique to around 700 on irrigated plantations with manual harvesting in Tanzania (Deininger et al., 2011). In addition, although the study finds improvements to the status quo, wages would need to increase in the long-term in order to lift workers out of poverty (cf. Jayne et al., 2014).

Both investments analyzed were also special cases as they operate on previous government land, whereas investments targeting village land may face a multitude of legitimate claims by rural people, with a greater risk of land conflicts. Alternative models, such as joint ventures with communities, where the community retains land ownership, might be more suitable in such cases (cf. Cotula & Leonard, 2010).

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Appendix

Table A1: Matching quality – covariance balance (appendix)

		Unmatched	Mean	%reduct	t-test			
	Variable	Matched	Treated	Control	%bias	bias	t	p>t
Rice worker	age_head	Unmatched	39.00	41.89	-26.9		-1.44	0.153
		Matched	39.00	39.64	-5.9	78	-0.22	0.829
	edu_type_bin	Unmatched	0.58	0.49	18.5		0.99	0.325
		Matched	0.58	0.56	4.1	77.9	0.15	0.88
	agework_maleb	Unmatched	1.45	1.42	3.6		0.19	0.849
		Matched	1.45	1.54	-9.7	-172.8	-0.35	0.728
	agework_femaleb	Unmatched	1.15	1.38	-35.9		-1.93	0.056
		Matched	1.15	1.30	-23	35.8	-0.99	0.324
	dependentsb	Unmatched	1.60	1.73	-11.4		-0.61	0.543
		Matched	1.60	1.54	5.4	52.7	0.2	0.841

lntotal_land	Unmatched	1.02	1.43	-73.4		-3.94	0.00
	Matched	1.02	1.22	-36.3	50.6	-1.42	0.16
orga_member	Unmatched	0.45	0.29	33.1		1.77	0.079
	Matched	0.45	0.30	31.8	3.9	1.15	0.253
born_village	Unmatched	0.53	0.62	-17.1		-0.91	0.362
	Matched	0.53	0.62	-17.8	-4.3	-0.66	0.513

	Variable	Unmatched Matched	Mean Treated	%reduct Control	t-test %bias	bias	t	p>t
Sugar (worker)	age_head	Unmatched	39.40	42.74	-30.2		-1.81	0.072
		Matched	39.40	38.68	6.5	78.6	0.41	0.685
	edu_type_bin	Unmatched	0.29	0.28	1.3		0.08	0.938
		Matched	0.29	0.31	-5.1	-304.6	-0.28	0.779
	agework_maleb	Unmatched	1.24	1.16	11.5		0.7	0.483
		Matched	1.24	1.11	19.1	-65.6	1.14	0.258
	agework_fem~b	Unmatched	1.33	1.26	9.9		0.63	0.532
		Matched	1.33	1.29	6.6	34	0.37	0.713
	dependentsb	Unmatched	1.79	1.90	-9.1		-0.56	0.574
		Matched	1.79	1.87	-6.1	32.3	-0.35	0.727
	ln_totland08	Unmatched	0.70	0.83	-18.7		-1.16	0.248
		Matched	0.70	0.69	2.2	88.5	0.12	0.901

	Variable	Unmatched Matched	Mean Treated	%reduct Control	t-test %bias	bias	t	p>t
Sugar (outgrower)	age_head	Unmatched	44.56	42.74	14.8		0.97	0.335
		Matched	44.44	43.77	5.4	63.3	0.34	0.734
	sex_head	Unmatched	0.09	0.18	-25.3		-1.62	0.106
		Matched	0.10	0.11	-3.8	84.8	-0.25	0.8
	edu_type_bin	Unmatched	0.41	0.28	28.1		1.85	0.065
		Matched	0.38	0.37	2.2	92.3	0.12	0.901
	agework_maleb	Unmatched	1.32	1.16	21.2		1.39	0.165
		Matched	1.30	1.27	3.1	85.5	0.19	0.852
	agework_fem~b	Unmatched	1.32	1.26	8.4		0.55	0.582
		Matched	1.24	1.24	-0.6	93.1	-0.04	0.971
	dependentsb	Unmatched	1.83	1.90	-6.4		-0.42	0.675
		Matched	1.89	1.79	8.7	-35	0.54	0.59

ln_totland03	Unmatched	0.83	0.67	21.7		1.44	0.152
	Matched	0.81	0.80	0.9	95.8	0.05	0.958
member_before	Unmatched	0.27	0.27	-0.7		-0.05	0.961
	Matched	0.27	0.27	-1.4	-89.4	-0.08	0.933
born_village	Unmatched	0.65	0.67	-3.5		-0.23	0.819
	Matched	0.63	0.62	2.4	32.9	0.14	0.891

Source: Author's calculations, Kilombero survey rice & sugar

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4 Technology spillovers of large-scale agricultural investments: case study evidence from rice in Tanzania

Abstract

This article studies the potential socio-economic effects of large-scale rice investments in Tanzania, focusing on productivity spillovers on small-scale farmers. Specifically, a public-private-partnership that aims at increasing productivity among farmers surrounding a large-scale rice investment through training improved methods and distribution of a Green Revolution type technology package is evaluated. Yield and income effects of adoption are assessed on plot and household level and compared to the labor market effects of the investment. Cross-section data on project participants, non-participants and agro-industry workers collected in Kilombero Valley, a priority cluster for Tanzania's Southern Agricultural Growth Corridor, is analyzed using propensity score matching and a treatment effects model. Although at the household level only small yield and income effects are observed, a plot-specific analysis to account for partial adoption reveals substantial effects from technology adoption. Labor market participation is also associated with higher per capita incomes but has effects inferior to those of the smallholder rice project. The results suggest that participation as worker in such investments may contribute to improving incomes, especially for land-poor households. However, projects that increase the productive capacity of surrounding areas, such as smallholder productivity projects, are likely to yield greater welfare benefits if technology use and diffusion continues after the end of the projects.

Keywords: large-scale agricultural investments, technology spillovers, smallholder farmers, rice Green Revolution, Tanzania

4.1 Introduction

Agricultural productivity and output growth are important for food security and poverty reduction in Sub-Saharan Africa (SSA) (De Janvry and Sadoulet, 2011a). However, compared with other regions, major food crops have experienced little improvement in terms of productivity (De Janvry and Sadoulet, 2011a; Otsuka, 2006). This is also true for rice, which played a central role in the agricultural growth of many Asian countries that adopted Green Revolution (GR) type strategies (Estudillo and Otsuka, 2013). In SSA, the demand for rice has grown over the last decades, mainly driven by increased urbanization and income growth which have made rice an important staple crop for many countries (Balasubramanian et al., 2007). In most countries, however, domestic production has failed to meet the demand so that SSA has become the world's largest rice-importing region, with imports needed for nearly 40% of the rice consumed (Larson et al., 2010). Increased reliance on imports has created greater concerns about food security – most recently when prices for domestic rice and other cereals skyrocketed in the wake of the 2007 global-food-price crisis (Ivanic and Martin, 2008; Otsuka and Kijima, 2010). As a result, increasing rice production has become an important policy priority for many SSA countries (Seck et al., 2010).

In much of SSA, low rice production is associated with poor yields that are due to the low adoption of high-yielding varieties, fertilizer, irrigation,[20] and improved cultivation practices (Balasubramanian et al., 2007) that were key to the rice GR in Asia (Estudillo and Otsuka, 2013; Otsuka, 2013). Some argue that increasing the use of such modern practices and technologies in SSA will significantly boost productivity (Estudillo and Otsuka, 2013).

In recent years, one strategy to modernize agriculture in SSA has been attracting large-scale agricultural investments (LSAIs) in rice and other crop subsectors from other countries (Deininger et al., 2011; LMGO –Land Matrix Global Observatory, 2015). The development implications of such investments have been controversially debated, with widespread concerns voiced over their social and ecological risks, including the negative effects for smallholder farmers' access to land ('land grabbing') (Cotula et al., 2009). However, such LSAIs may also boost productivity in the smallholder sector through such spillovers as improved access to modern inputs, credit, know-how, or high-value markets – factors that are deemed important for a rice GR in SSA (Diao et al., 2007; Otsuka and Kijima, 2010).

The empirical research about rice GR methods and technologies in SSA and their contribution to smallholder farmers' productivity and welfare is still limited. Some studies have been made on the adoption of modern rice types, such as the new NERICA upland varieties (in Uganda, Kijima et al., 2008) or improved lowland rain-fed varieties (in Tanzania, Nakano and Kajisa, 2012; in Uganda, Kijima et al., 2012), which hold great potential for climatically favorable

[20] Less than 20% of rice produced in SSA comes from irrigated land (Balasubramanian et al., 2007).

regions in SSA (Balasubramanian et al., 2007; Larson et al., 2010; Kijima et al., 2012). Only a few studies have focused on entire technology packages: adopting irrigation and fertilizer (in Mozambique, Kajisa and Pyongayong, 2011; in Kenya, Njeru et al., 2014) or improving cultivation practices (e.g., water control techniques, line-planting, and construction of bunds) and using modern inputs (in Ghana, DeGraft-Johnson et al., 2014). Almost no research has been conducted on productivity spillover effects of LSAIs in SSA, except for Deininger et al. (2015), who used data about large- and small-scale farmers throughout Mozambique. The authors found evidence of some positive spillovers, with small-scale farmers adopting some of the same practices, fertilizer, and pesticides used by their large-scale-farmer neighbors.

This article aims to make three contributions to the literature: First, by studying the yield and income effects of introducing a rice GR technology package in Tanzania that includes improved varieties, fertilizer, and cultivation practices (line-planting, bund construction, and field-leveling), it contributes to the literature on rice technology adoption in smallholder agriculture. It adds to the work of DeGraft-Johnson et al. (2014), who show that, in Ghana, the dissemination of a technology package like the one in this study has been associated with large gains in productivity and income.

Second, the article investigates the potential spillover effects of LSAIs on the smallholder sector by studying a technology transfer project in the area around the largest rice investments in Tanzania. The project is a public-private-partnership (PPP) between Kilombero Plantation Limited (KPL) and USAID. Finally, the article compares the spillover channel of LSAIs with the most relevant alternative direct impact channel – labor market effects due to plantation and factory employment. Despite their relevance in influencing the development outcomes of LSAIs, only a few studies have compared how effective the different impact channels and business models are for LSAIs (Vermeulen and Cotula, 2010; Deininger et al., 2011). Notable exceptions are Maertens and Swinnen (2009) on horticulture in Senegal and Herrmann and Grote (2015) on sugar in Malawi, both of which focus on contract farming and wage employment.

Rice in Tanzania is an interesting case. Tanzania is one of SSA's major rice producers with large expansion potentials (FAOSTAT, 2015; Barreiro-Hurle, 2012). The country has been one of the top three recipients of LSAI in SSA, with much government attention focusing on attracting LSAIs in the rice subsector via major investment promotion initiatives, such as the Southern Agricultural Growth Corridor (SAGCOT) and Big Results Now (BRN) (GoT – Government of Tanzania, 2015; LMGO, 2015). The study uses data from a farm and worker household survey implemented in villages participating in the smallholder rice project that surround the country's largest rice investment.

The next section presents the background of rice production in Tanzania and the case studies. Section 3 describes the data source and methodology, Section 4 presents descriptive results, Section 5 contains the econometric results, and Section 6 concludes.

4.2 Rice investments in Tanzania and the smallholder project

Rice sector development in Tanzania

As in most SSA countries (Larson et al., 2010), rice is important for human consumption in Tanzania, where it is third only to maize and cassava in terms of cereal intake (Barreiro-Hurle, 2012). Tanzania is the largest rice producer in East Africa and the fifth largest in SSA, with an annual increase of 6% in rice production between 2000 and 2012 (FAOSTAT, 2015). In contrast to the rest of the region, imports to Tanzania have declined since the 2000s; in some years the country even exported rice (FAOSTAT, 2015). Further production potential is considered large, which could transform Tanzania into a major exporter to the region (SAGCOT, 2011; Wilson and Lewis, 2015). However, low rice yields and current trade policies continue to constrain production and exports (Barreiro-Hurle, 2012).

