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Disentangling the Impact of a Multiple-Component Project on SDG Dimensions: The Case of Durum Wheat Value Chain Development in Oromia (Ethiopia)

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Disentangling the Impact of a Multiple-Component Project on SDG Dimensions: The Case of Durum Wheat Value Chain Development in Oromia (Ethiopia)

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1. Introduction

In low- and middle-income countries, poverty among smallholder farmers (SHF) is widespread and, in many countries, it is significantly higher than the national average (Davis et al., 2010; Rapsomanikis, 2015).[1] Therefore, getting SHF out of poverty is critical for achieving the Sustainable Development Goals (SDGs). Specifically, improving the living conditions of SFH is key for the achievement of SDG1 (No poverty), SDG2 (Zero hunger), and SDG10 (Reduced inequalities), and contributes to the achievement of many other SDGs such as SDG8 (Decent work and economic growth) and SDG12 (Responsible consumption and production) (FAO, 2018).

As emphasized by Beegle and Christiaensen (2019), although modernizing agriculture and promoting rural development is not a sufficient condition for eradicating poverty (SDG1) and achieving food security (SDG2), it emphasizes "a policy entry point" (p. 5) to pursue these goals, that is ensuring conditions for SHF to achieve higher levels of income through innovation adoption, participation in agrifood value chains and diversifying rural jobs into non-farm activities. However, SHF have lagged behind in modernizing because of extensive market and government failures (Barrett et al., 2012). Overcoming such failures can be achieved through two complementary strategies (de Janvry and Sadoulet, 2019): (i) removing the major constraints to technology adoption such as liquidity, risk, information, and access to markets, and (ii) developing inclusive value chains through technical and institutional changes favoring the involvement of marginalized actors such as smallholders, small-scale businesses, and landless laborers.

Pursuing these strategies requires complex interventions, usually designed as multifaced projects/programs integrating several components such as transfer of productive assets, consumption support, training and coaching, savings encouragement, and provision of education and health services (Emran et al., 2014). There is evidence that such an integrated approach is more effective in improving livelihoods among the poor – and able to bring more lasting results – that stand-alone interventions (Banerjee et al., 2015; Pace et al., 2017).

The overall objective of this paper is to test the effectiveness of such integrated approach in the specific case of an inclusive value chain development project in the Bale region (Oromia, Ethiopia). This project offers to SHF cooperative members a package of interventions – i.e. training, seed provision, storage, processing, and marketing through cooperatives – aiming at stimulating their participation in a high-quality durum wheat value chain (IAO, 2010; IDC, 2016). In doing this, the project is expected to affect several SDG dimensions, pursuing directly SDG2 (Zero hunger) and SDG4 (Quality education). Moreover, empowering SHF is seen instrumental for the achievement of

[1] About 80% of world's extreme poor live in rural areas, with nearly two third of them gaining their living from agriculture (Davis et al., 2017; Castañeda et al., 2018). Roughly 90% of world's farms are family farms, i.e. farms run by an individual or a family and relying primarily on family labor, and the vast majority of them are small farms, i.e. agricultural holdings not exceeding 2 hectares (Lowder et al., 2019).

these SDGs: as such the project is expected to affect also SDG16 (Peace, justice and strong institutions).

Specifically, we address the following research questions: (i) How effective is the project in improving the food security status of SHF households (SDG2), achieving better education attainment for SHF household children (SDG4) and strengthening collective action and building social capital in the intervention area (SDG16); (ii) Which project components, and combinations thereof, are more effective in achieving the expected impacts on SDG2, SDG4 and SDG16; and (iii) What is the role of collective action and social capital (SDG16) in initiating production for the market and participation in a value chain, and eventually in determining SDG2 and SDG4. Possible co-benefits and synergies among the SDGs are explored using a number of selected indicators (Table 1).

<TABLE 1 ABOUT HERE>

The paper is organized as follows. Section 2 reviews the three strands of literature that are relevant for the study: the role of SHF in agricultural development strategies, inclusive agrifood value chain development, and the empirical evidence on the effects of inclusive value chain development interventions. Section 3 provides an overview of the case study – the Agricultural Value Chain Project in Oromia (AVCPO) – briefly describing the intervention context, the project components and the implied theory of change. Section 4 presents the data and the econometric strategy adopted in the study. In fact, addressing the research questions above requires a variety of approaches ranging from instrumental variable techniques to multi-valued treatment effect analysis and causal mediation modelling. Section 5 discusses the study results showing that the project has achieved the expected results on the considered SDGs, and institutional variables (SDG16) play a complex role in achieving food security (SDG2) and better education (SDG4). Section 6 concludes discussing the main results in the light of the existing literature and the policy implications that can be drawn from the study results.

2. Literature review

2.1. Smallholder farmers and agricultural development strategies

The development community widely agrees that "agriculture-based countries", i.e. countries with a high share of agriculture in GDP growth and a high share of rural poverty in total poverty such as Sub-Saharan Africa (SSA) countries,[2] should invest more in agriculture to foster economic growth and reduce poverty (World Bank, 2007). There is indeed a solid empirical evidence that poverty reduction can be more effectively achieved through productivity growth, i.e. investing in agriculture and non-farm rural activities where the poor live, than through a Lewis-type structural transformation based on the migration of the poor from rural-agricultural environment to an urban-industrial environment (World Bank, 2007; Diao et al., 2010; Loayza and Raddatz, 2010;

[2] This region accounts for 41% of the world's poor (Beegle and Christiaensen, 2019), 84% of which live in rural areas and gain their living primarily in farming or, when off-farm, in agriculture-related activities (Beegle et al., 2016; Allen et al., 2018; Castañeda et al., 2018). Small farms in SSA account for almost three quarter of total farms and more than one quarter of total agricultural land (Lowder et al., 2019).

Christiaensen et al., 2011; Christiaensen and Todo, 2014; Rodrik et al., 2016; Jayne et al., 2018; Ligon and Sadoulet, 2018).[3]

However, success requires not only increasing the growth rate of agriculture but also making this growth more effectively pro-poor, which implies that SHF have to be part of the approach, and that growth in commercial agriculture has to create benefits for the landless and smallholders through the labor market (Diao et al., 2010; Beegle and Christiaensen, 2019; de Janvry and Sadoulet, 2019).

The modernization of SHF agriculture and the associated agricultural and rural transformations are hampered by both market and government failures. As emphasized by de Janvry and Sadoulet (2019), the removal of these failures can be addressed through two complementary approaches. The first approach is based on "constraint removal" where development agents (governments, development agencies, donors, NGOs) facilitate overcoming the major constraints to adoption: liquidity, risk, information, and access to markets (Bridle et al., 2018). This approach is essential but likely to hit a low ceiling due to heterogeneity of conditions, lack of complementary factors, and diverse farmers' objectives and capacity (de Janvry et al., 2016; de Janvry and Sadoulet, 2019). A complementary approach is "inclusive value chain development" where agents in value chains (entrepreneurs, coordinating agencies, producer organizations) create incentives to SHF modernization through contracting and vertical coordination (Byerlee and Haggblade, 2013; World Bank, 2016). The advantage of value chain development as opposed to constraint removal is that the former does not predetermine the solution to adoption (as it does the latter) but seeks instead broad complementarities on how to achieve agent-tailored modernization, thus addressing the inherent heterogeneity of the intervention environment as well as of farmers (Winters et al., 2009).

In conclusion, inclusive value chain development, entailing technical and institutional innovations targeted to marginalized actors, along with complementary investment in rural public goods, is key to any strategy to raise SHF agricultural productivity, with raising staple crop productivity still an area of primary attention (Wiggins et al., 2010; Devaux et al., 2017; Beegle and Christiaensen, 2019). However, in order to achieve growth and poverty reduction a significant increase of investment in agriculture is required, especially in Sub-Saharan Africa which has been dramatically lagging behind with half of the countries spending less than 5% of their public expenditures on agriculture (Goyal and Nash, 2016).

2.2. Inclusive agrifood value chain development

Value chain development is an intervention that aims to address poverty through strengthened linkages among chain actors, allowing them to take advantage of market opportunities. Value chain development interventions that target marginalized actors in a value chain are known as "inclusive" value chain development (IVCD) (UNIDO, 2011).

[3] There are authors showing some pessimism about the possibility of an agriculture-based development (Collier and Dercon, 2014; Dercon and Gollin, 2014). This pessimism is rooted in the large differential between the labor productivity per person per year in agriculture vs. the non-agricultural sectors. However, as shown by McCullogh (2017), the labor productivity gap tends to disappear when considering the productivity per hour. In other words, the issue is the seasonality of agricultural activities and the lack of working opportunities in the lean season. Therefore, smoothing labor calendars through the provision of employment opportunities in agriculture (e.g. diversifying farming systems) and in the rural non-farm economy is key for poverty reduction (de Janvry et al., 2018).

Inclusive value chain development links farmers backward to their input and technology suppliers and forward to intermediaries, processors, and ultimately consumers, providing a variety of products ranging from low-value staple food, to medium-value traditional domestic consumption and export crops, and high-value non-traditional export crops (Swinnen, 2007; Swinnen and Maertens, 2007; Reardon et al., 2009). SHF can supply markets with various food products and they may have a comparative advantage in producing high-value, labor-intensive products, such as perishable fruits, vegetables and specialty crops (Bhattarai et al., 2013; Hazell and Rahman, 2014; Feyaerts et al., 2019).

There are many alternative business models for SHF being involved into agrifood value chains (Byerlee and Haggblade, 2013) such as spot markets, collective action for marketing,[4] contract farming with individual farmers or with producer organizations, outgrower schemes with plantations or estates, vertically integrated agribusiness commercial farms.

For SHF, benefits may include increased income, more secure market linkages, and access to new services for production (Bellemare and Bloem, 2018; Swinnen and Kuijpers, 2020). For wholesalers, processors, and other downstream enterprises, benefits may include improved quality and flow of raw material, reduced transaction costs, and enhanced environmental and social credentials (Deveaux et al., 2017; Swinnen and Kuijpers, 2020).

However, while participating in value chains may be an opportunity for SHF, it can be a high toll for many of them for they are required to deliver regular supplies of produce of consistent quality and sufficient quantity. Meeting these conditions requires access to land, inputs, technology, knowledge, organization, capacity, skill, and infrastructure, which may not exist in some communities or among some groups of asset-poor producers (Reardon et al., 2009)

Several authors have reviewed the empirical evidence on successful inclusion of SHF into agrifood value chains (Deveaux et al., 2017; de Janvry and Sadoulet, 2019; Swinnen and Kuijpers, 2020), emphasizing what are the conditions conducive to success. SHF often find it difficult to exploit the opportunities presented by expanding markets because of their limited access to resources such as land, credit, technical advice, and current information on market prices and conditions (Carter and Barrett, 2006; Barrett, 2008; Winters et al., 2009; Davis et al., 2010; Barrett et al., 2016). Therefore, a minimum asset endowment under the form of land, capital, health, knowledge and skills, and social capital is required for SHF to initiate production for the market and participation in a value chain (Stoian et al., 2012).[5] This is usually achieved through a large variety of resource providing contracts (Bellemare and Lim, 2018) aiming at overcoming market failures (credit, insurance, and inputs) and government failures (information and access to markets) that can prevent an effective SHF participation.