Rice production in Tanzania is dominated by small-scale farmers, of which more than 1.1 million are estimated to produce rice (GoT, 2012). Most production is under rainfed conditions (70% of locally produced rice) dominated by lowland production systems (GoT, 2012). Large commercial farms play a limited role, with only around 5,500 hectare (ha) (139 farms) estimated to be used for large-scale rice farming 2007–08 (GoT, 2012), although growing LSAIs have probably increased the area (see GoT, 2015). Yields for rainfed lowland rice production have been estimated to be only about 1.5–1.8 tons per ha (Seck et al., 2010; Nakano and Kajisa, 2012) – comparable to the SSA average (Seck et al., 2010) but significantly lower than global averages of 4.3 tons per ha (Fischer et al., 2014). As in other parts of SSA, low yields are associated with the low adoption of new technologies (Seck et al., 2010; GoT, 2009). A National Rice Sector Development Strategy was therefore formulated to boost the adoption of modern methods (high-yielding seeds, fertilizers, machinery, and improved farming practices) and introduction of innovative approaches and partnerships in order to double production to almost 2 million tons by 2018 (GoT, 2009).

Another strategy to increase rice production has been to promote LSAIs through SAGCOT and BRN. SAGCOT was established in 2010 as a multi-stakeholder initiative to mobilize agribusiness investment along Tanzania's southern transport corridor (SAGCOT, 2011). BRN was adopted in 2012 as a government initiative to accelerate agricultural investments and complement SAGCOT, in particular by establishing 25 large-scale commercial farming deals (GoT, 2015). SAGCOT and BRN consider rice to be a priority subsector for LSAIs (SAGCOT, 2011; GoT, 2015). Both strategies have also adopted inclusive business models in their blueprints, for example, by focusing on outgrower schemes (SAGCOT, 2013).

Rice investments in the Kilombero Valley

Kilombero District in Morogoro Region, one of Tanzania's major rice-producing areas, is a priority cluster for SAGCOT (2011). The district has extensive freshwater wetlands – the largest at low altitudes in East Africa (Kangalawe and Liwenga, 2005). Agriculture is the main economic activity there; most farmers use the wetlands found along Kilombero river to grow a range of crops, with paddy rice the most popular (Kangalawe and Liwenga, 2005; Kato, 2007). Although poor infrastructure and other factors have limited diversifying into high-value crops, the area's high agricultural potential has led to strong immigration (Kato, 2007; Nindi et al., 2014). Large-scale farming is underdeveloped, except for some teak, sugarcane, and rice plantations (Nindi et al., 2014). When this study's survey was conducted, SAGCOT investments were still in preparation. One exception was KPL, a large-scale commercial rice investment already operational in the area and which was considered a best-practice case for future SAGCOT investments because of its linkages to smallholder farmers (SAGCOT, 2013).

The smallholder rice project

KPL is a joint venture between the British company Agrica and RUBADA (Rufiji Basin Development Authority), a Tanzanian parastatal organization. KPL started operations in 2008 on a 5,818-ha government property, a former Tanzanian–North Korean joint venture that had been liquidated in 1993 (KPL, 2009). Since its establishment, KPL has built an industrial rice mill and a large warehouse (SAGCOT, 2013). When fully operational, KPL is expected to produce 20,000 tons of milled rice, making KPL Tanzania's largest rice producer, employing 160 full-time and 300 seasonal workers (KPL, 2009).

The plantation investment is based on highly mechanized rice cultivation, with weeding the main activity for casual manual labor. The capital-intensive model is unsuitable for smallholder producers, but in 2009, KPL initiated a project with USAID to increase spillovers to local communities through a smallholder "rice intensification" project (SAGCOT, 2013). The project is based on Asian GR methods and technologies: it follows best agricultural practices (transplanting, line-planting, and bund construction) and improves access to a high-yielding variety of rice used by KPL, named SARO 5[21], as well as chemical fertilizer and weeding machines. Assistance includes training in Farmer Field Schools (FFS), support to form associations, and linkages to microcredit institutions to facilitate access to inputs. Farmers access microfinance loans through collateral provided by the investor.

The project started in 2009 with an initial group of 25 farmers in the villages around the KPL investment, increased to 250 farmers in the second year, and finally targeted 4,000 farmers in 2013 (SAGCOT, 2013). It covers all of the 10 villages in an approximately 65-km2 area. Project extension officers, most of whom are employed by KPL, operate at least one demonstration plot for each participating village. In the first year, farmers are trained on demonstration plots and receive improved seeds and chemical fertilizer free of charge if they apply improved cultivation techniques and technologies on their 0.25-acre plots. In the second year, after successfully completing the training and joining a local rice-growers association, the farmers get subsidized access to improved seeds and fertilizer through microfinance, first for a one acre and the subsequent year for a one hectare plot size. KPL has also considered developing contract farming. At times, it has bought rice from the smallholders, but at the time the survey was conducted, there was no contract-farming scheme in operation.

4.3 Data and methodology

Data

The main objective of the study was to measure the welfare effects of adopting the GR-type of technology package for rice promoted through the project (a high-yielding variety, fertilizer, and modern farming practices) and comparing it with the labor market channel of LSAIs. Between April and May 2013, a farm household survey was conducted in the 10 project villages, focusing on three household groups: (1) farmers participating in the smallholder rice project, (2) households employed by KPL as factory or plantation workers, and (3) a control group of non-participating households. 355 households were interviewed, 142 of which participated in the project, 61 had members employed as factory or estate workers, and 152 did not participate.[22]

Project participants were selected by the random sampling of lists provided by KPL. The sampling frame comprised all farmers who had participated in the FFSs during the first two

[21] SARO 5 (TXD-306) is a variety developed in 2002 at the Rice Research Center in Dakawa, Morogoro Region (GoT, 2009).

[22] Because of missing data on labor, 16 households (10 participants and 6 non-participants) were excluded from the analysis.

years of the project and had a chance to adopt the practices and sell their harvests. Data was collected for the 2012 season when rice brought high prices: these declined by 50% the following year due to abrupt tariff waiving and rice import surges (Agritrade, 2014). In the same villages, non-participants were sampled from existing village population lists, lists drawn up by knowledgeable villagers, or by applying a random walk method. Agro-industry workers live in three of the villages. They were sampled and interviewed at the workplace.

Measurement issues

Project benefits are expected to come from increased adoption of new technologies and techniques, which could raise yields and crop and household income. At the same time, however, income may be adversely affected because adopting an input-intensive system may raise the costs of inputs and household labor (Takahashi and Barrett, 2014) and reduce returns from other income sources. Empirical evidence exists about the positive yield and income effects of similar rice innovations in SSA (DeGraft-Johnson et al., 2014), and recent studies have also found positive yield effects from adoption of improved cultivation practices, such as SRI (Sustainable Rice Intensification) (Noltze et al., 2013; Takahashi and Barrett, 2014). However, the labor intensity of these practices – which can lead to their later rejection – returns ambiguous evidence regarding income effects (Moser and Barrett, 2006). Producer prices of improved and traditional varieties may also differ if, for example, consumers perceive traditional varieties to be superior.[23] However, learning effects with the new technologies as well as changing consumer perceptions can reduce costs, thereby increasing prices and project benefits over time. Agro-industry employment is sometimes seen critically because of the low quality of the jobs (Barrientos et al., 2005) – although such jobs may be significantly better than most of their other rural job opportunities. International agribusiness firms, for example, may bring in capital, new ideas, and technologies – thus increasing both worker productivity and incentives to pay higher wages (Maertens and Swinnen, 2009; Herrmann and Grote, 2015).

Measuring the welfare effects of these different channels is not straightforward. First, it is difficult to evaluate adoption of the technology package because the project is still in an early stage, with many farmers still benefiting from free access to the new technologies (seeds and fertilizer). Therefore, the study imputes market prices for the technology package in order to simulate conditions under 'real' market conditions. Second, at this early stage, farmers are

[23]Rice traders, for example, claimed that improved varieties have lower prices given their inferior aroma compared with local varieties (personal communication).

unlikely to adopt the technology package for an entire rice farm and are more likely to follow a stepwise approach of initially testing specific plots before expanding it to the entire farm (cf. Barrett et al., 2006). Thus, measuring average outcomes across the entire rice farm may understate the technologies' true potential. The survey has detailed plot-level information on rice revenues, costs, planting methods, rice varieties, and input use, so that traditional technology plots can be compared with new ones, and plot-level can be compared with household-level effects.

Finally, it is difficult to measure impacts with cross-section data. In impact evaluation, we are usually interested in estimating the Average Treatment Effect on the Treated (ATT) (Heckman et al., 1999): $ATT=E[Y_{1i}-Y_{0i}|X,D=1] = E[Y_{1i}|X,D=1]-E[X_{0i}|X,D=1]$, where conditional on covariates X and treatment D, ATT is the average outcome difference between adopting/participating and non-adopting/non-participating. $E[Y_{1i}|X,D=1]$ can be calculated using survey data on adopters/participants, but $E[Y_{0i}|X,D=1]$ is unknown and must be estimated using average outcomes of non-adopters/non-participants, $E[Y0_i|X,D=0]$ (Heckman et al., 1998). Technology adoption and labor-market participation decisions are seldom random because households or plots are selected due to certain characteristics. Thus, estimating ATTs by simply comparing adopters/participants with non-adopters/non-participants leads to under- or overestimating the true effects (selection bias). Selection bias may arise, for example, if those farmers who are more skilled are also more likely to adopt because they can expect higher yields than less-skilled farmers (De Janvry et al., 2011b). Farmers might also adopt technologies on plots with better or worse soil or water conditions (Barrett et al., 2006). Labor-market participation may be influenced by wealth status or social capital, for example, with well-connected households accessing better-paid jobs and the resource-poor pushed into low-paid off-farm jobs (Ellis, 2000).

Empirical approach

In order to address the measurement issues, first plot-level yield and income functions for technology adopters and non-adopters were estimated using ordinary least squares (OLS), which yields efficient ATTs if D_i is exogenous. Since D_i is likely to be endogenous, a plot-level Heckman treatment effects model (TEM) with an endogenous binary variable was estimated. Previous studies (e.g., Jena and Grote, 2012; DeGraft-Johnson et al., 2014) have used this to address the selection bias. It relies on two equations: a first-stage selection equation, $D_1 = Z_1\gamma + \delta_i$, with the adoption/participation dummy D_i, a vector of explanatory variables Z_i, and the error term δ_i, and a second-stage outcome equation, $Y_i = D_i\alpha + W_1\beta + \varepsilon_i$, with outcome Y_i as a function of D_i, other characteristics W_i, and an error term ε_i. TEM corrects for the part of ε_i that is correlated with D_i (λ_i) so that $E(\varepsilon_i - \lambda_i \mid D_i, X_i)=0$. The correction term λ_i, the Inverse Mill's Ratio (IMR), is estimated using a probit model and is included as an additional covariate in the outcome equation. Thus, the correlated part between D_i and ε_i is withdrawn from the error term. However, TEM has limitations because it relies on its strong functional form and normality assumptions and requires an exclusion restriction (Briggs, 2004).

As a robustness check, propensity score matching (PSM) (Caliendo and Kopeinig, 2008) was used to compare adoption plots with non-adoption plots that are similar in terms of pre-adoption characteristics, expressed as 'propensity scores' (Faltermeier and Abdulai, 2009). The propensity scores – the probabilities of adopting – were estimated using a probit model. Matching only plots that are sufficiently similar improves the overall model efficiency – as opposed to using the entire sample (Caliendo and Kopeinig, 2008). PSM is not based on linearity assumptions or exclusion restrictions. It requires (a) sufficient similarity of adoption/non-adoption plots in terms of propensity scores and (b) selection only on observables. Condition (b) is particularly challenging in technology adoption studies (De Janvry et al., 2011b) because adopters and non-adopters may also differ in unobservable plot and household characteristics (e.g., soil quality, risk behavior, and experience) (see Barrett et al., 2006).

In a second step, PSM was used to estimate rice-farm and household-level yield and income effects by comparing the two treatment groups (rice project participants and agro-industry workers) with non-participants.