Institutional innovations such as organizing farmer and providing them with innovative contract-farming arrangements play key roles in IVCD. Collective action through farmer organizations contributes to reduce transaction costs in input and product markets by improving product assembly and quality assurance and by organizing supplies of inputs, credit, and technical assistance (Wollni and Zeller, 2007; Bijman and Wollni, 2008; Barrett, 2008; Poulton et al., 2010; Fischer and Qaim, 2012; Devaux et al., 2016; Swinnen and Kuijpers, 2020). It can also increase the

[4] This means SHF buy inputs and sell products through producer organizations and cooperatives. An example of this is our case study (cf. section 3), corresponding to Model 1b – "Farmer collective action" by Byerlee and Haggblade (2013).

[5] This is consistent with the "BRAC graduation model" for the rural ultra-poor that starts with meeting minimum asset thresholds to engage in agricultural entrepreneurship (Bandiera et al., 2013; Emran et al., 2014).

SHF bargaining power vis-à-vis intermediaries as productive alliances aid in negotiating more favorable contracts for smallholders (World Bank, 2016). At the same time these alliances decrease the risks of SHF side-selling and contract defaulting (Fafchamps, 2004). Collective action can also contribute to widen access to information and knowledge (Anyonge and Messer, 2014; Bernier and Meinzen-Dick, 2014) and strengthen voice and power in policy processes (Prato and Longo, 2012; IFAD, 2016).

Effective facilitation, which involves forming networks, coordinating interactions, mediating disputes, and documenting results, is crucial for the success of IVCD. An institutional innovation that proved useful for this is the development of multi-stakeholder platforms, tailored to fit specific local conditions and flexible enough to evolve in response to changing conditions. They allow individuals with different stakes to interact, improve their mutual understanding, develop trust, and engage in joint activities (Biggeri et al., 2016; Devaux et al., 2017; Schut et al., 2017; de Janvry et al., 2019).

Asset-building and institutional innovations might not be sufficient for successful value chain development. In fact, participation of SHF in high-value markets exposes them to new risks, which might outweigh the potential benefits (Ricketts et al., 2014). Furthermore, marketing opportunities and performance of SHF are strongly influenced by the local economic environment (Berdegue et al., 2015). Therefore, IVCD efforts need to be part of a broader rural development strategy pursuing agricultural and rural transformations (de Janvry and Sadoulet, 2019). Finally, another factor that has been emphasized as essential for results to emerge is time (Devaux et al., 2017). In fact, institutional change, that often requires also capacity building, is a long-term result (Bowles and Gintis, 2002). The most successful inclusive value chain development experiences benefitted from continuous support – from donors, international organizations, and national partners – over a decade or more.

The main results of the literature above can help identifying the key components of a successful strategy IVCD (Stür et al., 2013; Devaux et al., 2017; de Janvry and Sadoulet, 2019): a minimum asset endowment for SHF to enable them to participate in value chains; an innovation sufficiently upstream in the value chain that provides immediate benefits to SHF thus creating incentives to improve their current practices; a participatory, systems-oriented innovation process that includes the formation of a coalition of local stakeholders to facilitate and manage the innovation process (multi-stakeholder platform) and provide a vision for local stakeholders; production organizations with capacities, disciplines and bargaining power to engage in contracting and to provide technical support to SHF. All the above should be implemented over a sufficiently long period of time to allow innovation processes to become sustainable.

2.3. Empirical evidence on the effectiveness of inclusive value chain development interventions

IVCD interventions are typically complex interventions that entail several components aiming at removing the constraints to SHF participation, creating an enabling institutional environment and providing SHF with the right incentives to participate. Those interventions require significant institutional innovations that can take the form of resource providing contracts and coordination mechanisms.

Resource providing contracts are difficult to implement and enforce (Bellemare, 2015) because of monopsony power of contracting agents (agribusiness, agroexporters, supermarkets) that can lead to hold-up practices and lower prices on deliveries (Swinnen et al., 2010) and side-selling by SHFs

when the contract price is inferior to the local market price at harvest time that can undermine the enforcement and credibility of contracts (Fafchamps, 2004). Generally, empirical studies report positive benefits of these contracts for SHFs although many impact studies have limited internal and external validity (Bellemare, 2015).

Contracts are usually complemented by innovation platforms that help actors in a value chain communicate and coordinate actions to address bottlenecks to value chain development (World Bank, 2012; 2016). The emergence of innovation platforms in the value chain can come from downstream agents – e.g. from leading private sector enterprises (Swinnen, 2018) – as well as from upstream agents – e.g. from producer organizations, cooperatives (Collion, 2018) – even if the latter tends to be more common than the former.

Rigorous impact evaluations of IVCD interventions are not very common. In fact, the rigorous implementation of such studies is usually hampered by self-selection and by the lack of adequate counterfactuals (Bellemare, 2015; de Janvry and Sadoulet, 2019). Most of the studies aiming at estimating the impact of contract farming on farmer welfare use observational methods (Barrett et al., 2012; Bellemare and Bloem, 2018), using propensity score matching to find counterfactuals to participating farmers or instrumental variable techniques to try to overcome the endogeneity of participation. At the best of our knowledge, the only study which is close enough to a randomized evaluation is Ashraf et al. (2009) who found that entering in a contractual arrangement increased SHF production and lowered marketing costs, leading to a significant income gain for new adopters. The assessment of the impact of IVCD are based on ex-post evaluations in which counterfactual – i.e. non-treated similar communities – are identified through propensity score matching. For example, Cavatassi et al. (2011) for potato farmers in Ecuador and Biggeri et al. (2018) for durum wheat producers in Ethiopia found that linking smallholder to high-value markets determined a large increase in yield and in gross value per hectare through selling more produce at a higher price.

The complexity of agricultural innovation and IVCD processes has important implications for the design and implementation of interventions.[6] There is an increased common understanding that interventions that focus narrowly on either expanding production or developing value chains have limited benefits for the poor while interventions that combine agricultural innovation and IVCD have synergistic effects (Devaux et al., 2017).[7] The implication is that those who design and implement programs should seek to combine efforts that promote both agricultural innovation and IVCD.

IVCD presents many challenges to evaluators and more applied research and evaluation are needed to draw lessons from experience and test the assumptions and the theory of change behind value chain interventions. The priorities for future research are to "find practical methods … for more holistic assessments of asset endowments that would better inform the planning and implementation of VC interventions" and "find the ways to capture heterogeneity and achieve greater impact at scale – that is, to understand how much the results achieved can be extrapolated to other areas or even other value chains of similar commodities" (Devaux et al, 2017: 117). In doing

[6] Traditionally, while agricultural research organizations have focused on increasing agricultural production and productivity, NGOs and others concerned with agribusiness development have focused on marketing and value chain development. The overall impact of interventions in these two areas has been limited by the lack of a more holistic approach that addresses challenges and opportunities all along the value chain (Devaux et al., 2017)

[7] This is consistent with the findings of other authors showing that multi-faceted programs have larger – and more persistent – results on the wellbeing of the ultra-poor than stand-alone interventions (Banerjee et al., 2015; Pace et al., 2017).

this, it has been suggested that rigorous experimental evaluation approaches should be coupled with participatory and collaborative ones (Patton, 2011; Biggeri and Ferranini, 2015; Bamberger et al., 2016; Chatterji, 2016). More generally, in evaluating complex interventions the use of mixed approaches combining quantitative and qualitative methods is likely to provide a better understanding of research problems than does either approach alone (Palinkas et al., 2019).

3. The Case Study: AVCPO

3.1. The project

The Agricultural Value Chains Project Oromia (AVCPO) is a project implemented between 2011 and 2016 in the Bale Zone in the Oromia State, Ethiopia within the framework of the Ethiopian-Italian cooperation.[8] The AVCPO objectives were twofold: (i) increasing the domestic production of high-quality durum wheat to meet the increasing demand of the Ethiopian pasta industry (Taffesse et al., 2013), and (ii) improving the livelihoods of local SHF by involving them in the high-quality durum wheat value chain and linking them to the pasta industry via farmers' cooperatives (IAO, 2010; IDC, 2016).

The AVCPO has been designed as a multiple-actor, multiple-component project[9] targeting local actors – primarily SHF, farmers' cooperatives and local public research centers – as well as public institutions at the local, State and federal level, and the industrial association of Ethiopian pasta producers. In order to pursue the above-mentioned objective, AVCPO was designed as a package of interventions – i.e. training, seed provision, storage, processing, and marketing through the cooperatives – targeted to 6,520 SHF organized in 15 cooperatives.

The AVCPO diagnostics had identified a number of technical and institutional problems (Table 2) that undermined SHF ability to produce durum wheat in the right quantity, quality and timing as required by the pasta-making industry (Biggeri et al., 2016; 2018). The project was structured along two main interdependent axes (IAO, 2010): (i) removing some production constraints to the adoption by SHF of more productive practices based on higher quality produce; and (ii) introduce institutional innovations to reduce the high and pervasive risk of farming and increase coordination among actors along the value chain.

<TABLE 2 ABOUT HERE>

[8] Bale Zone is a high potential area for wheat production characterized by relatively homogeneous socio-economic and agro-climatic conditions (IAO, 2010). Slightly less than 90% of its 1.8 million inhabitants lives in rural areas, 95% of which depend on agriculture (BZADO, 2012). About 10.6% of the land is arable land used for crop production, of which some 140,000 hectares were cultivated with bread wheat at the beginning of the project. The durum wheat production in the project area increased about ninetyfold between 2012 and 2016 (Sall et al., 2019).

[9] The AVCPO was designed building on the previous experience of the Arsi-Bale Rural Development Project (ABRDP) implemented by the Italian Cooperation from 1996 to 2004. The ABRDP addressed rural development through an integrated territorial approach promoting agricultural activities as well as investment in rural infrastructures (schools, water management, research and extension). The legacy of the ABRDP from both the technical (e.g. local seed research and rural extension capacities) and institutional viewpoint (e.g. pre-existing administrative organization, strong ownership at national, state and local levels) represented a tremendous asset for setting-up and implementing the AVCPO.

In order to favor the introduction and the adoption of improved durum wheat varieties, the involvement of public research centers and cooperatives was critical as well as closing the quality seed cycle via seed multiplier cooperatives (Abebaw and Haile, 2013). The introduction of these new varieties was accompanied by the promotion of appropriate agronomic practices through training SHF on technical aspects of production and commercialization as well as promoting contractual agreements for the provision of industrial-grade seeds and making available storage and processing facilities through the cooperatives.

The second axis concerned organizational aspects and, in particular, the overall institutional architecture of the value chain, paying special attention to capacity-building of cooperatives' boards, establishing links between cooperatives and public agricultural research centers and using cooperatives to establish contract farming arrangements (Biggeri et al., 2016) securing SHF access to pasta-making industries through the cooperatives (Sall, 2019). Furthermore, a protein-content-based premium for durum wheat delivered to the cooperatives was introduced to provide SHF with appropriate incentives to improve high-quality durum wheat production and prevent side-selling of their harvest (Biggeri, 2018).

3.2. The theory of change

The effectiveness of the AVCPO depends on how its various components are integrated: farm-level impacts can be achieved as long as the coordination of multiple actions is ensured. For instance, the use of improved seeds is only sustainable if SHF, cooperatives and public agricultural research centers are part of a consistently designed durum wheat seed production cycle. Moreover, since the quality of durum wheat is measured at the cooperative/area level, individual farmers have an incentive to invest in quality-enhancing practices – such as the adoption of higher quality seeds, the application of more fertilizer, etc. – only if other members of the cooperative do not free ride. This explains the critical role played by institutional change along with technical change (Figure 1).