Outcome and explanatory variables

Household welfare was measured using intermediate and overall outcome indicators: (1) rice yields (plot level), (2) rice income (plot and farm level), (3) agricultural income, and (4) total household income. Rice income (paid out) is defined as 'producer net revenue' – the difference between total production value and the variable costs of production (Barnard et al., 2012). Total production value comprises both marketed and self-consumed produce valued at the 2011–12 season's market prices. Production costs include all costs for inputs, hired labor, and land rental. Rice net return (profits) was calculated by deducting imputed family labor costs from rice income. Agricultural income is the sum of marketed, subsistence, and in-kind crop and livestock income, while total household income also accounts for non-farm income sources, including wages and income from self-employment.[24]

To derive credible PSM estimates, it is necessary to account for a large set of relevant covariates (Caliendo and Kopeneig, 2008). For that reason, the adoption and outcome models used a wide range of plot-level and household-level explanatory variables – as found in the literature on technology adoption and diversification (e.g., Barrett et al., 2006; Ellis, 2000). Plot characteristics used in the plot-level models included plot location (lowland/upland), soil fertility (fertile/unfertile), plot manager, field-leveling, crop damages (whether or not external damages occurred), plot distance from homestead, land ownership status and titling, mechanization, and plot size (only in the outcome model). In household-level analyses, these factors would be considered 'unobservables'. Plot-level factors, such as soil fertility, field leveling, technology use, and ownership status, are likely to affect adoption behavior and may affect yields independent of the technology used. Household characteristics in both the plot- and farm- or household-level models included household demographics (head of household's age, education, and sex, and number of working-age household members), which are expected to raise yields by affecting human capital – independent of the inputs. Institutional and social capital (e.g., belonging to an organization, being born in the village, owning a mobile phone), as well as farm assets (total landholding and livestock ownership), credit access, and non-farm income, are expected to affect technology access and overall income-generating capabilities.

Correct identification in the TEM relies on an exclusion restriction – an additional variable in the first stage that influences participation but not the outcome variable, except through participation. Two exclusion restrictions were used: (1) the share of project participants in the village population and (2) a perception index to measure a farmer's openness to new technologies. These were derived from five questions (such as whether the household is among the first in the village to adopt new technologies, or perceptions of change) using a Likert scale, with the lower number suggesting greater openness. I include these variables because we expect the overall share of participants in a village to influence the probability of adopting because of observation or social network effects. I also expect that farmers' overall openness to new technologies will increase their adoption. However, I cannot know for sure

[24] Plot-specific information for agro-industry workers was not collected for this study, whose main outcome indicators are overall agricultural income and household income.

that these instruments independently affect the outcome variable.[25] For that reason, the TEM results are compared using OLS and PSM for robustness checks.

4.4 Descriptive results

Household-level characteristics

This subsection examines the descriptive results by comparing the household characteristics of farmers participating in the rice project, agro-industry workers, and non-participants (Table 1). The groups differ across a number of variables referred to in the previous section, including the age of the head of household, their education level, land ownership, organizational membership(s), and credit access. Although organizational membership (e.g., belonging to a rice association) and better credit access may be due to their participation, other factors, such as better education, the household head's greater age, and larger landholdings, suggest systemic differences between the groups. Agro-industry workers, however, differ in fewer aspects from non-participants; for example, they have slightly younger household heads, higher educational levels, and smaller landholdings.

Table 1. Household characteristics

	Non-participants (NP) (n=146)		Project participants (PP) (n=132)		Agro-industry workers (AIW) (n=61)		NP vs PP	NP vs AIW
	Mean	SD	Coeff	SD	Mean	SD	t-test	t-test
Age of household (HH) head	42	10.13	45	9.54	39	11.01	20.6***	1.7
Female-headed HH (%)	8%	0.27	5%	0.22	7%	0.25	1.8***	0.1
HH member has at least secondary education (%)	46%	0.50	52%	0.50	61%	0.49	-2.1**	4.58**
HH head born in village (%)	41%	0.49	47%	0.50	52%	0.50	-2.1**	2.2
Organizational membership (%)	37%	0.48	79%	0.40	44%	0.50	-2.3**	0.8
HH size	4.71	1.72	5.02	1.64	4.34	1.64	11.8***	1.9
Number of working-age HH members	2.69	1.21	2.96	1.26	2.69	1.23	11.9***	0.02
Credit access (%)	7%	0.26	73%	0.45	18%	0.39	-11.1***	2.33
Access to non-farm employment (%)	44%	0.50	34%	0.47	100%	0.00	3.6***	51***
Livestock ownership (%)	71%	0.45	79%	0.40	74%	0.44	-3.2***	0.45

[25] With regard to the first exclusion restriction, it could be argued that project placement is affected by market access or the suitability of soils in the area, although we control for this variable in the model. For the technology perception variable, one could argue that the effect on the outcome variable is also because more highly skilled farmers tend to be more likely to be open to new technologies, and independently generate higher yields or incomes.

TLU [a]	0.38	0.92	0.72	1.30	0.38	0.68	6.4**	1.26
Owns a mobile phone (%)	84%	0.37	89%	0.31	77%	0.42	-2.3**	0.5
Average landholding (ha)	1.48	0.99	1.91	1.40	0.93	0.80	34.1***	16.5***

Note: ** and *** indicate the significance of the t-statistic of the mean difference at the 5 and 1% levels, respectively. [a] Tropical Livestock Unit. Source: Author's calculations, Kilombero survey rice

Comparisons at rice plot and rice farm level

This subsection focuses on project participants and non-participants to explore rice technology adoption patterns and plot-level gross margins. Table 2 shows the importance of rice production, with almost all participants producing – and more than 90% of them selling – rice. An average of 50%–70% of the total rice production is sold. Project participation is associated with the use of modern inputs, with 96% of participants using the promoted SARO 5 variety,[26] as opposed to only 14% of the non-participants. Improved varieties still only account for 42% of the participants' rice farm area. While low use is due to the project's early stage, farmers also explained a reluctance to adopt SARO 5 due to consumers negative perceptions of SARO 5. Chemical fertilizer is used by 87% of participants, but applied to only 37% of their rice areas. Of non-participants, only 4% use fertilizer, which could be due to financial constraints but also because traditional rice varieties respond less well to fertilizer. Of the training participants, 77% applied the full rice technology package of improved seeds, fertilizer, and crop husbandry (transplanting and straight-line planting), but to only 26% of their rice areas. In contrast to the low use of modern inputs, mechanization of certain farming operations is very common, especially the use of hired tractor services, relied on by 70%–80% of the participants and non-participants. Hiring labor for weeding and harvesting operations is also common among more than 90% of the participants and 75% of the non-participants. Differences in technology adoption are also associated with yield differences. Whereas non-participants produce only 1.1 tons per acre, participants produce 1.5 or even 2.4 tons per acre on the plots in the project technology package.

Table 2. Rice farm characteristics

	Project participants (n=132)		Non-participants (n=146)		
	Mean	SD	Mean	SD	t-test
Households producing rice (%)	100%		98%		

[26]Most farmers in Tanzania grow older improved varieties which suit the environment and consumer tastes, but produce low yields. SARO 5 is the most common modern variety but is not widely adopted (Nakano and Kajisa, 2012).

Rice farm size (acre)	3.85	2.7	2.75	1.9	12.20***
Share of farmers selling rice (binary)	98%	0.27	92%	0.15	-2.11**
Rice commercialization (sale/total production in kg)	69%	0.33	51%	0.89	-2.57**
Uses modern rice variety (binary)	94%	0.24	17%	0.38	-12.91***
Share of total area with improved rice variety	41%	0.38	15%	0.35	34.38***
Uses chemical fertilizer (binary)	85%	0.36	4%	0.20	-13.48***
Share using chemical fertilizer (% of total ha)	37%	0.20	4%	0.20	82.71***
Applies technology package (binary)	85%	0.37	2%	0.14	-13.77***
Share using new technology package (% of total area)	29%	0.32	2%	0.14	84.15***
Uses tractor for farm operations (binary)	83%	0.38	68%	0.47	-2.86***
Hires labor for farm operations (binary)	90%	0.30	77%	0.42	-3.06***
Rents land for rice farming (binary)	21%	0.41	21%	0.46	1.85*
Uses pesticides on the rice farm (binary)	0.71	0.45	0.55	0.55	-2.82***
Total rice yields (t / acre)	1.5	0.8	1.1	1.6	13.78***
Rice yields of improved plots (t / acre)	2.4	1.2			

Note: *, **, *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. Source: Author's calculations, Kilombero survey rice

Qualitative discussions with farmers about production constraints underscored the potentials of such technology packages (Table 3) with – apart from weeds and pests – a lack of access to inputs such as seeds and fertilizer, and a lack of farming knowledge are seen as the main constraints. A lack of markets and buyers were not considered to be major constraints. However, farmers complained about low rice prices as a result of the government's decision to waive rice import duties on 60,000 tons in 2013 (Agritrade, 2014).

Table 3. Major rice business constraints

Production challenges	Important challenge (%)	Most important challenge (%)
Cost and access to inputs	65	27
Low rice prices	50	11
Lack of rice farming knowledge	41	22
Lack of transport	41	10
High price fluctuations	41	7
Lack of buyers or markets	30	8
Weeds and pests	24	24
Climatic conditions	10	10

Source: Kilombero survey rice

During the 2011–12 survey, prices were relatively high, reaching more than 90,000 Tanzanian shillings (TSH) (Table 4). Prices for SARO 5 and local varieties differed only slightly, not confirming worries that SARO 5 gets substantially lower prices. Given that season's high demand, preferences might have played a minor role in price determination so that price differences may be more pronounced in years with an oversupply. Nonetheless, prices fluctuated throughout the season, increasing by more than 30% over post-harvest prices towards the end of the year.

Table 4. Rice price comparison – improved and local varieties

	SARO 5		Local variety		
	Mean	SD	Mean	SD	t-test
Average price (TSH/80 kg-bag)	85,777	24,547	91,054	26,042	1.877**
Price after harvest (April–September)	76,273	22,563	78,068	24,074	0.497
End-of-season price (October–March)	99,226	20,796	100,289	23,376	0.289

Note: In late 2012, USD 1 = TSH 1.578; *, **, and *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. Source: Author's calculations, Kilombero survey rice

Although participation is associated with increased land yields, income may be compromised by costs of hired labor, imputed family labor costs and other input costs. Rice labor input in person-days, for example, was 13% higher among project participants; when comparing plots with the technology package to unimproved plots, the gap reached 70%.

Table 5 combines the information regarding plot-level gross margins for rice grown on plots with no improvements, plots with the improved variety of rice, and plots using the full-technology package. While improved-variety plots have revenues per acre almost double those of unimproved plots, the full-technology-package plots have revenues that are 139% higher. Costs are also substantially higher, with hired and imputed family labor costs more than double on technology package plots compared to unimproved plots. Still income differences remain substantial, with net returns (profits) more than double for full-technology-package plots.

Table 5. Plot-level rice income (per acre)

	Unimproved plots[1] (N=168)		Improved variety[2] (N=213)		Technology package[3] (N=118)	
	Mean	SD	Mean	SD	Mean	SD
Number of plots (with labor & seed info)	168		213		118	

Plot characteristics						
Plot location (1=plot in flat bottom – not sloped or flat top)	64%		59%		58%	
Soil fertility (1=fertile & very fertile soil)	85%		84%		86%	
Plot manager (1=HH head involved)	71%		62%		58%	
Field-leveling (1=well-leveled)	85%		89%		92%	
Rice crop damage (1=rice crop damage during 2011–12)	72%		65%		65%	
Mechanization (1=use of mechanization)	79%		77%		77%	
Plot distance (minutes)	63.1	52.5	51.9	38.5	55.3	41.2
Ownership status of plot (1=plot owned by HH)	90%		91%		95%	
Plot title (1=title deed)	15%		15%		17%	
Gross margin analysis ('000 TSH/acre):						
Plot area (acre)	2.4	1.8	1.4***	1.2	0.9***	0.9
Yield (tons per acre)	1.1	0.6	2.0***	1.3	2.4***	1.2
Value of production	646	331	1,269***	799	1,545***	802
Labor costs	263	157	458***	431	587***	501
Hired labor	70	67	126***	193	152***	245
Imputed labor	192	169	332***	378	435***	434
Current input costs						
Seed	3	9	14***	15	16***	16
Fertilizer	0	0	32***	45	56***	48
Pesticides	8	13	15***	28	18***	36
Machinery	33	29	43**	65	46*	73
Total paid-out costs	137	94	265***	258	325***	313
Total costs[4]	329	161	597***	476	760***	538
Income (paid out)	509	307	1,004***	736	1,221***	770
Net return (profit) (imputed labor costs)	317	357	673***	792	786***	917
Labor share (labor costs/total costs)	56%		48%		52%	

Note: In late 2912, USD 1=TSH 1.578; *, **, and *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. [1]Without improved rice varieties, fertilizer, or modern farming methods. [2]Used improved rice varieties. [3]Used the full package of improved rice varieties, fertilizer, and modern farming methods.[4]Imputed family labor costs added to total paid-out costs. Source: Author's calculations, Kilombero survey rice

Comparisons at rice plot and rice farm level

Given the early stage of the project and the resulting heterogeneous adoption pattern of the participants, the farm- and household-level analysis focuses on a comparison of households that had at least partly adopted the full technology package with those who were still relying on unimproved systems. These groups are compared with the benefits from participating in the agro-industry labor market channel, the most relevant alternative impact channel of LSAIs. Table 6 reports farm- and household-level yield and income data for the different groups. Rice income per acre is substantially higher for technology adopters than for non-adopters but these differences are much lower than in the previous plot-level comparison. Although differences in non-farm income are not significant, among technology adopters agricultural incomes as well as total and per capita household income are around 50% higher. Differences between agro-industry workers and non-adopters are negligible in terms of total household income but because of workers' smaller household size, their per capita income is 23% higher.