The AVCPO implied changes in the in the durum wheat value chain are expected to increase SHF's revenues (SDG2 Target 2.3) by increasing the quantity produced and sold and/or selling at higher price. Furthermore, direct access to the durum wheat national market through the cooperatives is expected to increase the SHF's value-added share by providing marketing channels alternative to traditional intermediaries and by increasing the farmers bargaining power. SHF household income may rise as long as additional costs (e.g. fertilizers) are lower than the increase of revenue, which is actually what happened (Biggeri et al., 2018). The increase in household income as well as the empowerment (SDG16 Targets 16.6 and 16.7) of disfranchised SHF will eventually impact several well-being dimensions such as food security (SDG2 Targets 2.1 and 2.2) as well as education (SDG4 Target 4.1).[10]

<FIGURE 1 ABOUT HERE >

There are several contextual factors that can influence AVCPO ability to achieve the expected impacts. Natural risks such as weather shocks and pest outbreaks as well as price shocks are quite common in the intervention area. While the AVCPO did not address the former, it well addressed

[10] Other well-being dimensions (e.g. health) might be impacted as well. However, our dataset does not include data on such dimensions.

the latter through input and output contracts. Political stability is also key for the project success critically depends on establishing a positive business climate and on building cooperation among stakeholders. This was ensured by the strong commitment of all involved stakeholders, including state and central government institutions developed during the years by the Arsi-Bale Rural Development Projects and further strengthened by AVCPO. In short, the project ownership guarantees multilevel commitment by all involved stakeholders (Biggeri et al., 2016).

4. Data and Methods

4.1. Data

The data were collected through a survey conducted in August-September 2014. The sample was selected according to a two-stage procedure:[11] first, selection of AVCPO and non-AVCPO cooperatives, and then random selection of 30-40 farmers within each AVCPO and non-AVCPO cooperative. Ten AVCPO cooperatives[12] were selected to cover different agro-ecological settings in view of a future scale-up and twelve suitable non-AVCPO cooperatives were identified as controls among the ones located far enough from treated cooperatives to mitigate spillover effects.

The final sample size after dropping incomplete questionnaires was 738 farmers, identified through a standard power analysis procedure (Biggeri et al., 2018), of which 253 treated farmers (34.3% of total) and 485 control farmers (65.7%) (Table 3). Treated farmers are members of an AVCPO cooperative who grow durum wheat and participate in at least one project activity. Control farmers are either members of a non-AVCPO cooperative or farmers members of an AVCPO cooperative who did not enroll in the project (i.e. no durum wheat, no AVCPO activities).[13]

<TABLE 3 AROUND HERE>

4.2. Output indicators

We consider three groups of indicators to represent the project's impacts on selected SDGs (see Table A1 in the Appendix for the definition of indicators and Table 4 for some summary statistics). The first group of indicators entails various SDG2 targets, namely hunger (SDG Target 2.1) malnutrition (SDG Target 2.2) and SHF productivity and incomes (SDG Target 2.3). Whenever appropriate these indicators are disaggregated in order to highlight the impacts on more vulnerable groups – e.g. children (SDG Target 2.2) – consistently with SDG2 target statements. This is why we selected a quite comprehensive set of SDG2 indicators (I.1–I.9). Food security is measured at the

[11] The AVCPO evaluation study was conceived as mixed-method study using both qualitative and quantitative approaches. The qualitative participatory methods were used to capture the perspectives of different stakeholders on the effectiveness of AVCPO and acquire the information needed to design the survey for the quantitative impact evaluation (Biggeri et al., 2016). In early 2014, 15 semi-structured interviews were conducted in Addis Ababa with international and federal stakeholders, while nine focus groups were conducted in the Bale Zone involving representatives of local governments, leaders of cooperatives and unions, and farmers.

[12] The project originally involved 15 cooperatives. Five of them left the project after few months of activity: two cooperatives dropped out because they were not able to keep with project workplan, while three other cooperatives were hit by weather shocks during at seed multiplication stage.

[13] Clearly, this raises an issue of self-selection into treatment. See section 4.3.1 for a discussion of how this issue has been addressed.

household level through the Household Food Insecurity Access Scale (HFIAS) that is an indicator of undernourishment (Coates et al., 2007) and the Household Dietary Diversity Score (HDDS) that is an indicator of malnourishment (Swindale and Bilinsky, 2006). We computed also a Child Dietary Diversity Score (CDDS) (WHO, 2008) for children below the age of six to monitor child malnutrition (SDG Target 2.2). The rationale of SDG Target 2.3 is that improving SHF yields and incomes is key to achieving food security. This is proxied by indicators I.7-I.9, that refer to the growth of cereal production gross value, the (logarithm of) return to family labor in agriculture and the share of cereals sold through the cooperative.[14]

As shown by the AVCPO theory of change (see section 2.3), the project might be able to impact also other household wellbeing dimensions such as education (SDG4). The magnitude and the sign of this impact is the resultant of two effects. On the one hand, the growth of household income can relax the household budget constraint inducing more investment in education. On the other hand, increased labor productivity might also increase the opportunity cost of time, including education time. This is why we consider enrollment (I.10a-c) as well as the time spent in education at school and at home (I.11a-c), both disaggregated by gender.

Institutional change plays a critical role in any IVCD project. This change aims at creating an environment enabling the empowerment of SHF at community level and connecting them to markets through farmer cooperatives. This is consistent with SDG16, specifically its Targets 16.6 and 16.7 that focus on the development of "effective, accountable and transparent institutions at all levels" and on strengthening "responsive, inclusive, participatory and representative decision-making at all levels", respectively. We evaluate such changes using two sets of indicators: (i) collective action at grassroot level focusing on cooperatives (I.12-I.14), as they are specific AVCPO targets, as well as collective action not related to cooperatives (I.15), which is a proxy for project spill-overs at local level (Schipmann and Qaim, 2010), and (ii) social capital strengthening focusing on "vertical" relationships, i.e. related to farmers involvement in the cooperatives (I.16-I.17), as well as "horizontal" relationships among the actors within communities, i.e. how do farmers perceive the quality of relations with their own peers (I.18-I.19).

<TABLE 4 AROUND HERE>

4.3. Econometric strategy

The econometric strategy mirrors the three research questions addressed by the study (see section 1), namely:

a) How effective is AVCPO as a whole in achieving the expected impacts on SDG 2, SDG4 and SDG16: in order to account for potential violations of the exclusion restriction assumption, the overall impact is estimated using (i) propensity score matching and instrumental variable analysis to manage pre-project unbalances of key variables, and (ii) a nonparametric estimator for the estimation of local average treatment effect with covariates (Frölich, 2007; Frölich and Melly, 2010);

[14] According to SDG Target 2.3 this can be pursued also "… through … markets and opportunities for value addition …". Therefore, linking SHF to higher value markets through the cooperatives, which is an AVCPO core objective, is a legitimate indicator.

b) Which AVCPO components, and combinations thereof, is more effective in achieving the expected impacts: a multi-valued treatment effect analysis (Cattaneo, 2010; Cattaneo et al., 2013) is used to assess the impact of each treatment on SDG 2, SDG4 and SDG16;
c) What is the role of collective action and social capital (SDG16) in initiating production for the market and participation in a value chain (Devaux et al., 2017) and eventually in determining SDG2 and SDG4: a causal mediation analysis is carried out according to the procedure suggested by Imai et al. (2010).

4.3.1. IV and non-parametric estimations of the AVCPO impact on SDGs

The program uptake is determined by the farmer's choice to participate which depends on observed and unobserved characteristics. Instrumental variables (IV) approaches are widely used to get unbiased estimates of programs based on the voluntary uptake of improved inputs, innovative contract farming schemes and other innovations (Bellemare, 2012; Yirga et al., 2016; Barrett et al., 2012).

Membership to an AVCPO cooperative can be considered a proxy of the intention-to-treat. We use it – i.e. a binary variable equal to one if the farmer is a member of a cooperative targeted by the project – as an instrument (Appendix 2.A). Being a member of an AVCPO cooperative is highly correlated with the probability of actually uptaking the program (the compliance rate is 66.7%). Vice versa, members of non-AVCPO cooperatives did not participate to project activities. In other words, the chosen instrument seems to be a strong instrument.[15] However, its validity is not directly testable: we can only defend the instrument validity by describing the evaluation setting. As shown by Biggeri et al. (2018), the assignment of the intention-to-treat can be clearly considered random and exogenous as it ultimately depends on the place of birth.[16]

We cannot exclude (and we cannot formally test) that the instrument could have influenced the outcomes via channels other than the decision of actually uptaking the program, therefore violating the exclusion restriction assumption. In order to test the sensitivity of our results to the violation of the instrument validity we use two strategies. The first is based on a two-step procedure where pre-treatment variables were used to perform a propensity score matching with caliper on the instrument (i.e. membership to AVCPO cooperative). With a small enough caliper (0.025), we obtain a sufficient reduction of pre-matching bias (Tables A2 and A3 in Appendix 3). Non-matched observations were dropped from the sample and then a standard IV estimation was conducted on the selected sub-sample. The second strategy is based on the work of Frölich (2007) and operationalized by Frölich and Melly (2010) who proposed a non-parametric approach to address the issue of a strong but potentially endogenous estimator. A local average treatment effect (LATE) is computed meeting the exclusion restriction by conditioning on the covariate matrix only (Appendix 2.B).

[15] This statement has been formally tested using the Anderson-Rubin test whose value (477.291; p-value = 0.000) shows that the instrument is indeed strong.

[16] There is only one cooperative in each *kebele* – the smallest administrative unit of Ethiopia, similar to a ward. In other words, living or not living in an AVCPO *kebele*, and therefore being or not a member of an AVCPO cooperative, is primarily determined by the place of birth (more than 98% of interviewees still live in the same *kebele* in which they were born). Consequently, from an individual point of view, the assignment of the intention to treat can be considered random.

4.3.2. Multi-valued treatment effect to disentangle the impact of AVCPO components on SDGs

AVCPO is a complex project where participants have the opportunity to be involved in a number of activities such as: participation to training sessions on durum wheat production and marketing; buying seeds of improved durum wheat varieties delivered by the Sinana Agricultural Research Center or by accredited seed-multiplier cooperatives; using cooperative facilities to store the harvest; using seed grading machines and other machineries provided by AVCPO to cooperatives; selling SHF durum wheat to pasta-making industries through AVCPO cooperatives.

This is an example of complex treatments where the treated units can potentially be involved in different activities and combinations thereof. Therefore, a multi-valued treatment affect analysis (Cattaneo, 2010; Cattaneo et al., 2013) is required in order to assess the contribution of the different components of the project to various SDGs. The rationale behind this approach is to adapt the standard binary potential outcome model to a multiple treatment scenario. The model does it by estimating a multi-valued propensity score where each unit has a specific probability of receiving a given treatment conditional to a vector of observed characteristics (Appendix 2.C). Finally, pairwise contrasts are computed comparing each pair of treatments to assess the treatment effects.

4.3.3. Causal mediation analysis of the effect of SDG16 on SDG2 and SDG4 outcomes

The AVCPO is built around the idea that a more structured collective action and a stronger social capital (SDG16) can be catalyzers of impact leading to improvements in terms of food security (SDG2) and education (SDG4). This hypothesis is tested through a causal mediation analysis (CMA) that analyzes the channels through which a treatment variable may affect an outcome variable by testing whether the impact is channeled through one or more mediators (Baron and Kenny, 1986; Imai et al., 2010). CMA yields three main outputs. The total effect of the treatment on the outcome is the average treatment effect (ATE). The ATE can be decomposed in a direct effect (ADE) and in an indirect causal mediation effect (ACME). The former is the share of the total effect not conveyed through the mediator while the latter is the share of ATE channeled through the mediator.