Table 6. Rice farm- and household-level income calculation (in '000 TSH) (Adopters, non-adopters, agro-industry workers)

	Non adopters (NA)[1] (n=117)		Adopters (n=112)		Agro-industry workers (AIW) (n=61)		NA vs OG	NA vs AIW
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*T-test*	*T-test*
<u>*Rice farm income (per acre):*</u>								
Yields (tons/acre)	1.02	0.52	1.59	0.87			35.82***	
Total production value	640	359	1,027	595			35.22***	
Rice farm income	508	332	818	535			27.45***	
Rice farm net return (profit)	316	368	612	566			21.70***	
<u>*Household income:*</u>								
Agricultural income	1,527	1,373	2,973	3,443	1,278	1,232	16.25***	1.53
Non-agricultural income	676	1,244	679	1,972	1,303	1,088	0.01	12.16***
Total household income	2,204	1,849	3,653	4,066	2,580	1,649	11.57***	1.94
Total household income (per capita)	516	419	795	989	661	425	7.49***	4.79**

Note: *, **, and *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. [1]Non-adopters in this table refer to farmers not having adopted any technology (fertilizer, new variety, improved methods). Source: Author's calculations, Kilombero survey rice

4.5 Econometric results

The differences between the groups reported in the last section suggest positive effects from adoption and participation. However, they could also result from other factors. This section therefore conducts an econometric analysis, by first evaluating the plot-level yield and income effects of two different treatments – (1) the improved variety SARO 5 was planted and (2) the entire technology package (SARO 5, fertilizer, and improved planting methods) was applied – and compares improved with unimproved plots. In a second step, agro-industry worker data is integrated to evaluate farm- and household-level effects on both impact channels.

4.5.1 Plot-level analysis

Table 7 reports the plot-level probit regressions for adopting at least improved varieties and the full technology package, which are used to estimate the propensity scores for PSM and calculate the IMR of the TEM.[27] Most variables have the same direction in both models. Having a plot title, owning livestock, being open to new technologies, as well as having a high share of participants living in the village all correlate positively and significantly with adoption on a given plot. For female-headed households, having been born in the village, and the distance between house and plot are significant and negative for the improved variety model but not for the full package. In contrast, a well-leveled plot positively influences adoption of the full package.

Table 7. Plot-level adoption of technology package

	Improved variety	Technology package
	Independent probit model	Independent probit model
	Coef.	Coef.
Plot location (binary)	0.199	0.102
	(0.236)	(0.198)
Soil fertility (binary)	-0.0318	-0.133
	(0.290)	(0.263)
Plot manager (binary)	-0.145	-0.347*
	(0.239)	(0.204)
Field-leveling (binary)	0.0173	0.575**
	(0.281)	(0.235)

[27]The probit model estimations in the TEM are in A1 and A2, which differ only slightly in their parameters.

Rice crop damage (binary)	-0.451**	-0.010
	(0.184)	(0.188)
Plot distance (minutes)	-0.006***	-0.001
	(0.002)	(0.002)
Ownership status of plot (binary)	-0.004	0.204
	(0.269)	(0.302)
Plot title (binary)	0.484*	0.445*
	(0.281)	(0.243)
Mechanization (binary)	-0.190	0.0135
	(0.214)	(0.187)
Age of HH head	-0.001	0.014
	(0.010)	(0.009)
Female-headed HH (binary)	-0.730***	-0.243
	(0.280)	(0.288)
Secondary education in HH (binary)	0.258	-0.0171
	(0.197)	(0.188)
Working-age HH members (numbers)	0.0004	-0.0412
	(0.077)	(0.069)
Non-agricultural income (binary)	0.241	0.309*
	(0.218)	(0.178)
Total rice area (acre)	0.0211	0.0250
	(0.038)	(0.039)
Born in the village (binary)	-0.551***	0.0504
	(0.168)	(0.167)
Owns livestock (binary)	0.443**	0.339*
	(0.218)	(0.195)
Owns a mobile phone (binary)	-0.111	0.120
	(0.260)	(0.220)
New technology index[a]	-0.0648**	-0.0463*
	(0.0298)	(0.025)
Participants of overall village population (%)	1.884*	3.003***
	(1.139)	(1.058)
Constant	0.173	-2.680***
	(0.758)	(0.787)
Observations	376	376
Pseudo R2	0.175	0.118

Note: Numbers in parentheses are the robust standard errors; *, **, and *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. [a] The innovativeness index comprises five dimensions of openness to new technology and willingness to adopt (1=very willing to adopt, 5=very unwilling to adopt). Source: Author's calculations, Kilombero survey rice

As mentioned before, the treatment variables are likely to suffer from selection bias; hence, to derive the plot-level impacts, TEM and PSM were used along with simple OLS. Table 8 reports the main outcome coefficients for yields, income, and net return. The complete regression results are reported in Annexes 1 to 3. The magnitudes between the models differ substantially, with TEM showing significantly higher ATTs than OLS and PSM. Nevertheless, all models predict substantial ATTs for all outcome variables significant at the 1% level, suggesting that simply adopting SARO 5 is associated with significant yield and income improvements. When the entire technology package is adopted, the improvements are even greater. These positive effects hold even after accounting for imputed family labor costs (net return). Specifically, adopting at least SARO 5 leads to improvements associated with yields of 0.8 to 1.1 tons per acre (80%–100% yield improvements) and around 1.3 to 1.5 tons (122%–145%) when the full technology package is adopted. Rice income is predicted to increase by at least TSH 440,000 (around 90%) when SARO 5 is adopted, and TSH 660–770,000 for the full package, an improvement of at least 135% per acre. Improvements in net returns are also substantial, doubling with just SARO 5 and the full package, in spite of the substantially higher labor costs for these plots.

Table 8. Plot-level ATT of rice yields, revenues and gross margins (improved variety) (income in TSH '000)

	OLS			Treatment effects model			PSM (KM[a])		
	ATT	Robust SE	% change	ATT	Robust SE	% change	ATT	Robust SE	% change
Adoption of improved variety:									
Rice yields (kg/acre)	826***	120	78%	1,073***	152	101%	1,083***	119	98%
Rice income	442***	79	87%	626***	108	123%	559***	72	104%
Total rice income	355***	80	114%	599***	117	193%	364***	89	106%
Adoption of technology package:									
Rice yields (tons/acre)	1,259***	132	122%	1,496***	173	145%	1,313***	147	122%
Rice income	663***	82	137%	768***	112	159%	713***	84	139%
Total rice income	467***	90	174%	617***	118	230%	445***	100	129%

Note: *** indicates the significance of the t-statistic of the mean difference at the 1% level. [a]Kernel matching. Source: Author's calculations, Kilombero survey rice

In Annexes 1 to 3, the full OLS- and TEM-regression results for Models 2 and 4 show the endogeneity-tests (*athrho*), which are significant at 1% or 5% levels, suggesting that endogeneity is indeed a problem, supporting the use of TEM over OLS and thus higher treatment effects. Apart from that, the explanatory variables reveal that better perceived soils are positively correlate with yields, whereas external production shocks lower yields and incomes. Larger total rice areas negatively correlate with yield as expected. Education is positively correlated with both yield and income.[28]

4.5.2 Farm- and household-level analysis

With the adopters' land share of the full technology package small, it is important to ask if plot-level effects of the project technology package translate into overall household-level welfare effects and how these compare with participation in an alternative impact channel of LSAIs, namely the agro-industry labor market effect.

Table 9 presents bivariate probit models of technology adoption at the household level and participation in the agro-industry labor market to derive the propensity scores needed to implement PSM. Two different probit models for each channel are derived, comparing adopters of the technology package or workers with farmers not adopting the full technology package (Model 2 and 4) as well as with farmers relying completely on traditional methods (Model 1 and 3). For the technology adoption case at the household level (Model 1 and 2), the household head's age is positively correlated with adoption. Livestock ownership and the availability of non-agricultural income – factors that may relate to rice farming – are also positively correlated household wealth or asset ownership. The innovativeness index previously explained explaining the openness to new technologies is significant, suggesting that farmers with more positive perceptions of new technologies and towards risk are more likely to adopt the technology. In the agro-industry wage labor model (Model 3 and 4), the availability of male household members and the household head's secondary education increase participation probability, with the latter potentially relating to the skill bias of some factory jobs, as well as the fact that some younger graduates take these jobs because there are no others. Land ownership is negatively related to participation, which could suggest push effects because such households have fewer opportunities to make a livelihood from agriculture.

[28]Balancing tests of the PSM model are not presented here because of limited space, but they indicate significant reductions in covariate differences from before to after matching between improved and unimproved plots. Results are available upon request.

Table 9. Household-level participation in the smallholder project & agro-industry labor market (probit model)

	Technology package adoption (1)		Technology package adoption (2)		Agro-industry employment (3)		Agro-industry employment (4)	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
Age of hh head	0.198***	0.077	0.119*	0.064	-0.057	0.074	-0.070	0.071
Age of hh head (squared)	-0.002**	0.001	-0.001	0.001	0.000	0.001	0.001	0.001
Sex of hh head	-0.399	0.309	-0.277	0.319	0.388	0.562	0.283	0.552
At least secondary education in hh (binary)	0.196	0.205	0.032	0.193	0.565**	0.286	0.726***	0.269
Working age male members	-0.143	0.136	-0.109	0.128	0.515**	0.232	0.394*	0.211
Working age female members	-0.026	0.142	-0.007	0.131	-0.356	0.218	-0.278	0.227
Number of dependents	-0.034	0.062	-0.099*	0.056	-0.055	0.108	-0.083	0.097
Non agricultural income (binary)	0.433**	0.211	0.447**	0.185				
Total land owned	0.026	0.037	0.010	0.031	-0.239***	0.072	-0.246***	0.067
Born in the village (binary)	-0.065	0.198	0.112	0.193	-0.527*	0.295	-0.348	0.266
TLU	0.342*	0.184	0.285*	0.163	0.717*	0.377	0.450*	0.271
Owns a mobile phone (binary)	-0.126	0.260	-0.068	0.240	-0.880**	0.392	-0.969**	0.393
New technology perception [a]	-0.102***	0.032	-0.055**	0.025				
Village fixed effects	Yes		Yes		No		No	

Constant	-4.786***	1.821	-3.649**	1.536	2.622	1.613	2.792*	1.525
Obs	239		277		114		128	
Pseudo R2	0.250		0.174		0.224		0.205	

Note: Model (1) compares technology package (TP) adopters (including 7 worker households) with farmers using no improvements; model (2) compares the TP adopters with farmers not adopting the TP; model (3) compares agro-industry employment with farmers using no improvement from the worker villages; model (4) compares agro-industry workers with farmers not adopting the TP. *, **, and *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. aThe innovativeness index comprises five dimensions of openness towards new technology and willingness to adopt (1 = very willing to adopt, 5 = very unwilling to adopt). Source: Author's calculations, Kilombero survey rice

Table 10 and 11 present the ATTs of the two treatments – adoption of the technology package and agro-industry wage employment – using PSM with three different matching algorithms (nearest-neighbor, kernel, and radius matching) and OLS.[29] In both cases, the treatments are compared to the group of farmers not adopting the full technology package, but who might use improved varieties, and to the group of farmers not adopting any modern technology.