CMA is usually operationalized as a system of three linear equations where the outcome is regressed on the treatment, the outcome is regressed on both the treatment and the mediator, and the mediator is regressed on the treatment (Appendix 2.D). It is possible to identify robust causal linkages as long as the outcome and the mediator are independent of the participation to the treatment after conditioning on pre-treatment observed characteristics (Imai et al., 2010). However, the assignment to treatment (i.e. participation to AVCPO) is not random. This is likely to lead to selection bias as the characteristics between treated and control units may systematically differ. We manage this issue by using in CMA the same set of observable covariates used in the previous steps of the analysis as they proved to be effective in reducing the bias due to pre-matching unbalances between treated and control group (Table A2 in Appendix 3).

5. Results

5.1. The AVCPO impact on SDG2, SDG4 and SDG16

The causal impacts on food security (SDG2), education (SDG4) and collective action and social capital (SDG16) has been estimated through IV estimation on a sub-sample including only

the nearest neighbor matching observations.[17] The selected set of SDG indicators are regressed on a common set of controls including demographic variables, household and agricultural assets, agricultural production variables, agro-ecological characteristics, shocks and treatment dummy (Appendix 3). However, in Tables 5 to 7 show we report only the results for the treatment coefficients in the case of SDG2 and SDG4 indicators and marginal effects at the sample mean for SDG16 indicators.

The AVCPO has a clear positive and significant impact on all SDG2 targets with the exception of HDDS (Table 5). Production-related effects are remarkable: the growth of cereal production value is 86% (p<0.01) over the analyzed period, the return to family labor increases by almost 40%[18] and the share of cereals sold through the cooperative by 17%.

The AVCPO impacts on food security outcomes among the treated households are also important. The project successfully reduces the frequency of eating smaller and fewer meals by 26% and 26%, respectively, and the overall household's food insecurity score by 56%. However, we do not find significant evidence about AVCPO effects on the HDDS. Finally, the variables representing the quality of children diet are non-significant.[19]

The AVCPO impact on the SDG4 (Table 6) shows mixed results. Interestingly the project has a positive and statistically significant impact on the enrolment ratio for girls in schooling age (8% higher than in control group, although at p<0.1). The effect on time devoted to education further supports this result: girls living in treated households spend significantly more time at school and studying at home than their control peers – on average, 7 hours more per week. These are important results for reducing the gender disparities in education evoked by the SDG4. The results for boys – and for children in general – are statistically not significant.

Table 7 shows the AVCPO impacts on SDG16 outcomes. The marginal effects calculated at the sample mean are positive and highly statistically significant (p<0.01) for almost all the variables related to the engagement in collective action. The project increases the probability of participation in the activities of cooperatives and other formal activities by 12% to 19% compared to controls. The AVCPO effect on social capital are mixed.[20] Results show that participation to the AVCPO increases the likelihood of having better horizontal relationships: the satisfaction of being farmer on average is about 17% higher (p<0.01) and feeling respected within the community is 9% higher (p<0.1). We do not find significant impacts on the vertical relationships.

<TABLE 5 TO TABLE 7 ABOUT HERE >

Finally, Tables 8 to 10 show the non-parametric LATE estimates (Frölich, 2007). The results are largely in line with IV estimates. They confirm the AVCPO has a positive and significant impact on the considered SDGs, with the exception of the girls' enrolment ratio and feeling

[17] The final sample after dropping the non-matched observations is composed of 603 units: 161 treated units and 442 controls.

[18] The exponentiated coefficient for the treatment $e^{1.37}$ shows that treated farmers have 39.4% higher returns per unit of labor than the control peers, everything else constant.

[19] We are not able to say whether the lack of significance of diet-related variables is due to a true ineffectiveness of AVCPO or rather to the short time occurring between the beginning of the project and the survey time (i.e. three years) that does not allow to capture the change in the quality of the diet, which generally needs a longer time to materialize.

[20] To address possible biases in farmers' responses, we perform the estimates for social capital-related outcomes on a reduced sample of households excluding the farmers who reported the maximum score in both 2010 and 2013.

respected within the community that turned from being marginally significant to still positive but no longer significant.

<TABLE 8 TO TABLE 10 ABOUT HERE >

5.2. The impact of AVCPO components on SDG2, SDG4 and SDG16

We use a multi-valued treatment effect analysis to estimate the impacts of AVCPO components on SDGs. Figures 2 to 4 show the results of the analysis for selected SDG indicators as "pairwise contrasts", i.e. comparing a pair of treatments at time (Appendix 2.C). The estimates are considered statistically significant at the 0.05 level if the associated 95% confidence interval does not cross the zero line.

Figure 2 panel a and b show that the estimated average treatment effect of switching from t = 0 (controls) to any of the treatment class t = 1, …, 4 on production-related outcomes (SDG2) are positive and statistically different from zero. Furthermore, households involved in a combined treatment (t = 2, 3, 4) achieve better results vis-à-vis controls (t = 0) than those uptaking only the training (t = 1) and, by and large, the more the number of combined treatments the more positive the impact. In general, comparing combined treatments (t = 2, 3, 4) to training only (t = 1) result in statistically not significant impacts. Figure 2 panels c and d show the results for the food security indicators. Almost all treatment levels (t = 2, 3, 4) are effective in reducing undernourishment (HFIAS) vis-à-vis controls (t = 0). Generally, in this case also it is confirmed that households combining the training with the other activities (t = 2, 3) show better results compared to households participating only in training (t = 1). The pattern for dietary diversity (HDDS) is rather complex and no clear trend emerges (Figure 2 panel d). Nevertheless, considering only the pairwise contrasts that are statistically significant we can conclude that households engaging in all AVCPO components (t = 4) have a better diet compared to households receiving other or no treatments.

Figure 3 shows the AVCPO effects on the SDG4 that appear to be specular between boys (panel a) and girls (panel b). Girls in households engaging in multiple treatments (t = 2, 3, 4) generally experience an increase in the time devoted to education though this is statistically significant at 0.05 level only when compared with training (t = 1). Perhaps this is a consequence of relaxing the household's budget constraint resulting from the income increase due to the involvement in the durum wheat value chain. The opposite is true for boys, which probably reflects the increased demand for family labor resulting from the household involvement in the durum wheat value chain, thus shifting boy time from education to labor.

Pairwise comparisons of the effects of AVCPO components on SDG16 (Figure 4) show that the impact of various treatments are generally more relevant for collective action variables (panel a and b) than social capital variables (panel c and d). Specifically, households involved in more complex treatments (t = 3 and t = 4) are more engaged in coop activities (panel a) and are more trustful towards the cooperative management than household in the control group (panel c).[21] This result, confirmed also in focus groups with farmers, highlights the important role of selling durum wheat through the cooperative as an incentive to participate in the activities of the cooperatives. The same

[21] In the case of participating in cooperative activities this is also true comparing more complex treatments (t = 3, 4) to a less complex combination (t = 2).

can be said, to a lesser extent, for trust with reference to training only (t = 1). Less clear is the impact of various treatments on the participation in social activities such as religious organizations, NGOs, self-help groups, etc. (panel b). Finally, Figure 4 panel d shows that participating in any of the activity has also a large and positive impact on farmers feeling satisfied about their own job vis-á-vis controls.

<FIGURE 2 TO 4 ABOUT HERE >

5.3. Causal mediation analysis

The AVCPO theory of change assumes that the project's effect on SDG2 and SDG4 could be mediated through SDG16: the foreseen institutional changes – i.e. increased collective action and social capital strengthening – are instrumental to the achievement of food security and better education (Figure 5).

< FIGURE 5 ABOUT HERE>

The key hypothesis in causal mediation analysis is that the mediator is an important pathway through which the treatment (in our case the AVCPO) is linked to the outcomes (in our case SDG2 and SD4 indicators). Mediation happens when the treatment variable is significantly related with the mediator and the mediator impacts significantly the outcome (Appendix 2.D). This pathway is captured by the so-called average causal mediation effect (ACME). Other channels linking the treatment to outcomes are captured by the average direct effect (ADE). The sum of ACME and ADE totals the average treatment effect (ATE). ACME is relevant only if the ATE is statistically significant.

In order to provide an overview of the mechanisms linking the treatment (AVCPO) to the outcomes (SDG2 and SDG4) we summarize the most important results in Table 11 reporting only the signs and significance levels of the ACME and ADE, while statistically insignificant ATEs are shaded in grey.[22]

<TABLE 11 ABOUT HERE>

The ATEs are generally consistent with the results of the previous analyses, i.e. among SDG2 indicators are positively and significantly affected by the AVCPO and the SDG4 indicators are positively affected only for girls.

The causal mediation analysis shows that SDG16 mediators are able to channel AVCPO effects only to SDG2. Specifically, the project's ACMEs on SDG2 production-related indicators are significant only as far as collective action variables (i.e. participation in activities and meetings) are included as mediators. These channels explain around 5% of the total AVCPO impacts on return to family labor and 2% of the project's impacts on sales of durum wheat through the cooperative (Table A.4 in Appendix 3). This indicates that cooperative activities and formal meetings are

[22] The full list of estimates including the magnitude of coefficients and their significance along with the ATE is reported in Appendix 3, Tables A4 and A5. However, the results should be interpreted with a word of caution as the estimated effect of the mediators and the mediated impact are not experimentally identified.

strategic information exchange platforms where stakeholders share best agricultural practices and farming experiences that effectively set the ground for social networks development and support farming and agricultural marketing. In addition, the participation in coop activities channel is also effective in explaining part of the impact on HFIAS (10% of ATE, $p < 0.1$). Conversely, AVCPO impacts on SDG2 are generally not channeled through social capital, except in the case of satisfaction of being farmer, which mediates 5% of ATE of the change in production value (Table A.5).

Generally, SDG16 variables are not significant as mediators of AVCPO to education. Only the participation in other formal meetings such as field days, demo trials, etc. has a role mediating about 14% ($p = 0.1$) of the ATE on the girls' time spent in education (Table A.4).

6. Conclusions

Understanding how different SDGs interact is one of the most important topics in the Agenda 2030 related research (Nilsson et al., 2016; Barbier and Burgess, 2019). However, the interactions between the SDGs and their targets are still largely unexplored by the empirical literature (UN, 2019). This paper does it analyzing the specific case of the AVCPO, a multiple-actor, multiple-component inclusive value chain development project. As such it is a good case study to assess co-benefits and synergies between and within three SDGs, namely zero hunger (SDG2), quality education (SDG4) and peace, justice and strong institutions (SDG16). In doing this, the study also evaluates the effectiveness of IVCD as a strategy to improve the livelihood of SHF and contributing to the overall development in agriculture-based countries (Devaux et al., 2017; de Janvry and Sadoulet, 2019).

The paper's contribution to the existing literature is twofold: in terms of contents, it provides insights on how much effective an IVCD project is in achieving the above-mentioned SDGs and highlights which project components are more effective in promoting these achievements; from the methodological viewpoint it shows how such an assessment could be carried out, addressing the validity issues (Bellemare, 2015; de Janvry and Sadoulet, 2019) that usually have to be tackled in order to conduct rigorous impact evaluations in the specific case of complex, integrated interventions such as IVCD.

The results show that the AVCPO aggregate impact is positive and highly significant on most of the considered outcomes, namely better food intake and higher SFH farm revenue but it has no significant effect on diet diversification (SDG2); better education for girls but not for boys (SDG4); and stronger collective action and partially social capital improvement (SDG16).[23] This is a further micro-evidence that well designed and implemented value chain development interventions can improve the standards of living of SHF (Cavatassi et al., 2011; Stür et al., 2013) and indirectly concurs to the well-known result that agricultural growth is highly effective in fostering overall development (Christiaensen et al., 2011; Ivanic and Martin, 2018; Ligon and Sadoulet, 2018). The policy implication of this result is that IVCD is indeed an effective approach to improve the livelihood of SHF and a successful strategy to achieve multiple SDG dimensions.

[23] Social capital is significant only as far as the reputation of beneficiaries within the community – proxied by feeling satisfied of being farmer and feeling respected within the community – increases. Vice versa, other dimensions of social capital – proxied by building trust and having more voice in the cooperatives – are not statistically significant. This is probably so because social capital requires time to be developed (Bowles and Gintis, 2002) while our study covers a time horizon of only three years.

The analysis of the effects of project components shows mixed results. Training is an important determinant of the improvement of all considered SDG target indicators but trust. In order to have a positive impact on trust, training needs to be coupled with other AVCPO component such as selling durum wheat through the cooperatives and using storage facilities. Moreover, combined treatments – e.g. training plus provision of storage facilities and the opportunity to sell durum wheat through the cooperatives – generate larger impacts than stand-alone interventions – e.g. training only or providing storage facilities only. This is consistent with expectations as well as with the results of the scanty literature on this topic (Banerjee et al., 2015; Pace et al., 2017). The policy implication is that implementing integrated interventions is better than implementing separately stand-alone interventions. This is true for each SDG and it is especially true if the objective is to pursue more than one SDG at the same time. Furthermore, the specific policy implication for the design of agricultural development strategies is that removing constraints – e.g. providing high quality seeds, building human capital through training – should go hand in hand with inclusive value chain development – e.g. offering technical innovation sufficiently upstream in the value chain as well as institutional innovations (price incentives, contracts, revitalizing the role of cooperative) to promote an effective participation of SHF in the value chain (Devaux et al., 2017; de Janvry and Sadoulet, 2019).

The causal mediation analysis shows that positive socio-institutional changes (SDG16) are important channels that favor food security improvement (SDG2) but only to a lesser extent better education (SDG4). Among the various socio-institutional dimensions, collective action results more effective than social capital variables to enhance the quantitative dimension of food insecurity (Target 2.1) as well as production-related dimensions of SDG2 (Target 2.3), while it is confirmed the weakly positive impact on girl education only (Target 4.1). This confirms the importance of collective action already emphasized in the literature with specific reference to SHF market access (Bernard and Spielman, 2009; Markelova et al., 2009; Shiferaw et al., 2011). The policy implication of these results is that in designing interventions for food security (and education) it is needed to include also actions specifically aiming at creating a conducive institutional environment. This institutional change is an important channel of transmission that plays a synergistic effect strengthening the direct effect of specific food security (and education) enhancing activities.

From the methodological viewpoint, the most important message from this study is that there is no silver bullet to address all the problems posed by impact evaluation of intervention such as AVCPO. The researcher in the choice of the most suitable approach is guided by the specific research questions, the intervention characteristics and limitations imposed by the quality of available data. In short, it is suggested an eclectic, pragmatic approach selecting the appropriate method from the whole battery of methods in the analysist's tool-kit in order to achieve a high level of internal and external validity.

In cases where randomization is not an available option, such as in the case of the AVCPO, a mix of instrumental variable econometric technique to get rid of endogeneity problems coupled with propensity score matching to identify good counterfactuals can be used. Furthermore, in order to single out the impact of various components of a complex project on multiple outcomes a multi-valued treatment effect analysis can be adopted. Finally, a causal mediation analysis can be used to explore the role played by various channels influencing the ultimate outcomes of a given intervention. Internal validity is ensured not only by designing an appropriate data analysis strategy and choosing the appropriate techniques to get rid of statistical problems, but also by the convergent validity of results obtained using different approaches and by the internal consistency of our results – i.e. combined treatments show a higher impact of stand-alone treatments.

Unfortunately, the same cannot be said for external validity. In fact, the area of intervention (Bale Zone in Oromia state) shows quite peculiar features even with reference to the Ethiopian context: relatively larger than average size farms, specific agro-ecological conditions favoring wheat crops, relatively good research centers and extension service (improved by a previous project), etc. All these features, while creating opportunities for local producers, mean that caution is required in extrapolating the AVCPO results to other Ethiopian regions or to other agrifood products (Benfica and Thurlow, 2017). More generally, the issue of external validity is a yet unresolved problem (Devaux et al., 2017) and more research is needed to capture heterogeneity and scale-up single project results. This is even more compelling in assessing the impact of programs/projects on the SDGs and critically calls for a renewed effort to test suitable methods to evaluate multiple outcomes and better understand their interactions, processes and dynamics. This challenge is critical to make the development debate consistent with the inclusive and multi-dimensional sustainable development framework of the UN 2030 Agenda (Biggeri et al., 2019).

Appendix 1

Table A.1. Indicator description

Indicators	Type	Formula/Description	Notes
SDG2 indicators			
Growth in cereal production value (%)[a]	Continuous	$\frac{\text{Cereal production value 2013} - \text{Cereal production value 2010}}{\text{Cereal production value (2013)}}$	
Ln Return to family labor (Ln ETB)	Continuous	$\ln\left(\frac{\text{Cereal production net value}}{\text{\% of cereal plot area} * \text{equivalent family labor unit during main crop season}}\right)$	1 eq working unit = 40 h/week
Share of cereal production sold through the cooperative (%)	Continuous	$\frac{\text{total value of cereals sold through cooperative}}{\text{total gross value of cereal production}}$	
Household Food Insecurity Access Scale (HFIAS)	Categorical	Sum of the frequency of occurrence during the four weeks before the interview of the "eating fewer meals" and/or "eating smaller meals" conditions	2 = both 1 = one of the two 0 = none
HFIAS - Eating fewer meals	Categorical	Frequency of occurrence during the four weeks before the interview of the "eating fewer meals" condition	2 = often 1 = sometimes 0 = rarely
HFIAS - Eating smaller meals	Categorical	Frequency of occurrence during the four weeks before the interview of the "eating smaller meals" condition	2 = often 1 = sometimes 0 = rarely
Household Dietary Diversity Score (HDDS)	Count	Number of food items consumed by the household over the 24 hours before the interview	Min = 1 Max = 16
Children Dietary Diversity Score (CDDS) – Low diversity index	Dummy	Children consuming less of four food groups out of eight food groups	1 = yes 0 = no
Children Dietary Diversity Score (CDDS) - Ratio	Continuous	$\left(\frac{\text{n° of food groups consumed by children under 5 y. o.}}{\text{n° of total food groups potentially consumable}}\right)$	Min = 1 Max = 8
SDG4 indicators			
Enrollment ratio - Boys	Continuous	$\frac{\text{Number of boys } (6-18 \text{ y. o.}) \text{ enrolled in school}}{\text{Total number of boys } (6-18 \text{ y. o.}) \text{ in the household}}$	Min = 0 Max = 1
Enrollment ratio - Girls	Continuous	$\frac{\text{Number of girls } (6-18 \text{ y. o.}) \text{ enrolled in school}}{\text{Total number of girls } (6-18 \text{ y. o.}) \text{ in the household}}$	Min = 0 Max = 1

Enrollment ratio - All children	Continuous	$\frac{\text{Number of children } (6-18 \text{ y.o.}) \text{ enrolled in school}}{\text{Total number of children } (6-18 \text{ y.o.}) \text{ in the household}}$	Min = 0 Max = 1
Time spent in education - Boys	Continuous	Average amount of hours per week spent in education (school time + homework time) by boys 6-18 y.o.	
Time spent in education - Girls	Continuous	Average amount of hours per week spent in education (school time + homework time) by girls 6-18 y.o.	
Time spent in education - All children	Continuous	Average amount of hours per week spent in education (school time + homework time) by children 6-18 y.o.	
SDG16 indicators			
Collective Action			
Participation in cooperative activities/other formal meetings[b]	Dummy	Average frequency of participation in cooperative activities or other formal meetings over the 12 months before the interview	1 = more than once a month 0 = less than once a month
Participation in cooperative activities	Dummy	Average frequency of participation in cooperative activities over the 12 months before the interview	1 = more than once a month 0 = less than once a month
Participation in other formal meetings[b]	Dummy	Average frequency of participation in formal meetings other than cooperative's over the 12 months before the interview	1 = more than once a month 0 = less than once a month
Participation in other social activities[a,c]	Dummy	Positive change in the number of social organization membership between 2010 and 2013	1= yes 0= no
Social capital			
Have a say in cooperative decisions[a,d]	Dummy	Positive change in the capacity to express views in cooperative decision-making between 2010 and 2013: switch from "*never or sometimes*" to "*often or always*"	1= yes 0= no
Trust in cooperative management[a,d]	Dummy	Positive change in being trustful in cooperative management between 2010 and 2013: switch from "*never or sometimes*" to "*often or always*"	1= yes 0= no
Satisfaction of being farmer[a,d]	Dummy	Positive change in feeling satisfied of being farmer between 2010 and 2013: switch from "*not at all or little satisfied*" to "*rather or completely*"	1= yes 0= no
Respect within the community[a,d]	Dummy	Positive change in feeling respected within the community between 2010 and 2013: switch from "*not at all or little respected*" to "*rather or completely respected*"	1= yes 0= no

[a] Farmers retrospectively reported information for 2010; [b] Other formal meetings include field days, crop plot visits, demo trials, etc.; [c] Other social activities include memberships in: religious organizations, producer groups, NGOs, self-help groups, savings or credit groups, village committees; [d] Evaluation self-reported by the farmers using a 4-point Likert scale for both 2010 and 2013.

Appendix 2

A. The IV approach

A standard instrumental variable (IV) approach in an impact evaluation setting can be formalized as follows:

$$Y = D\beta + \mathbf{X}\gamma + e \quad (1a)$$

$$D = Z\pi + v \quad (1b)$$

where Y is the outcome variable, D is the (potentially endogenous) treatment variable, $\mathbf{X}$ is a set of covariates and Z is an instrument that is a variable that determines the treatment but not directly the outcome Y. Following Angrist and Imbens (1995), a two steps procedure can lead to an unbiased estimate of β. As long as the instrument Z is strong and relevant (i.e. correlated with D through π) and valid (i.e. no direct effect of Z on Y), we can use OLS to estimate the coefficients in equation (1b) and then use the fitted value of D to estimate the coefficients in equation (1a) including β.

This model can be easily adapted to the case where the dependent variable is binary. An IV probit model can be formalized as an equation where we have a binary dependent variable Y whose observed value can be either 1 or 0.

$$Y = \begin{cases} 0 & 0 \leq p \leq 1 \\ 1 & 1 - p \end{cases} \quad (1c)$$

$$Y = I(D\beta + \boldsymbol{X}\gamma + \varepsilon) \quad (1d)$$

$$D = Z\pi + \tau \quad (1e)$$

that yields the probability of Y being 0 or 1. $I(\cdot)$ is the probit function and Z is an exogenous and strong IV. The model is estimated by exploiting the flexibility of the Stata routine *cmp* developed by Roodman (2011) that handles the simultaneous presence of binary outcome variables (Y), binary endogenous variables (D) and binary instrument (Z) using a linear model in the first stage and a probit in the second stage (Angrist and Pischke, 2009).

B. The non-parametric approach

The non-parametric local average treatment effect (LATE) approach is a way to deal with a strong but potentially endogenous instrument Z. Frölich (2007) proposed a fully non-parametric estimator for estimating LATE with covariates. The instrument is supposed to fulfil the exclusion restriction condition conditioning only on a set of covariates $\mathbf{X}$.