Although in terms of overall rice farm yields, incomes, and net returns, the estimated ATTs of technology adoption are still positive and significant –especially when comparing to those farmers not adopting any technology at all – they are significantly lower than plot-level estimates. PSM and OLS results are very similar, with both models showing that technology adoption is associated with significant farm-level yield differences between adopters and non-adopters of around 300 to 500 kg per acre (24%–47% higher yields). Rice income differences, even accounting for family labor costs, are still significant and differ by 30%–65%. When considering overall household-level outcomes, differences are still positive, with agricultural income and per capita income around 29%–50% higher for adopters. However, these overall household income differences are only statistically significant when compared to farmers not using any technology.

For agro-industry worker participation, the models predict negative ATTs for agricultural income, which may suggest some negative – but statistically insignificant – intra-household substitution effects. In fact, household income-level effects are similar, but slightly lower than the technology adoption case: between 10%– 24%, or 18%–36% for total and per capita income, respectively, but with only weak statistical significance.

[29]The full OLS-regression results are presented in Table A4 to A7 of the attachment.

Table 10. Household-level ATT of rice farm and household income – Technology adoption (income in TSH '000)

	NNM		**KM**		**RM**		**OLS**	
	ATT	**% change**	**ATT**	**% change**	**ATT**	**% change**	**ATT**	**% change**
Adoption of technology package (compared to farmers not adopting full package)								
Rice farm level:								
Rice yields (kg/acre)	340***	27%	307***	24%	338***	27%	347***	31%
	110		119		119.1887		105	
Rice income (per acre)	210,591***	35%	197,262***	32%	192,617***	31%	179,891**	32%
	68,587		70,718		70717.68		71,116	
Rice net return	202,890**	50%	199,715**	49%	181,559**	43%	157,911**	44%
	78,824		74,857		74857.32		72,805	
Household level:								
Total agricultural income	863,724**	42%	809,217	39%	734,722	34%	510,811*	29%
	402,154		451,843		451842.6		305,427	
Household income	758,719	26%	759,552	26%	731,511	25%	574,102	24%
	475,524		504,892		504891.5		422,710	
Household income (per capita)	180,053*	30%	188,599	32%	178,028	30%	159,554	30%

	109,301		112,133		112133.4		113,075	
Adoption of technology package (compared to farmers not adopting any technology)								
Rice farm level:								
Rice yields (kg/acre)	512***	47%	479***	43%	478***	43%	448***	44%
	118		124		102		104	
Rice income (per acre)	283,932***	52%	247,031***	43%	252,907***	45%	237,796***	47%
	70,966		68,391		60,563		65,776	
Rice net return	234,946**	62%	199,296***	48%	204,102***	51%	204,572***	65%
	70,563		67,848		66,286		68,690	
Household level:								
Total agricultural income	1,008,360**	53%	937,616***	48%	974,687**	52%	763,746***	50%
	436,361		385,652		419,202		265,697	
Household income	1,051,468*	41%	982,834**	37%	1,015,982**	40%	853,282**	39%
	531,183		483,999		504,789		426,080	
Household income (per capita)	266,181**	51%	235,376**	42%	243,407**	46%	216,392*	42%
	113,388		110,480		104,045		123,084	

Note: Numbers in the parentheses are the robust standard errors; *, **, and *** indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. NNM = Nearest Neighbor Matching; KM = Kernal Matching; RM = Radius Matching. Source: Author’s calculations, Kilombero survey rice

Table 11. Household-level ATT of rice farm and household income –agro-industry wage employment (income in TSH '000)

	NNM		**KM**		**RM**		**OLS**	
	ATT	**% change**	**ATT**	**% change**	**ATT**	**% change**	**ATT**	**% change**
Participation in agro-industry labor market (compared to farmers not adopting full package)								
Household level:								
Total agricultural income	-70,289	-5%	-189,695	-13%	-165,140	-11%	-6,171	0%
	299,049		220,529		211,294		202,266	
Household income	589,784	24%	477,727	23%	467,189	22%	445,723	18%
	366,111		310,127		289,658		302,825	
Household income (per capita)	200,713**	33%	170,233**	35%	175,738**	36%	96,808	18%
	86,694		75,086		72,422		71,757	
Participation in agro-industry labor market (compared to farmers not adopting any technology)								
Household level:								
Total agricultural income	-37,179	-3%	-41,202	-3%	12,900	1%	238,653	16%
	238,251		242,985		228,221		170,195	
Household income	400,371	10%	384,648	17%	538,214	26%	630,599**	29%
	366,111		349,674		316,368		292,781	

Household income (per capita)	101,423	18%	136,119*	26%	157,756**	31%	117,410	23%
	112,938		85,012		78,010		72,354	

Note: Numbers in the parentheses are the robust standard errors; ∗, ∗∗, and ∗∗∗ indicate the significance of the t-statistic of the mean difference at the 10, 5, and 1% levels, respectively. NNM = Nearest Neighbor Matching; KM = Kernal Matching; RM = Radius Matching. Source: Author's calculations, Kilombero survey rice

4.6 Conclusions

The study investigated household welfare effects of large-scale rice investments in Tanzania's Southern Agricultural Growth Corridor region, focusing on two potential impact channels: productivity spillovers on small-scale rice farmers and agro-industry labor market linkages. This article evaluates yield and income effects of a PPP project implemented by Tanzania's largest rice producer and USAID that aims at distributing a type of Asian Green Revolution technology package of high-yielding rice varieties, chemical fertilizer, and modern planting methods. The article also compares these technology spillovers to alternative LSAI-participation channels of estate and factory labor markets to understand their differential welfare implications (cf. Vermeulen and Cotula, 2010; Ali et al., 2015). Unlike previous studies, analysis of farm and household levels is complemented with detailed plot-level yield and profit information, using TEM and PSM with cross-section data.

One main finding of the study is that technology adoption along the lines of an Asian Green Revolution type leads to substantial plot-level differences between adopters and non-adopters, suggesting large pay-offs for smallholder rice incomes. Plot-level yield improvements were estimated to be at least 122%. In spite of higher production costs, rice income effects are substantial (around 140%), even when accounting for imputed family labor costs. These results are broadly in line with similar empirical studies on technology adoption by rice farmers in other SSA countries (Mozambique: Kajisa and Payongayong, 2011; Uganda: Kijima et al., 2012; Ghana: DeGraft-Johnson et al., 2014). Moreover, in line with the results of DeGraft-Johnson et al. (2014), this study found that the joint adoption of a bundle of innovations, such as improved high-yielding varieties, inputs, and planting methods, promises much higher effects than only adopting improved seeds.

However, the study also found that looking at farm level effects to account for only partial adoption, the yield and income differences per acre decline to around 25% and 35%, respectively. In terms of total and per capita household income, the estimated differences are only weakly significant. However, most likely a major reason for the absence of substantial differences at the household level was that the project was new: even at farm level there was little diffusion of technologies and techniques. With the increased technology experience of farmers and other value chain actors, greater household-level effects may be created through diffusing improved rice technologies. Qualitative interviews also point to open questions regarding further diffusion and scaling-up: The project provided farmers the technology package free of charge, but only some of them were making use of microcredit to purchase improved seeds and fertilizer. There was still no information about credit repayment, but which is central to the sustainability of such a project. Moreover, the labor-intensive nature (in-line planting and increased weeding) of improved rice-planting techniques may limit scaling-up by labor-constrained farmers. As the survey was being conducted, the use of mechanical weeding machines piloted in the area was marginal: this may require further research. In addition, the benefits of increased access to modern rice technology are dependent on the market environment. For example, in recent years short-term trade policy decisions in Tanzania have resulted in imports of cheap rice, and caused a 50% decline in rice prices (Agritrade, 2014). Such changes in the market environment are likely to outweigh any positive effects of adopting innovations and may constrain the scaling-up of new technologies at the farm and village levels.

Another finding is that the household income effects from participation as estate or factory workers range between 25% and 35% – only slightly below those linked to the technology package adoption. Yet if technology adoption can be scaled up at the household and community levels with prices remaining competitive, there are likely to be substantially larger direct benefits for farmers in terms of overall household welfare (as opposed to simply providing low-skilled employment opportunities). Working for the agro-industry may remain an important strategy to overcome extreme household poverty, although it may not substantially increase incomes. Apart from direct income effects for participants, the broader welfare effects of agro-industry employment also depend on the employment intensity of the investment, which varies greatly among crops and production systems (Deininger et al., 2011). For example, for tree or perennial crops (e.g., palm or manual sugarcane production), benefits from substituting labor with capital in key tasks is more limited than for grains and other annual crops. This could cause employment-intensity differences by a factor of 70 per ha (see Deininger et al., 2011).

To sum up, the study underlines the potentials of making LSAIs more inclusive by linking plantation investments to the introduction of new farming methods and access to microfinance through collateral provided by the investor. However, other indirect effects must be considered for evaluating LSAIs more generally. For example, potential sector-wide positive effects may relate to a large rice producer’s greater ability to influence producer-favorable policies. At the same time, however, if such large producers primarily target the domestic market, they are likely to push small farmers and local processors out of the market. Such investments are also likely to have substantial intra-household effects and indirect implications for the community, and perhaps for the environment, such as the risks of water depletion, overuse of pesticides, deforestation, and biodiversity loss – all which must be accounted for in any strategy to develop sustainable and inclusive investments.

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Appendix

Table A1: Yield functions with OLS and TEM

	(1)	(2)	(3)	(4)
	OLSyieldNV	treatregyieldNV	OLSyieldTP	treatregyieldTP
main				
variety_saro5P	826***	1073.154***		
	(120)	(151.645)		
location	-84	-91.918	-101.477	-100.021

	(108)	(108.821)	(94.938)	(92.157)
fertility	295**	307.035**	291.950**	306.976***
	(116)	(119.328)	(118.074)	(118.585)
manager	-190	-175.850	-46.681	-19.666
	(125.)	(124.610)	(104.916)	(103.870)
leveling	10.924	11.188	45.467	26.450
	(127.962)	(130.035)	(90.942)	(89.244)
ricecrop_damage	-370.810***	-341.002***	-436.067***	-434.569***
	(124.171)	(131.096)	(102.179)	(101.751)
S52landprep_machine	104.991	111.706	84.984	81.632
	(100.618)	(102.958)	(83.067)	(82.843)
S51plot_dist	0.763	1.222	0.754	0.934
	(0.900)	(0.897)	(0.888)	(0.875)
S51_ownership	178.353	188.510	128.758	132.645
	(125.232)	(127.720)	(125.414)	(126.296)
S51_title	160.374	140.566	228.842	216.018
	(164.675)	(165.273)	(149.705)	(146.619)
age_head	1.457	1.441	1.429	1.068
	(4.481)	(4.278)	(4.225)	(4.000)
sex_head	-126.169	-83.711	-117.971	-105.315
	(141.770)	(145.219)	(149.314)	(149.831)
edu_type_bin	200.159*	161.829	176.215*	152.557
	(113.181)	(114.388)	(102.711)	(100.031)
agework	-51.387	-45.544	-43.536	-40.054
	(46.596)	(46.453)	(41.731)	(39.867)
total_rice_area	-54.947**	-58.129**	-45.395**	-48.988**
	(24.584)	(24.905)	(22.115)	(22.111)
village_price	-0.008	-0.006	-0.007	-0.006
	(0.006)	(0.006)	(0.005)	(0.005)
sri_varplantfert_v2			1259.051***	1495.609***
			(132.016)	(172.946)
_cons	1844.665***	1505.185***	1615.726***	1508.341**
	(559.851)	(580.641)	(568.213)	(588.094)
variety_saro5P				
location		0.131		0.113
		(0.260)		(0.229)
fertility		-0.364		-0.390
		(0.328)		(0.325)
manager		-0.105		-0.363
		(0.264)		(0.232)

leveling	-0.140	0.386
	(0.309)	(0.295)
ricecrop_damage	-0.496**	-0.116
	(0.207)	(0.210)
S51plot_dist	-0.007***	-0.004**
	(0.002)	(0.002)
S51_ownership	-0.017	0.110
	(0.294)	(0.353)
S51_title	0.480	0.470*
	(0.300)	(0.280)
S52landprep_machine	0.133	0.257
	(0.242)	(0.235)
age_head	0.000	0.010
	(0.010)	(0.010)
sex_head	-0.822**	-0.522
	(0.319)	(0.332)
edu_type_bin	0.157	0.054
	(0.216)	(0.217)
working_ageb	0.035	0.010
	(0.078)	(0.078)
non_agric_inc	0.377*	0.499**
	(0.216)	(0.210)
total_rice_area	-0.004	0.012
	(0.041)	(0.040)
born_village	-0.539***	-0.110
	(0.182)	(0.189)
livestock_binary	0.715***	0.705***
	(0.224)	(0.215)
phone_bin	-0.107	0.052
	(0.261)	(0.252)
village_price	-0.000**	-0.000
	(0.000)	(0.000)
new_technology_b	-0.093***	-0.094***
	(0.031)	(0.031)
sri_share_vill	3.433***	4.287***
	(1.201)	(1.207)
_cons	2.725**	-0.397
	(1.234)	(1.373)
athrho		
_cons	-0.236**	-0.256***

		(0.101)		(0.092)
lnsigma				
_cons		6.598***		6.395***
		(0.073)		(0.062)
N	329	329	283	283
adj. R^2	0.293		0.427	

Note: [a] Tropical Livestock Unit; *, **, and *** indicate significance of t-statistic of the mean difference at the 10%, 5%, and 1% level, respectively, Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01 Source: Author's calculations, Kilombero survey rice

Table A2: Income functions with OLS and TEM

	(1) OLSincomeNV	(2) treatregincomeNV	(3) OLSincomeTP	(4) treatregincomeTP
main				
variety_saro5P	441,934.355***	626,090.455***		
	(79,114.749)	(108,086.136)		
location	-98,523.558	-103,945.145	-103,818.546*	-103,196.088*
	(77,568.491)	(75,167.731)	(62,813.944)	(601,34.395)
fertility	193,821.329**	202,665.822***	191,797.596***	198,499.564***
	(76,416.160)	(78,649.253)	(66,198.375)	(65,969.574)
manager	-31,886.235	-21,027.813	17,075.167	29,153.325
	(84,218.865)	(82,229.995)	(75,818.441)	(74,184.367)
leveling	68,212.733	68,406.991	85,570.343*	77,069.586
	(94,583.452)	(94,444.771)	(48,850.467)	(48,168.844)
ricecrop_damage	-127,321.186	-105,088.194	-179,910.759**	-179,270.135***
	(84,100.878)	(87,985.153)	(69,854.028)	(68,733.934)
S52landprep_machine	-16,045.803	-11,040.399	-43,604.245	-45,086.019
	(69,000.776)	(71,647.114)	(64,843.175)	(64,867.405)
S51plot_dist	-742.971	-400.558	-598.165	-517.944
	(539.903)	(533.123)	(539.432)	(529.782)
S51_ownership	36,195.191	43,777.498	-7,297.583	-5,563.305
	(84,694.118)	(88,194.892)	(86,324.109)	(85,518.571)
S51_title	88,103.742	73,335.269	115,782.335	110,058.042
	(119,087.800)	(119,404.202)	(113,755.019)	(111,345.692)
age_head	-1,951.579	-1,965.244	-2,447.605	-2,603.873

	(2,905.655)	(2,840.725)	(2,955.772)	(2,866.898)
sex_head	-32,212.993	-515.566	-23,280.584	-17,740.948
	(87,181.557)	(87,397.789)	(92,568.613)	(90,446.796)
edu_type_bin	113,409.607	84,792.538	76,528.293	66,062.072
	(71,310.638)	(68,489.845)	(64,731.882)	(62,558.243)
agework	-3,056.992	1,331.706	-253.756	1,175.139
	(26,819.153)	(27,023.178)	(23,415.466)	(22,785.108)
total_rice_area	-7,641.765	-10,019.267	-2,998.027	-4,589.649
	(15,660.868)	(16,034.740)	(14,396.229)	(14,330.242)
village_price	0.492	2.174	3.286	3.623
	(4.324)	(4.203)	(3.502)	(3.500)
sri_varplantfert_v2			662,715.565***	768,437.015***
			(82,391.273)	(112,286.944)
_cons	488,685.125	235,451.692	288,243.219	240,171.859
	(405,076.750)	(394,884.931)	(331,192.015)	(331,556.710)
variety_saro5P				
location		0.145		0.105
		(0.264)		(0.235)
fertility		-0.368		-0.424
		(0.325)		(0.327)
manager		-0.131		-0.379
		(0.267)		(0.236)
leveling		-0.144		0.446
		(0.310)		(0.297)
ricecrop_damage		-0.505**		-0.129
		(0.208)		(0.214)
S51plot_dist		-0.007***		-0.004**
		(0.002)		(0.002)
S51_ownership		-0.027		0.054
		(0.292)		(0.353)
S51_title		0.511*		0.496*
		(0.297)		(0.279)
S52landprep_machine		0.144		0.232
		(0.243)		(0.234)
age_head		0.000		0.011
		(0.010)		(0.010)
sex_head		-0.826***		-0.497
		(0.319)		(0.336)
edu_type_bin		0.175		0.115

		(0.212)		(0.214)
working_ageb		0.045		-0.001
		(0.078)		(0.077)
non_agric_inc		0.392*		0.445**
		(0.211)		(0.210)
total_rice_area		-0.006		0.015
		(0.041)		(0.040)
born_village		-0.559***		-0.069
		(0.183)		(0.192)
livestock_binary		0.711***		0.664***
		(0.221)		(0.216)
phone_bin		-0.077		0.102
		(0.259)		(0.249)
village_price		-0.000**		-0.000
		(0.000)		(0.000)
new_technology_b		-0.093***		-0.090***
		(0.031)		(0.031)
sri_share_vill		3.140***		3.865***
		(1.190)		(1.207)
_cons		2.760**		-0.330
		(1.214)		(1.367)
athrho				
_cons		-0.280***		-0.176**
		(0.092)		(0.089)
lnsigma				
_cons		13.045***		12.851***
		(0.073)		(0.057)
N	329	329	283	283
adj. R^2	0.199		0.310	

Note: [a] Tropical Livestock Unit; *, **, and *** indicate significance of t-statistic of the mean difference at the 10%, 5%, and 1% level, respectively. Source: Author's calculations, Kilombero survey rice

Table A3: Total income functions with OLS and TEM

	(1)	(2)	(3)	(4)

	OLSToIncNV	treatregoIncNV	OLSToIncTP	treatregoIncTP
main				
variety_saro5P	354,749.255***	598,983.056***		
	(79,990.486)	(117,059.781)		
location	-54,961.570	-62,158.710	-59,280.501	-58,398.857
	(88,072.408)	(83,520.079)	(78,472.967)	(74,521.942)
fertility	184,742.386**	196,469.177**	176,268.199**	185,827.690**
	(82,593.714)	(85,816.003)	(84,569.622)	(87,186.716)
manager	-49,316.048	-34,918.575	-31758.783	-14524.269
	(94,789.286)	(89,863.453)	(91991.616)	(88279.876)
leveling	69,850.045	70,110.089	111889.502	99760.084
	(98,603.214)	(96,980.300)	(67836.172)	(67049.107)
ricecrop_damage	-162,960.020**	-133,471.862	-186008.518**	-185101.107**
	(82,807.941)	(87091.590)	(75756.195)	(74662.628)
S52landprep_machine	112,234.884	118876.565	96074.236	93963.800
	(71,364.360)	(73156.853)	(66980.254)	(66845.086)
S51plot_dist	-550.588	-96.557	-364.287	-249.918
	(585.408)	(584.056)	(593.907)	(580.867)
S51_ownership	-79,656.691	-69605.589	-122277.839	-119803.998
	(85,075.080)	(88805.301)	(87748.859)	(86552.227)
S51_title	67,855.669	48262.566	72105.412	63939.531
	(11,8423.516)	(117282.617)	(116479.637)	(113117.362)
age_head	-2,945.098	-2962.065	-3370.081	-3591.862
	(2,966.620)	(2956.883)	(2936.002)	(2866.928)
sex_head	9,661.415	51676.983	28471.199	36348.431
	(9,6471.095)	(99704.681)	(105006.414)	(104013.452)
edu_type_bin	151,356.193**	113425.207	92833.496	77924.814
	(74,499.743)	(71437.156)	(71697.865)	(69653.220)
agework	-30,564.555	-24770.899	-24843.632	-22834.246
	(31,406.629)	(31198.280)	(30328.014)	(29215.263)
total_rice_area	23,231.161	20081.440	28518.955*	26251.227*
	(15,926.690)	(16255.916)	(15489.950)	(15221.122)
village_price	-1.458	0.773	1.563	2.044
	(4.527)	(4.416)	(3.534)	(3.590)
sri_varplantfert_v2			466587.812***	617433.544***
			(90179.325)	(118403.494)
_cons	466,610.233	130760.178	219124.252	150516.654
	(432,468.769)	(422362.844)	(341994.132)	(347832.925)
variety_saro5P				

location	0.143	0.094
	(0.263)	(0.233)
fertility	-0.353	-0.398
	(0.326)	(0.328)
manager	-0.130	-0.381
	(0.266)	(0.233)
leveling	-0.176	0.413
	(0.306)	(0.297)
ricecrop_damage	-0.511**	-0.129
	(0.207)	(0.214)
S51plot_dist	-0.007***	-0.004**
	(0.002)	(0.002)
S51_ownership	-0.023	0.063
	(0.288)	(0.350)
S51_title	0.526*	0.515*
	(0.294)	(0.280)
S52landprep_machine	0.163	0.247
	(0.243)	(0.233)
age_head	0.000	0.010
	(0.010)	(0.010)
sex_head	-0.862***	-0.513
	(0.326)	(0.337)
edu_type_bin	0.153	0.093
	(0.211)	(0.215)
working_ageb	0.064	0.016
	(0.079)	(0.080)
non_agric_inc	0.426**	0.460**
	(0.212)	(0.212)
total_rice_area	-0.009	0.012
	(0.041)	(0.040)
born_village	-0.570***	-0.063
	(0.182)	(0.188)
livestock_binary	0.734***	0.697***
	(0.220)	(0.218)
phone_bin	-0.110	0.073
	(0.258)	(0.250)
village_price	-0.000***	-0.000
	(0.000)	(0.000)
new_technology_b	-0.089***	-0.087***

		(0.031)		(0.032)
sri_share_vill		3.243***		4.030***
		(1.177)		(1.199)
_cons		2.700**		-0.386
		(1.206)		(1.357)
athrho				
_cons		-0.351***		-0.222**
		(0.103)		(0.093)
lnsigma				
_cons		13.121***		12.983***
		(0.071)		(0.058)
N	329	329	283	283
adj. R^2	0.164		0.197	

Note: [a] Tropical Livestock Unit; ∗, ∗∗, and ∗∗∗ indicate significance of t-statistic of the mean difference at the 10%, 5%, and 1% level, respectively. Source: Author's calculations, Kilombero survey rice

Table A4: Total rice farm yields and rice income regression (household-level) (OLS)

	(1) OLSyieldHHfarm	(2) OLSrincHHfarm	(3) OLSrnretHHfarm
improved_hh_prod	346.705***	179891.541**	157911.308**
	(105.057)	(71116.495)	(72804.890)
age_head	8.710	-682.140	-8518.330
	(29.512)	(20224.324)	(20913.923)
age_head_sq	-0.081	16.543	99.474
	(0.303)	(205.963)	(212.470)
sex_head	-146.312	-83127.129	-90394.861
	(140.345)	(74222.898)	(73026.221)
edu_type_bin	-32.699	34203.490	99863.836
	(110.018)	(71231.484)	(74813.973)
agework_male	-14.699	33451.386	42679.607
	(72.664)	(47754.799)	(47958.813)
agework_female	-2.079	-8507.950	-25332.084
	(67.220)	(43511.432)	(48393.252)
dependents	-7.653	-10028.685	-21038.720
	(21.648)	(13013.183)	(13901.314)
non_agric_binary	110.765	107534.694*	153425.127**
	(92.860)	(58326.920)	(66303.369)
total_land	-37.940**	-16540.728*	-5721.774