Let $\bar{\beta}$ be the LATE estimate. Considering the conditional mean functions:

$$m_z(x) = E[Y|X = x;\ Z = z] \quad (2a)$$

$$\mu_z(x) = E[D|X = x; Z = z] \quad (2b)$$

$\bar{\beta}$ can be estimated as the ratio between two matching indicators as follows:

$$\bar{\beta} = \frac{\sum_i m_1(X_i) - m_0(X_i)}{\sum_i \mu_1(X_i) - \mu_0(X_i)}. \quad (2c)$$

We use to Stata *nplate* command coded by Frölich and Melly (2010) to implement this procedure.

C. The multi-valued treatment approach

A multi-valued treatment model is used to estimate an impact when the treatment is not a binary variable (0/1) as for complex treatments. In this case the treated units can potentially be involved in several treatments. To estimate multi-valued treatment effects, we use the Efficient Influence Function (EIF) semi-parametric estimator proposed by Cattaneo (2010) and operationalized by Cattaneo et al. (2013).

The rationale of this approach is to adapt the binary outcome model to a multiple treatment scenario. As long as we have multiple treatment we can also have multiple potential outcomes for each unit. Let y_i be the generic outcome for the i-th unit and J the number of potential treatments D, we have:

$$y_i = d_i(0)\, y_i(0) + d_i(1)\, y_i(1) + \cdots + d_i(J)\, y_i(J). \quad (3a)$$

Let be $d(k)$ the only observable outcome out of the $J+1$ potential outcomes. The analysis of the impacts of the various treatments rests on our ability to impute a value to all other $d(J) \neq d(k)$.

The model does it by estimating a multi-valued propensity score, with p_j being the probability of receiving a specific treatment, given a vector of observed characteristics **X**:

$$p(x) = \{p_0(x)\, , p_1(x), \ldots , p_j(x)\}. \quad (3b)$$

The parameters to be estimated are the average potential outcome μ_j (equation 3c below) and the average treatment effect as a difference of the mean expected outcome in case of treatment k compared to a benchmark treatment j (equation 3d):

$$\mu_j = E\{y(j)\} \quad (3c)$$

$$ATE = E[y(j) - y(k)] = E[y(j)] - E[y(k)]. \quad (3d)$$

Pairwise contrasts, that is the difference between each pair of treatment effects, are computed between using STATA's *pwcompare* command, which performs Wald tests using linear combinations of marginal linear predictions and uses the delta method to estimate the variance.

D. The Causal Mediation Analysis approach

A Causal Mediation Analysis (CMA) can be easily formalized following Imai et al. (2010) as a system of three equations as follows:

$$Y = i_1 + cW + d\mathbf{X} + e_1 \quad (4a)$$

$$Y = i_2 + c'W + b_1 M_1 + d\mathbf{X} + e_2 \quad (4b)$$

$$M_1 = i_3 + a_1 W + d\mathbf{X} + e_3 \quad (4c)$$

where Y are the outcome variables (i.e. SDG2 and SDG4 indicators, in our study), W is the treatment (i.e. participation in AVCPO activities), **X** is a vector of covariates, M_1 is the mediator (i.e. an SDG16-related variable in our study), i_1, i_2 and i_3 are the intercepts and e_1, e_2 and e_3 are the error terms.

The modelling objective is to get unbiased estimates of the coefficients a_1, b_1 and c': they are the regression coefficients needed to identify the relation between Y, M and W.

We can identify a mediating effect as long as:

1. a_1 in (4c) is significantly different from zero, i.e. there is a significant linear relationship between W and M_1;
2. c in (4a) is significantly different from zero, i.e., there is a significant linear relationship between W and Y;
3. b_1 in (4b) is significantly different from zero, i.e., M_1 is a meaningful determinant of the outcome variable Y;
4. c' in (4b) is smaller than c as identified in (4a), that is the direct effect (i.e. the effect not transmitted through the mediator) must be smaller (or equal) to the total effect (i.e. the ATE).

To sum up, in the case a_1 or b_1 are not significantly different from zero, it is not possible to identify a mediation, that is the whole impact of W on Y is through channels other than the mediator. Conversely, when the four above-mentioned conditions hold, we can identify a full or partial mediation depending on the relative magnitude of the coefficients.

Appendix 3

Table A2. Pre- and post-matching differences between farmers from AVCPO and non-AVCPO cooperatives

Variable (pre-AVCPO)	Pre-matching means				Post-matching means			
	(a) AVCPO Coop	(b) Non-AVCPO Coop	(a) – (b)		(c) AVCPO Coop	(d) Non-AVCPO Coop	(c) – (d)	
Household Asset								
Value of owned livestock (ETB)	55,267	56,092	-825		54,791	53,573	1,218	
Value of agricultural assets (ETB)	2,829	2,656	173		3,113	2,950	163	*
Value of HH productive plants (ETB)	4,957	3,241	1,716	**	3,341	3,901	-560	
Farm size (ha)	3.95	3.5	0.45	**	3.75	3.61	0.14	
= 1 HH owned a horse kart	0.13	0.15	-0.02		0.15	0.14	0.01	
= 1 HH owned at least 1 mobile	0.33	0.32	0.01		0.33	0.33	0	
= 1 HH owned at least 1 radio	0.41	0.41	0		0.42	0.4	0.02	
= 1 the dwelling has a roof in iron	0.75	0.63	0.12	***	0.67	0.69	-0.02	
= 1 HH has access to piped water	0.40	0.34	0.06	*	0.4	0.4	0	
Agro-ecological Characteristics								
= 1 the farm experienced flood	0.30	0.43	-0.13	***	0.4	0.4	0.01	
= 1 the farm experienced a drought	0.06	0.07	-0.01		0.06	0.06	0	
= 1 the farm experienced frost	0.08	0.13	-0.05	**	0.1	0.1	0	
Bread wheat yields (q/ha)	28.87	26.43	2.44	*	25.61	25.38	0.23	
Share of land cropped with cereal	0.84	0.82	0.02		0.83	0.85	-0.01	
Household Characteristics								
Number of adults equivalent	5.85	5.39	0.46	**	5.5	5.65	-0.15	
= 1 HH head is muslim	0.64	0.45	0.19	**	0.54	0.57	-0.02	
= 1 HH head is a man	0.96	0.95	0.01		0.96	0.96	0	
Age of HH head	41.79	44.16	-2.37	*	42.96	42.89	0.07	
Year of education of HH head	5.56	5.32	0.24		5.4	5.42	-0.02	
Infrastructure								
Dist. from coop office (in min)	13.52	14.5	-0.98	*	14.24	13.9	0.34	
Dist. from mobile network (in min)	3.42	4.7	-1.28		4.07	3.97	0.1	
Dist. from health service (in min)	24.67	21.52	3.15	*	22.07	22.37	-0.3	

* p <0.1, ** p<0.05, ***p<0.001.

Source: Biggeri et al. (2018).

Table A3. Matching quality statistics

Sample	Pseudo R2	LR chi2	Mean stand. bias	Median stand. bias	Rubin's B	Rubin's R	% Variance
Before matching	0.10	101.86	12.4	10.5	77.3	0.92	33
After matching	0.01	6.11	3.3	3.3	22.1	1.18	20

Source: Biggeri et al. (2018).

Table A.4. Causal Mediation Analysis: OLS estimates of ACME, ADE, ATE of SDG 16 (collective action) on selected SDG2 and SDG4 indicators

		[I.12] Participation in cooperative activities/ other formal meetings					[I.13] Participation in activities of cooperatives					[I.14] Participation in other formal meetings					[I.15] Participation in other social activities				
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.7] Growth of cereal production value	ACME	-0.01	-0.03	0.00	-0.90		-0.01	-0.04	0.01	-0.77		-0.01	-0.03	0.01	-0.84		-0.01	-0.03	0.00	-0.72	
	ADE	0.44	0.31	0.54	7.53	***	0.44	0.31	0.54	7.38	***	0.44	0.31	0.54	7.47	***	0.44	0.31	0.54	7.45	***
	ATE	0.43	0.31	0.52	8.07	***	0.43	0.31	0.52	8.02	***	0.43	0.31	0.52	8.11	***	0.43	0.31	0.52	8.04	***
	% Mediated	-0.02	-0.03	-0.02			-0.02	-0.03	-0.02			-0.02	-0.02	-0.01			-0.02	-0.02	-0.01		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.8] Ln Return to family labor	ACME	0.03	0.01	0.06	2.43	**	0.03	0.00	0.05	2.30	**	0.02	-0.01	0.04	1.53		0.01	-0.01	0.03	1.06	
	ADE	0.71	0.48	0.90	6.65	***	0.72	0.49	0.91	6.68	***	0.73	0.50	0.92	6.76	***	0.22	-0.02	0.42	1.94	*
	ATE	0.75	0.51	0.92	7.18	***	0.75	0.51	0.92	7.11	***	0.75	0.51	0.92	7.12	***	0.23	-0.02	0.44	1.93	*
	% Mediated	0.05	0.04	0.07			0.04	0.03	0.06			0.02	0.02	0.04			0.04	-1.54	0.12		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.9] Share of cereal production sold through cooperatives	ACME	0.00	0.00	0.00	2.52	**	0.00	0.00	0.00	3.06	***	0.00	0.00	0.00	0.06		0.00	0.00	0.00	1.14	
	ADE	0.16	0.13	0.18	11.82	***	0.16	0.13	0.18	11.76	***	0.16	0.13	0.19	12.05	***	0.16	0.13	0.19	11.85	***
	ATE	0.16	0.13	0.19	12.00	***	0.16	0.13	0.19	11.88	***	0.16	0.13	0.19	12.34	***	0.16	0.13	0.18	12.26	***
	% Mediated	0.01	0.01	0.02			0.02	0.02	0.02			0.00	0.00	0.00			0.01	0.01	0.01		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.1] HFIAS	ACME	-0.03	-0.06	0.00	-1.72	*	-0.03	-0.08	0.00	-1.54		-0.03	-0.06	-0.01	-1.76	*	-0.01	-0.03	0.00	-0.68	
	ADE	-0.24	-0.37	-0.14	-4.01	***	-0.24	-0.37	-0.13	-3.85	***	-0.24	-0.37	-0.13	-3.95	***	-0.26	-0.40	-0.15	-4.24	***
	ATE	-0.27	-0.40	-0.17	-4.54	***	-0.27	-0.41	-0.17	-4.49	***	-0.27	-0.40	-0.17	-4.56	***	-0.27	-0.40	-0.17	-4.52	***
	% Mediated	0.10	0.06	0.15			0.11	0.07	0.17			0.10	0.06	0.15			0.02	0.01	0.03		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.2] HFIAS - Eating smaller meals)	ACME	-0.01	-0.03	0.00	-1.72	*	-0.01	-0.03	0.00	-1.64		-0.01	-0.03	0.00	-1.77	*	0.00	-0.01	0.00	-0.77	
	ADE	-0.13	-0.19	-0.08	-4.53	***	-0.13	-0.19	-0.08	-4.47	***	-0.13	-0.19	-0.08	-4.47	***	-0.14	-0.20	-0.09	-4.82	***
	ATE	-0.14	-0.20	-0.10	-5.11	***	-0.14	-0.21	-0.10	-5.04	***	-0.14	-0.20	-0.09	-5.14	***	-0.14	-0.20	-0.09	-5.11	***
	% Mediated	0.10	0.07	0.14			0.10	0.07	0.14			0.10	0.07	0.14			0.02	0.01	0.03		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.3] HFIAS - Eating fewer meals	ACME	-0.01	-0.03	0.00	-1.62		-0.01	-0.03	0.00	-1.57		-0.01	-0.03	0.00	-1.66	*	0.00	-0.01	0.00	-0.61	
	ADE	-0.12	-0.18	-0.07	-4.29	***	-0.12	-0.18	-0.07	-4.22	***	-0.12	-0.18	-0.07	-4.24	***	-0.13	-0.19	-0.08	-4.58	***
	ATE	-0.13	-0.20	-0.09	-4.81	***	-0.13	-0.20	-0.09	-4.74	***	-0.13	-0.20	-0.09	-4.83	***	-0.13	-0.20	-0.09	-4.82	***
	% Mediated	0.09	0.06	0.14			0.10	0.06	0.14			0.09	0.06	0.14			0.02	0.01	0.02		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.4] HDDS	ACME	0.01	-0.01	0.03	0.88		0.01	-0.02	0.04	0.69		0.01	-0.01	0.03	0.99		0.00	-0.03	0.02	0.04	
	ADE	0.02	-0.30	0.28	0.13		0.02	-0.30	0.28	0.14		0.02	-0.31	0.28	0.11		0.03	-0.30	0.30	0.18	
	ATE	0.03	-0.29	0.28	0.20		0.03	-0.29	0.28	0.21		0.03	-0.29	0.28	0.20		0.03	-0.29	0.28	0.19	
	% Mediated	0.04	-0.26	0.83			0.04	-0.28	0.71			0.05	-0.33	1.26			0.00	-0.02	0.05		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.5] CDDS – Low dietary index	ACME	0.00	-0.02	0.00	-0.56		0.00	-0.02	0.00	-0.56		0.00	-0.02	0.01	-0.49		-0.01	-0.03	0.01	-0.93	
	ADE	-0.01	-0.12	0.09	-0.12		-0.01	-0.12	0.09	-0.12		-0.01	-0.12	0.09	-0.12		0.00	-0.11	0.09	-0.03	
	ATE	-0.01	-0.12	0.08	-0.19		-0.01	-0.12	0.08	-0.19		-0.01	-0.12	0.08	-0.19		-0.01	-0.12	0.08	-0.20	
	% Mediated	-0.04	-1.38	0.27			-0.04	-1.38	0.27			-0.05	-0.96	0.28			-0.12	-3.28	0.68		