	(17.686)	(9884.841)	(10605.380)
born_village	-86.234	-43475.639	-64971.178
	(108.269)	(66365.509)	(68628.699)
tlu	197.255**	171681.646***	197577.930***
	(81.220)	(56074.144)	(58106.967)
phone_bin	-14.780	38083.849	77372.177
	(110.364)	(72416.653)	(78963.749)
new_technology_b	-11.958	-4386.130	-3691.033
	(14.577)	(9603.684)	(10260.038)
news1vn1	-369.017**	-221256.915**	-239216.144**
	(155.538)	(105980.929)	(111819.505)
news1vn2	-138.228	-24092.340	-104002.487
	(163.152)	(122037.615)	(136313.491)
news1vn3	188.365	135924.235	121594.725
	(207.986)	(132119.905)	(144324.749)
news1vn4	7.028	-97350.851	-109664.273
	(179.297)	(120197.964)	(132278.579)
news1vn5	104.734	120463.144	160368.428
	(180.422)	(113835.470)	(126341.483)
news1vn6	-265.847	-86543.568	-88757.821
	(169.458)	(119212.425)	(127562.430)
news1vn7	309.028*	157233.464	140045.478
	(168.952)	(108349.241)	(117898.072)
news1vn8	-88.226	33377.773	8688.292
	(203.294)	(156785.683)	(171418.630)
news1vn9	520.149***	203761.347	45606.459
	(188.361)	(160637.424)	(175308.339)
news1vn10	.	.	.
	.	.	.
_cons	1149.619	482905.454	377130.037
	(712.140)	(486058.924)	(506773.773)
N	274	274	274
adj. R^2	0.168	0.136	0.151

Note: [a] Tropical Livestock Unit; ∗, ∗∗, and ∗∗∗ indicate significance of t-statistic of the mean difference at the 10%, 5%, and 1% level, respectively. Source: Author’s calculations, Kilombero survey rice

Table A5: Agricultural income and total household income regressions (smallholder project and agro-industry workers) (household-level) (OLS)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS aincHHfarm	OLS incHHfarm	OLS pcincHHfarm	OLS aincHHwork	OLS incHHwork	OLS pcinc HHwork
improved_hh_prod	510810.605*	574102.073	159554.319			
	(305426.776)	(422710.092)	(113074.802)			
age_head	23560.561	-147430.400	-63560.989**	97896.191	9467.448	-35392.646*
	(98534.479)	(120758.337)	(29870.759)	(65515.920)	(81379.494)	(19757.671)
age_head_sq	87.774	1875.152	770.279**	-1110.145	-250.064	395.278*
	(1151.849)	(1348.993)	(317.800)	(714.225)	(906.223)	(213.881)
sex_head	-306154.311	-736015.876**	-83581.415	-20675.991	-30791.648	139970.440
	(333814.745)	(371284.560)	(98581.282)	(207980.724)	(319206.226)	(103911.700)
edu_type_bin	-77966.859	313540.279	36614.950	203768.319	811874.677***	203663.919***
	(319022.506)	(375819.151)	(88296.828)	(246808.913)	(311398.436)	(67876.251)
agework_male	29900.228	-65300.409	-107679.822**	82547.807	124319.728	-76908.414*
	(267314.540)	(262789.068)	(50503.637)	(176680.203)	(220998.736)	(45747.235)
agework_female	4726.166	-131335.321	-124234.721**	172781.047	13771.971	-111680.926**
	(231421.264)	(249505.005)	(53573.513)	(180409.826)	(229423.264)	(51138.714)
dependents	-30841.638	-85375.245	-82577.133***	19227.543	-584.374	-60807.047***
	(59207.755)	(76721.981)	(18347.474)	(51077.824)	(77328.233)	(14851.015)
non_agric_binary	646669.473*	1211591.841***	254009.896***			
	(341397.866)	(377338.397)	(78236.405)			
total_land	377914.218***	402467.061***	80167.273***	294699.685***	288390.240**	45480.523**

	(135802.656)	(139295.749)	(27421.136)	(93620.668)	(113514.155)	(20842.484)
born_village	313089.968	223557.263	46098.150	-190078.422	-237063.235	-32832.708
	(391302.634)	(416784.828)	(86020.419)	(268778.588)	(318152.533)	(70008.252)
tlu	568209.776	628749.906	109431.584	400264.159	474070.907*	86243.634
	(345463.863)	(388286.715)	(78462.104)	(253407.632)	(270094.274)	(57290.253)
phone_bin	376711.895	594262.856*	131662.540*	135368.559	260935.451	79088.559
	(261299.253)	(305430.077)	(67124.416)	(223339.078)	(281760.798)	(61317.954)
new_technology	-97544.712*	-96691.508	-15296.481			
	(54750.211)	(59748.690)	(12328.517)			
news1vn1	-887760.654*	-1448219.716	-375419.476			
	(477520.619)	(1059409.997)	(331569.300)			
news1vn2	-301440.108	-874013.053	-373074.347			
	(535810.976)	(1195392.923)	(366711.773)			
news1vn3	112675.191	-770884.447	-319644.592			
	(490354.301)	(1081250.826)	(341469.150)			
news1vn4	374540.722	-468214.142	-270663.749			
	(1091523.825)	(1472501.567)	(405122.921)			
news1vn5	-29114.790	-522000.339	-281126.022			
	(486601.311)	(1175700.441)	(367406.619)			
news1vn6	-934204.515	-1678570.289	-484156.640			
	(594926.382)	(1200119.168)	(366794.676)			
news1vn7	-137218.871	-664851.555	-336372.233			
	(564493.296)	(1198742.637)	(371693.092)			
news1vn8	-510376.574	-653883.154	-285888.033			
	(567397.689)	(1168267.480)	(353870.214)			

news1vn9	37677.893	-667806.279	-368092.240			
	(589189.195)	(1223391.899)	(374646.627)			
news1vn10	.	.	.			
	.	.	.			
treat_worker				-6170.998	445723.050	96807.879
				(202266.346)	(302824.898)	(71756.993)
_cons	-481793.489	4187199.990	2099140.981**	-2031292.311	572307.881	1328446.405***
	(2054913.974)	(3169612.535)	(901418.882)	(1372305.624)	(1738528.646)	(425245.460)
N	277	277	277	219	219	219
adj. R^2	0.292	0.250	0.200	0.289	0.207	0.179

Note: [a] Tropical Livestock Unit; ∗, ∗∗, and ∗∗∗ indicate significance of t-statistic of the mean difference at the 10%, 5%, and 1% level, respectively

Source: Author’s calculations, Kilombero survey rice

Table A6: Total rice farm yields and rice income regression (OLS) (comparing technology package adopters to farmers without any improved technology)

	(1)	(2)	(3)
	OLSyieldHHfarm2	OLSrincHHfarm2	OLSrnretHHfarm2
techn_package_non	447.999***	237796.603***	204572.346***
	(104.349)	(65776.027)	(68690.399)
age_head	-6.423	-16033.704	-27790.230
	(30.829)	(20209.783)	(21089.750)
age_head_sq	0.130	190.606	306.323
	(0.319)	(206.568)	(215.880)
sex_head	-132.814	-80774.220	-84170.985
	(147.448)	(76643.368)	(76249.194)
edu_type_bin	-129.891	-26283.626	22235.396
	(115.893)	(74901.190)	(77574.232)
agework_male	14.032	48118.559	54784.649
	(71.626)	(47563.494)	(48303.723)
agework_female	34.613	7636.054	287.331
	(67.764)	(42982.705)	(47931.133)
dependents	-12.790	-11498.185	-25307.796*
	(23.056)	(13800.959)	(14779.683)
non_agric_binary	165.468*	119328.442*	163580.072**
	(98.477)	(61757.412)	(67815.873)
total_land	-68.265***	-34114.625***	-16554.065
	(18.256)	(11517.204)	(12372.436)
born_village	-129.728	-83209.295	-97765.816
	(103.021)	(63419.141)	(66538.490)
tlu	174.415**	150371.351***	180012.590***
	(85.120)	(48565.477)	(51976.470)
phone_bin	99.605	98525.968	128267.240
	(116.474)	(77257.086)	(82103.778)
new_technology	-8.125	2534.046	2507.843
	(16.052)	(10744.398)	(11394.106)
news1vn1	-658.981**	-395031.434**	-390017.498**
	(294.364)	(165492.505)	(166996.413)
news1vn2	-378.639	-169784.193	-221954.368
	(308.786)	(177285.279)	(187234.673)
news1vn4	-160.138	-223426.833	-219481.071

	(311.135)	(178513.015)	(187263.800)
news1vn5	-57.690	-8519.269	67373.803
	(304.700)	(171556.315)	(180235.486)
news1vn6	-487.700	-232281.584	-207578.588
	(313.912)	(178301.131)	(182013.917)
news1vn7	47.601	-5032.880	12303.939
	(309.448)	(173163.591)	(177709.521)
news1vn8	-387.723	-92385.382	-85582.367
	(323.787)	(208209.850)	(218103.965)
news1vn9	-4.490	-78506.394	-173857.286
	(347.060)	(210883.785)	(215735.207)
news1vn10	-181.540	-148546.016	-129869.987
	(286.907)	(179285.043)	(189940.330)
worker_trad_tech			
_cons	1501.333*	878115.675*	844633.419
	(782.081)	(503336.253)	(533985.379)
N	236	236	236
adj. R^2	0.213	0.179	0.186

Source: Author’s calculations, Kilombero survey rice

Table A7: Agricultural income and total household income regressions - smallholder project and agro-industry workers (comparing to all farmers without improved technology)

	(4)	(5)	(6)	(7)	(8)	(9)
	OLSaincHHfarm2	OLSincHHfarm2	OLSpcincHHfarm2	OLSaincHHwork2	OLSincHHwork2	OLSpcincHHwork2
techn_package_non	763746.880***	853282.406**	216392.581*			
	(265696.952)	(426080.525)	(123084.494)			
age_head	-96845.459	-287545.677**	-88450.311**	34484.345	-42897.213	-38789.875**
	(107865.606)	(135108.530)	(34911.199)	(49939.961)	(75066.826)	(19204.194)
age_head_sq	1302.651	3316.722**	1008.241***	-549.628	231.558	397.205*
	(1323.292)	(1562.028)	(379.174)	(594.975)	(882.501)	(206.213)
sex_head	-136863.051	-530253.635	-33123.372	34891.519	20079.759	156729.516
	(362785.751)	(399489.063)	(106012.139)	(209680.676)	(316566.227)	(105143.855)
edu_type_bin	-384510.199	-77932.936	-47458.568	-139833.510	490018.618*	161782.176**
	(327529.972)	(412035.273)	(101632.638)	(173116.504)	(287873.744)	(67098.151)
agework_male	107502.202	28415.347	-77347.309	159896.390	196015.509	-52690.167
	(285980.417)	(275107.545)	(53616.367)	(140853.810)	(204127.153)	(43740.823)
agework_female	95934.542	-80046.851	-116228.954**	327702.490**	96343.216	-94982.902*
	(227741.543)	(248429.593)	(53294.715)	(128764.229)	(201507.906)	(49425.963)
dependents	-37805.015	-107800.633	-91617.745***	922.696	-30182.721	-69519.092***
	(63908.985)	(87360.018)	(21704.833)	(52815.537)	(83509.160)	(16258.534)
non_agric_binary	575329.500	1114464.990***	231318.116***			
	(348357.991)	(392771.939)	(83651.643)			
total_land	430467.355***	459488.234***	95837.178***	345292.798***	325558.512***	51191.694***
	(154998.471)	(149979.267)	(29583.704)	(63925.630)	(70826.668)	(13499.003)

born_village	263538.666	136325.839	29945.823	-219805.050	-303017.006	-52656.203
	(394813.444)	(424295.062)	(87575.166)	(156244.468)	(248705.919)	(61859.814)
tlu	370304.570	447070.256	53892.364	50163.902	135584.021	2342.758
	(336987.140)	(392908.446)	(84695.484)	(145568.571)	(168570.334)	(34552.743)
phone_bin	436088.621	661333.023**	114310.460	157339.648	250344.478	52762.090
	(278310.130)	(314760.820)	(69282.345)	(230305.183)	(304241.544)	(64158.907)
new_technology_b	-88978.454	-77445.460	-11003.724			
	(63081.613)	(69995.282)	(14532.087)			
news1vn1	-321585.924	9902.864	200812.668			
	(522352.917)	(669509.382)	(161191.793)			
news1vn2	302935.398	595247.223	183381.102			
	(519442.817)	(684244.443)	(151424.573)			
news1vn3	536043.311	536586.520	208434.343			
	(561121.129)	(634046.031)	(141877.675)			
news1vn4	962954.914	937411.662	216400.587			
	(1247920.067)	(1219747.363)	(240052.213)			
news1vn5	638677.130	974231.667	277181.884*			
	(527882.638)	(698729.628)	(145778.760)			
news1vn6	-380205.937	-311528.524	42970.236			
	(524935.809)	(607929.564)	(123156.131)			
news1vn7	330717.117	596747.768	173075.012			
	(494828.732)	(570477.890)	(116011.535)			
news1vn8	270748.223	1057946.726	334776.716*			
	(667405.983)	(808487.419)	(176906.564)			
news1vn9	.	.	.			