		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.10b] Enrollment ratio - Girls	ACME	0.00	-0.01	0.01	0.46		0.00	-0.01	0.01	0.46		0.00	0.00	0.01	0.94		0.00	-0.01	0.00	0.43	
	ADE	0.05	-0.01	0.09	1.93	*	0.05	-0.01	0.09	1.93	*	0.04	-0.01	0.09	1.91	*	0.05	0.00	0.09	1.99	**
	ATE	0.05	0.00	0.09	2.07	**	0.05	0.00	0.09	2.07	**	0.05	0.00	0.09	2.06	**	0.05	0.00	0.09	2.10	**
	% Mediated	0.03	-0.85	0.11			0.03	-0.85	0.11			0.05	-1.61	0.22			0.02	-0.77	0.08		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I11.b] Time spent in education - Girls	ACME	0.04	-0.34	0.32	0.22		0.04	-0.34	0.32	0.22		0.44	0.10	0.78	2.51	**	0.08	-0.30	0.31	0.52	
	ADE	3.04	-0.14	5.64	2.06	**	3.04	-0.14	5.64	2.06	**	2.66	-0.51	5.27	1.81	*	2.98	-0.19	5.58	2.03	**
	ATE	3.07	-0.10	5.54	2.13	**	3.07	-0.10	5.54	2.13	**	3.10	-0.18	5.59	2.11	**	3.07	-0.08	5.54	2.14	**
	% Mediated	0.01	-0.43	0.04			0.01	-0.43	0.04			0.12	-8.80	0.43			0.02	-2.09	0.08		

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets. Demographic characteristics of the household, household agricultural assets, agricultural production variables, agro-ecological characteristics are included as additional controls in the regression.

Table A.5. Causal Mediation Analysis: Full OLS estimates of ACME, ADE, ATE of SDG 16 (social capital) on selected SDG2 and SDG4 indicators

		[I.16] Have a say in cooperative decisions					[I.17] Trust in the cooperative management					[I.18] Satisfaction of being farmer					[I.19] Respect within the community				
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.7] Growth of cereal production value	ACME	0.00	-0.01	0.01	0.02		0.00	-0.04	0.01	-0.35		0.02	0.00	0.04	2.08	**	0.01	-0.01	0.02	0.63	
	ADE	0.49	0.34	0.62	6.79	***	0.46	0.32	0.59	6.73	***	0.38	0.24	0.49	5.77	***	0.40	0.22	0.54	4.95	***
	ATE	0.49	0.34	0.62	6.85	***	0.46	0.32	0.57	7.06	***	0.40	0.25	0.50	6.29	***	0.40	0.23	0.55	4.91	***
	% Mediated	0.00	0.00	0.00			-0.01	-0.01	-0.01			0.05	0.04	0.07			0.01	0.01	0.02		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.8] Ln Return to family labor	ACME	0.00	-0.05	0.02	-0.22		0.00	-0.03	0.01	-0.29		-0.03	-0.09	0.02	-1.04		0.00	-0.04	0.01	-0.04	
	ADE	0.74	0.46	0.97	5.73	***	0.68	0.39	0.92	5.08	***	0.69	0.41	0.92	5.36	***	0.69	0.28	1.02	3.68	***
	ATE	0.74	0.46	0.95	5.97	***	0.68	0.39	0.90	5.23	***	0.66	0.38	0.87	5.32	***	0.69	0.29	1.00	3.80	***
	% Mediated	-0.01	-0.01	0.00			0.00	-0.01	0.00			-0.04	-0.08	-0.03			0.00	0.00	0.00		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
I.9] Share of cereal production sold through cooperatives	ACME	0.00	0.00	0.00	-0.19		0.00	0.00	0.00	-0.16		0.00	-0.01	0.00	-0.73		0.00	0.00	0.00	0.30	
	ADE	0.17	0.13	0.20	9.62	***	0.18	0.14	0.21	10.79	***	0.16	0.13	0.19	10.08	***	0.16	0.11	0.19	7.89	***
	ATE	0.17	0.13	0.19	9.95	***	0.18	0.14	0.20	11.17	***	0.16	0.13	0.19	10.19	***	0.16	0.11	0.19	8.20	***
	% Mediated	0.00	0.00	0.00			0.00	0.00	0.00			0.34	-6.39	3.25			0.04	-0.56	0.36		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.1] HFIAS	ACME	0.00	-0.01	0.00	-0.17		-0.01	-0.05	0.02	-0.42		-0.03	-0.08	0.00	-1.53		-0.01	-0.07	0.02	-0.46	
	ADE	-0.31	-0.49	-0.16	-3.71	***	-0.31	-0.48	-0.16	-3.81	***	-0.23	-0.39	-0.10	-3.10	***	-0.19	-0.41	-0.02	-1.92	*
	ATE	-0.31	-0.49	-0.17	-3.84	***	-0.31	-0.48	-0.18	-4.07	***	-0.26	-0.43	-0.15	-3.74	***	-0.20	-0.42	-0.04	-2.11	**
	% Mediated	0.00	0.00	0.00			0.02	0.01	0.04			0.14	0.08	0.22			0.05	0.02	0.24		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.2] HFIAS – Eating smaller meals)	ACME	0.00	-0.01	0.00	-0.19		0.00	-0.02	0.01	-0.44		-0.02	-0.04	0.00	-1.52		0.00	-0.03	0.01	-0.47	
	ADE	-0.17	-0.25	-0.10	-4.31	***	-0.17	-0.25	-0.10	-4.47	***	-0.13	-0.20	-0.07	-3.82	***	-0.12	-0.21	-0.04	-2.59	***
	ATE	-0.17	-0.25	-0.10	-4.47	***	-0.17	-0.25	-0.11	-4.75	***	-0.15	-0.22	-0.09	-4.38	***	-0.12	-0.22	-0.05	-2.78	***
	% Mediated	0.00	0.00	0.00			0.02	0.01	0.03			0.12	0.07	0.17			0.04	0.02	0.09		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.3] HFIAS – Eating fewer meals)	ACME	0.00	-0.01	0.00	-0.20		0.00	-0.02	0.01	-0.42		-0.01	-0.03	0.00	-1.30		0.00	-0.03	0.01	-0.48	
	ADE	-0.15	-0.24	-0.09	-4.00	***	-0.15	-0.23	-0.09	-4.12	***	-0.12	-0.19	-0.06	-3.55	***	-0.10	-0.20	-0.02	-2.26	**
	ATE	-0.16	-0.24	-0.09	-4.17	***	-0.16	-0.23	-0.10	-4.37	***	-0.13	-0.21	-0.08	-4.00	***	-0.11	-0.20	-0.03	-2.45	**
	% Mediated	0.00	0.00	0.01			0.02	0.01	0.03			0.10	0.06	0.16			0.05	0.02	0.14		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.4] HDDS	ACME	0.00	-0.02	0.01	0.04		0.01	-0.02	0.03	0.57		0.07	0.03	0.12	3.27	***	0.01	-0.03	0.04	0.74	
	ADE	0.09	-0.29	0.40	0.50		0.06	-0.34	0.39	0.32		-0.08	-0.42	0.20	-0.51		-0.12	-0.57	0.25	-0.57	
	ATE	0.09	-0.30	0.40	0.51		0.07	-0.34	0.41	0.35		-0.01	-0.37	0.26	-0.04		-0.11	-0.56	0.27	-0.50	
	% Mediated	0.00	-0.23	0.10			0.03	-0.27	0.19			0.30	-3.06	5.29			-0.04	-1.49	1.15		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.5] CDDS – Low dietary index	ACME	0.00	-0.01	0.00	-0.19		0.00	-0.02	0.01	0.09		0.00	-0.01	0.01	0.41		0.00	-0.01	0.01	0.21	
	ADE	0.10	-0.03	0.20	1.70	*	-0.02	-0.15	0.08	-0.42		-0.20	-0.35	-0.07	-2.85		-0.12	-0.27	0.00	-1.79	
	ATE	0.10	-0.03	0.19	1.75	*	-0.02	-0.15	0.07	-0.42		-0.20	-0.34	-0.08	-2.93		-0.12	-0.27	-0.01	-1.82	
	% Mediated	0.00	-0.03	0.02			0.00	-0.13	0.12			-0.01	-0.02	0.00			-0.01	-0.16	0.00		

		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I.10b] Enrollment ratio - Girls	ACME	0.00	0.00	0.01	0.69		0.00	0.00	0.00	0.50		-0.01	-0.02	0.00	-1.74		0.00	0.00	0.01	1.17	
	ADE	0.08	0.01	0.13	2.49	**	0.06	0.00	0.11	2.02	**	0.07	0.01	0.12	2.56	**	0.06	-0.04	0.14	1.32	
	ATE	0.08	0.01	0.13	2.60	***	0.06	0.00	0.11	2.09	**	0.06	0.00	0.11	2.32	**	0.06	-0.03	0.14	1.43	
	% Mediated	0.02	0.01	0.12			0.01	-0.24	0.06			-0.15	-5.18	-0.10			0.06	-0.15	0.95		
		Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval	Mean	Lo	Hi	t	pval
[I11.b] Time spent in education - Girls	ACME	0.36	-0.29	0.98	1.11		0.12	-0.26	0.41	0.68		0.74	0.19	1.43	2.34	**	0.69	-0.09	1.39	1.83	*
	ADE	3.22	-0.66	6.39	1.79	*	4.27	0.50	7.36	2.44	**	2.22	-1.78	5.49	1.20		3.39	-1.56	7.45	1.48	
	ATE	3.58	-0.51	7.22	1.81	*	4.39	0.52	7.58	2.44	**	2.96	-1.18	6.15	1.58		4.08	-1.06	8.46	1.68	*
	% Mediated	0.09	-0.87	0.33			0.02	0.02	0.22			0.19	-0.90	1.39			0.14	-0.66	1.13		

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets. Demographic characteristics of the household, household and agricultural assets, agricultural production variables, agro-ecological characteristics are included as additional controls in the regression.