	.	.	.			
news1vn10	559868.382	1439526.277	571419.794			
	(706492.698)	(1532224.206)	(480085.602)			
worker_trad_tech				238653.877	630599.719**	117409.566
				(170195.003)	(292780.617)	(72354.022)
_cons	1342804.170	5577131.320**	2095569.961***	-765962.615	1764101.393	1469730.995***
	(2019722.342)	(2735472.809)	(710192.846)	(1052720.946)	(1602096.895)	(419209.522)
N	239	239	239	181	181	181
adj. R^2	0.323	0.262	0.210	0.383	0.197	0.200

Source: Author’s calculations, Kilombero survey rice

Additional information

1) Plot-level balance testing

Deriving reliable PSM-estimates requires that the distribution of propensity scores of adopters and non-adopters are similar and that pre-adoption differences are eliminated by matching. Figure 2 compares the distribution of the propensity scores for the adoption plots and the conventional plots and reveals that propensity scores are of a relatively equal distribution, suggesting comparability.

Figure 2: propensity score distribution – plot-level analysis

Source: Author's calculations, Kilombero survey 1

The matching quality is assessed using group mean and median comparisons. Table 1 reports the summary indicators of differences between explanatory variables before and after matching (model P-Values, R-squared, and mean / median biases). In spite of some remaining differences, the results indicate a significant reduction in the overall covariate median and mean differences between the two groups.

Table 1: Plot-level matching quality (summary indicators)

Model	Sample	Pseudo R2	LR chi2	p>chi2	MeanBias	MedBias
Improved variety	Raw	0.121	55.21	0.000	15.7	13.2
	Matched	0.057	24.94	0.204	9.4	6.5
Full package	Raw	0.113	43.33	0.002	16	12.9
	Matched	0.044	14.21	0.819	8.5	6.5

Source: Author's calculations, Kilombero survey rice

Likewise, Table 2 and Table 3 of the detailed t-test comparisons of individual explanatory variables before and after matching of the improved and unimproved plots, suggest that initial differences in most variables (plot manager, crop damage, livestock ownership, innovativeness, village share of project participants) is eliminated due to matching (except for village price differences), suggesting well balancing after matching.

Table 2: Plot-level covariate mean differences between & after matching (improved variety)

	Unmatched	Mean			%reduct	t-test	
Variable	Matched	Treated	Control	%bias	bias	t	p>t
location	Unmatched	0.60123	0.63855	-7.7		-0.7	0.487
	Matched	0.60759	0.6628	-11.3	-47.9	-1.02	0.31
fertility	Unmatched	0.84049	0.84337	-0.8		-0.07	0.943
	Matched	0.83544	0.84142	-1.6	-107.5	-0.14	0.886
manager	Unmatched	0.61963	0.71084	-19.4		-1.76	0.08
	Matched	0.62025	0.69165	-15.2	21.7	-1.34	0.183
leveling	Unmatched	0.90798	0.85542	16.3		1.47	0.141
	Matched	0.90506	0.86043	13.8	15.1	1.23	0.219
Rice_crop_damage	Unmatched	0.61963	0.71687	-20.7		-1.88	0.061
	Matched	0.63291	0.64544	-2.7	87.1	-0.23	0.817
S51plot_dist	Unmatched	52.957	63.361	-22.5		-2.03	0.043
	Matched	53.937	51.951	4.3	80.9	0.43	0.666
S51_title	Unmatched	0.18405	0.15663	7.3		0.66	0.51
	Matched	0.17089	0.20147	-8.1	-11.5	-0.7	0.487
S52landprep~e	Unmatched	0.73006	0.78313	-12.4		-1.12	0.263
	Matched	0.72152	0.74257	-4.9	60.3	-0.42	0.674
age_head	Unmatched	44.607	43.892	7.2		0.65	0.515
	Matched	44.405	44.579	-1.8	75.6	-0.16	0.876
sex_head	Unmatched	0.04908	0.09036	-16.2		-1.47	0.143
	Matched	0.05063	0.05345	-1.1	93.2	-0.11	0.911
edu_type_bin	Unmatched	0.55828	0.48795	14.1		1.28	0.203

	Matched	0.5443	0.55557	-2.3	84	-0.2	0.841
working_age	Unmatched	2.9141	2.8012	8.4		0.76	0.448
	Matched	2.8987	2.8582	3	64.1	0.27	0.785
non_agric_inc	Unmatched	0.74847	0.72289	5.8		0.52	0.6
	Matched	0.74051	0.7513	-2.4	57.8	-0.22	0.826
total_rice_land	Unmatched	3.3086	3.1705	5.8		0.52	0.602
	Matched	3.2899	3.677	-16.1	-180.3	-1.28	0.201
born_village	Unmatched	0.39264	0.45181	-12		-1.08	0.279
	Matched	0.40506	0.32333	16.5	-38.1	1.51	0.132
livestock_binary	Unmatched	0.84049	0.65663	43.2		3.92	0.00
	Matched	0.83544	0.73999	22.4	48.1	2.08	0.038
phone_bin	Unmatched	0.84663	0.83133	4.2		0.38	0.707
	Matched	0.85443	0.84566	2.4	42.7	0.22	0.828
village_price	Unmatched	87859	90807	-33.8		-3.07	0.002
	Matched	87820	90975	-36.2	-7	-3.24	0.001
new_technology_index	Unmatched	10.472	11.325	-29.9		-2.71	0.007
	Matched	10.481	10.786	-10.7	64.2	-0.95	0.344
sri_share_village	Unmatched	0.14992	0.12817	26.6		2.41	0.017
	Matched	0.14889	0.13932	11.7	56	1.01	0.311

Source: Author's calculations, Kilombero survey rice

Table 3: Plot-level covariate mean differences between & after matching (full technology package)

	Unmatched	Mean			%reduct	t-test	
Variable	Matched	Treated	Control	%bias	bias	t	p>t

location	Unmatched	0.5812	0.63855	-11.7		-0.97	0.331
	Matched	0.5812	0.54126	8.2	30.4	0.61	0.54
fertility	Unmatched	0.8547	0.84337	3.2		0.26	0.795
	Matched	0.8547	0.78628	19	-504	1.36	0.174
manager	Unmatched	0.57265	0.71084	-29		-2.42	0.016
	Matched	0.57265	0.55108	4.5	84.4	0.33	0.741
leveling	Unmatched	0.93162	0.85542	24.8		2	0.046
	Matched	0.93162	0.90923	7.3	70.6	0.63	0.529
rice_crop_damage	Unmatched	0.64957	0.71687	-14.4		-1.2	0.23
	Matched	0.64957	0.64295	1.4	90.2	0.11	0.916
S51plot_dist	Unmatched	55.624	63.361	-16.4		-1.33	0.185
	Matched	55.624	55.933	-0.7	96	-0.06	0.956
S51_title	Unmatched	0.17094	0.15663	3.9		0.32	0.749
	Matched	0.17094	0.22294	-14	-263.3	-1	0.319
S52landprep~e	Unmatched	0.76923	0.78313	-3.3		-0.28	0.783
	Matched	0.76923	0.82876	-14.2	-328.2	-1.13	0.258
age_head	Unmatched	45.265	43.892	13.8		1.13	0.26
	Matched	45.265	45.67	-4.1	70.5	-0.31	0.758
sex_head	Unmatched	0.05983	0.09036	-11.6		-0.94	0.347
	Matched	0.05983	0.06953	-3.7	68.2	-0.3	0.764
edu_type_bin	Unmatched	0.5641	0.48795	15.2		1.26	0.208
	Matched	0.5641	0.54605	3.6	76.3	0.28	0.782
working_ageb	Unmatched	2.9658	2.8012	12		1	0.32
	Matched	2.9658	2.9824	-1.2	89.9	-0.09	0.926
non_agric_inc	Unmatched	0.76068	0.72289	8.6		0.71	0.478

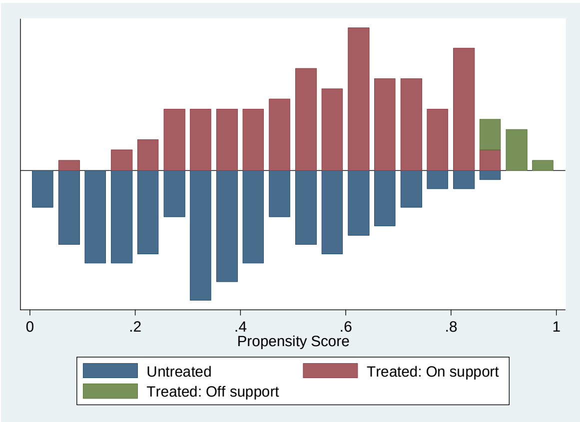
	Matched	0.76068	0.78367	-5.2	39.2	-0.42	0.677
total_rice_land	Unmatched	3.4684	3.1705	12		1	0.318
	Matched	3.4684	3.9903	-21.1	-75.2	-1.39	0.166
born_village	Unmatched	0.47863	0.45181	5.4		0.44	0.657
	Matched	0.47863	0.44638	6.4	-20.2	0.49	0.623
livestock_binary	Unmatched	0.82906	0.65663	40.1		3.26	0.001
	Matched	0.82906	0.74744	19	52.7	1.53	0.128
phone_bin	Unmatched	0.87179	0.83133	11.4		0.93	0.352
	Matched	0.87179	0.8673	1.3	88.9	0.1	0.919
village_price	Unmatched	89141	90807	-20		-1.69	0.093
	Matched	89141	90143	-12	39.9	-0.94	0.351
new_technol	Unmatched	10.359	11.325	-35		-2.86	0.004
	Matched	10.359	10.824	-16.9	51.8	-1.35	0.178
sri_share_village	Unmatched	0.15178	0.12817	28.8		2.39	0.017
	Matched	0.15178	0.15713	-6.5	77.3	-0.47	0.639

Source: Author's calculations, Kilombero survey rice

2) *Household-level balance testing*

Figure 3 presents the distribution of propensity scores for adopters and non-adopters, which are fairly similar, suggesting that there is sufficient overlap and similarity between the groups to justify the use of PSM. Matching is performed only on those observations that are within the same common support area. Eight adopters with very high propensity scores are not used as they are outside the area of common support.[30] Summary statistics (R-square, LR-test, Mean and Median bias) to compare the unmatched and matched sample (Table 13) show that differences in observable variables disappear after performing PSM.

Figure 3: matching quality – Household-level propensity score distribution



Source: Author's calculations, Kilombero survey rice

Table 13: Covariate balance on household-level: summary statistics

	Sample	Pseudo R2	LR chi2	p>chi2	MeanBias	MedBias
NNM:	Raw	0.169	56.4	0.000	18.1	19.0
	Matched	0.013	3.84	1.000	4.7	4.0
KM:	Raw	0.169	56.4	0.000	18.1	19.0
	Matched	0.011	3.36	1.000	4.5	3.1

	Off support	On support
Untreated	0	126
Treated	8	107

Source: Author's calculations, Kilombero survey rice

[30] Estimations (not reported here) including these observations, however, did not lead to large differences in the results.