References

Abebaw, D. & Haile, M.G. (2013). The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. *Food Policy*, *38*, 82–91.

Allen, T., Heinrigs, P. & Heo, I. (2018). Agriculture, food and jobs in West Africa. West African Papers No. 14. Paris: Organisation for Economic Co-operation and Development.

Angrist, J.D., & Imbens, G.W. (1995). Two-stage least squares estimation of average causal

effects in models with variable treatment intensity. *Journal of the American Statistical Association*, *90*(430), 431–442.

Angrist, J.D., & Pischke, J.S. (2009). *Mostly harmless econometrics: An empiricist's companion*. Princeton: Princeton University Press.

Anyonge, T. & Messer, N. (2014). Smallholder institutions and organizations: scaling up note. Rome: IFAD.

Ashraf, N., Gine, X. & Karlan, D. (2009). Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya. *American Journal of Agricultural Economics, 91*(4), 973–990.

Bamberger, M., Vaessen, J. & Raimondo, E. (2016) (Eds.). *Dealing with Complexity in Development Evaluation: A Practical Approach*. Los Angeles, CA: Sage.

Bandiera, O., Burgess, R., Das, N., Gulesci, S., Rasul, I. & Sulaiman, M. (2013). Can basic entrepreneurship transform the economic lives of the poor? LSE Working Paper (April 2013). London School of Economics. http://sticerd.lse.ac.uk/dps/eopp/eopp43.pdf.

Banerjee, A., Duflo, E., Goldberg, N., Karlan, D., Osei, R., Parienté, W., Shapiro, J., Thuysbaert, B. & Udry, C. (2015). A multifaceted program causes lasting progress for the very poor: Evidence from six countries. *Science, 348*(6236), 1260799-16.

Barbier, E. B., & Burgess, J. C. (2019). Sustainable development goal indicators: Analyzing trade-offs and complementarities. *World development*, *122*, 295-305. https://doi.org/10.1016/j.worlddev.2019.05.026.

Baron, R.M., & Kenny, D.A. (1986). The moderator-mediator variable distinction in social psychological research: Concept, strategic and statistical considerations. *Journal of Personality and Social Psychology*, *51*, 1173–1182.

Barrett, C.B. (2008). Smallholder market participation: Concepts and evidence from eastern and southern Africa, *Food Policy*, *33*, 299–317.

Barrett, C.B., Bachke, M.E., Bellemare, M.F., Michelson, H.C., Narayanan, S. & Walker, T.F. (2012). Smallholder participation in contract farming: comparative evidence from five countries. *World Development, 40*(4), 715–730.

Barrett, C.B., Garg, T. & McBride, L. (2016). Well-Being dynamics and poverty traps. *Annual Review of Resource Economics, 8*, 303–27.

Beegle, K. & Christiaensen, L. (2019). *Accelerating Poverty Reduction in Africa*. Washington, DC: The World Bank Group.

Beegle, K., Christiaensen, L., Dabalen, A. & Gaddis, I. (2016). *Poverty in a Rising Africa*. Washington, DC: The World Bank Group.

Bellemare, M. (2012). As you sow, so shall you reap: the welfare impacts of contract farming. *World Development*, *40*, 1418–1434.

Bellemare, M. (2015). Contract farming: What's in it for smallholder farmers in developing countries? *Choices, 30*(3), 1-4.

Bellemare, M. & Bloem, J. (2018). Does contract farming improve welfare? A review. *World Development*, *112*, 259-271. https://doi.org/10.1016/j.worlddev.2018.08.018.

Bellemare, M. & Lim, S. (2018). In all shapes and colors: varieties of contract farming. *Applied Economic Perspectives and Policy, 40*(3), 379-401.

Benfica, R. & Thurlow, J. (2017). Identifying priority value-chains in Ethiopia. ESSP Working Paper 110. Washington, D.C. and Addis Ababa, Ethiopia: International Food Policy Research Institute (IFPRI) and Ethiopian Development Research Institute (EDRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/131413.

Berdegue, J.A., Bebbington, A. & Escobal, A. (2015), Conceptualizing spatial diversity in Latin American rural development: structures, institutions, and coalitions, *World Development*, *73*, 1-10. https://doi.org/10.1016/j.worlddev.2014.10.015.

Bernard, T., & Spielman, D. (2009). Reaching rural poor through rural producer organizations? A study of the agricultural marketing cooperatives in Ethiopia. *Food Policy*, *34*(1), 60–69.

Bernier, Q. & Meinzen-Dick, E. (2014). Networks for resilience: the role of social capital. Food policy report, November 2014. Washington, DC: IFPRI. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128489.

Bhattarai, S., Lyne, M. & Martin, S. (2013), Assessing the performance of a supply chain for organic vegetables from a smallholder perspective. *Journal of Agribusiness in Developing and Emerging Economies, 3*(2), 101-118.

Biggeri, M., Burchi, F., Ciani, F. & Herrmann, R. (2018). Linking small-scale farmers to the durum wheat value chain in Ethiopia: Assessing the effects on production and wellbeing. *Food Policy*, *79*, 77-91. https://doi.org/10.1016/j.foodpol.2018.06.001.

Biggeri, M., Ciani, F. & Ferrannini, A. (2016). Aid effectiveness and multilevel governance: The case of a value chain development project in rural Ethiopia. *European Journal of Development Research*, *29*(4), 843-865.

Biggeri M., Clark D.A., Ferrannini A., & Mauro, V. (2019), Tracking the SDGs in an 'integrated' manner: A proposal for a new index to capture synergies and trade-offs between and within goals. *World Development*, *122*, 628-647, https://doi.org/10.1016/j.worlddev.2019.05.022.

Biggeri, M. & Ferrannini, A. (2015). The evaluation of complex development programs: An application of a mixed methods procedure proposal. Paper presented at the HDCA Annual Conference on Capabilities on the Move: Mobility and Aspirations, 10–13 September, Washington, DC.

Bijman, J. & Wollni, M. (2008). Producer organizations and vertical coordination: An economic organization theory perspective, International Conference on Cooperative Studies (ICCS), 7-9 Oct., Köln, Germany.

Bowles, S. & Gintis, H. (2002). Social capital and community governance. *Economic Journal*, *112*, 483, 419-436.

Bridle, L., Magruder, J., McIntosh, C. & Suri, T. (2018). Experimental Insights on the Constraints to Agricultural Technology Adoption. Working paper, ATAI, University of California at Berkeley.

Byerlee, D. & Haggblade, S. (2013). African Food Systems to 2030: Toward Inclusive Business Models. Working paper, Center on Food Security and the Environment, Stanford University.

BZADO (2012). Annual Report 2012. Bale Zone Agricultural Development Office (Unpublished). Bale-Robe: Bale Zone Agricultural Development Office.

Carter, M. & Barrett, C.B. (2006). The Economics of Poverty Traps and Persistent Poverty: An Asset-based Approach. *Journal of Development Studies, 42*(2),178-199.

Castañeda, A., Doan, D., Newhouse, D., Nguyen, M.C., Uematsu, H. & Azevedo, J.P. (2018). A New Profile of the Global Poor. *World Development, 101*, 250-67. https://doi.org/10.1016/j.worlddev.2017.08.002.

Cattaneo, M. D. (2010). Efficient semiparametric estimation of multi-valued treatment effects under ignorability. *Journal of Econometrics*, *155*(2), 138-154.

Cattaneo, M. D., Drukker, D. M. & Holland, A. D. (2013). Estimation of multivalued treatment effects under conditional independence. *Stata Journal*, *13*(3), 407-450.

Cavatassi, R., González-Flores, M., Winters, P., Andrade-Piedra, J., Espinosa, P. & Thiele, G. (2011). Linking smallholders to the new agricultural economy: The case of the plataformas de concertación in Ecuador. *Journal of Development Studies*, *47*(10), 1545-73.

Chatterji, M. (2016). Causal inferences on the effectiveness of complex social programs: Navigating assumptions, sources of complexity and evaluation design challenges. *Evaluation and Program Planning, 59*, 128–140. http://dx.doi.org/10.1016/j.evalprogplan.2016.05.009.

Christiaensen, L. & Todo, Y. (2014). Poverty Reduction During the Rural-Urban Transformation – The Role of the Missing Middle. *World Development, 63*, 43-58. https://doi.org/10.1016/j.worlddev.2013.10.002.

Christiaensen, L., Demery, L. & Kulh, J. (2011). The (evolving) role of agriculture in poverty reduction—an empirical perspective. *Journal of Development Economics*, *96*(2), 239–254.

Coates, J., Swindale, A. & Bilinsky, P. (2007). Household Food Insecurity Access Scale (HFIAS) for Measurement of Household Food Access: Indicator Guide (v. 3). Washington, DC: FHI 360/FANTA.

Collier, P. & Dercon, S. (2014). African agriculture in 50 years: Smallholders in a rapidly changing world? *World Development*, *63*, 92–101.

Collion, M.H. (2018). Inclusive value chains. Ferdi-AFD workshop on Agricultural Value Chain Development and Smallholder Competitiveness, Paris.

Davis, B., Di Giuseppe, S. & Zezza, A. (2017). Are African households (not) leaving agriculture? Patterns of households' income sources in rural Sub-Saharan Africa. *Food Policy, 67*, 153-174. https://doi.org/10.1016/j.foodpol.2016.09.018.

Davis, B., Winters, P., Carletto, G., Covarrubias, K., Quinones, E., Zezza,A., Stamoulis, K., Bonomi, G. & Di Giuseppe, S. (2010). A cross-country comparison of rural income generating activities. *World Development*, *38*(1), 48-63.

de Janvry, A., Duquennois, C. & Sadoulet, E. (2018). Labor Calendars and Rural Poverty: A case study for Malawi. Working Paper, University of California at Berkeley.

de Janvry, A., Macours, K. & Sadoulet, E. (2016). Learning for adopting: Technology adoption in developing country agriculture. Clermont-Ferrand: Fondation pour les études et recherches sur le développement international (Ferdi).

de Janvry, A. & Sadoulet, E. (2019). Transforming developing country agriculture: Removing adoption constraints and promoting inclusive value chain development, Ferdi Working Paper 253 (September 2019), Clermont-Ferrand: Fondation pour les études et recherches sur le développement international (Ferdi). https://ferdi.fr/dl/df-TkkSjWPHmP49LBkrVQqBFnSD/ferdi-p253-transforming-developing-country-agriculture-removing-adoption.pdf.

de Janvry, A., Sadoulet E., & Trachtman C. (2019). Achieving Coordination in Agricultural Value Chains: The Role of Lead Agents and Multi-stakeholder Platforms, Ferdi Working Paper P254, September (2019)), Clermont-Ferrand: Fondation pour les études et recherches sur le développement international (Ferdi). https://ferdi.fr/dl/df-zKjo5PSeifSSHLbxCfdHidx1/ferdi-p254-achieving-coordination-in-agricultural-value-chains-the-role-of.pdf.

Dercon, S. & Gollin, D. (2014). Agriculture in African development: Theories and strategies. *Annual Review of Resource Economics*, *6*(1), 471–492.

Devaux, A., Torero, M., Donovan, J. & Horton, D. (2016). *Innovation for Inclusive Value Chain Development: Successes and Challenges*. Washington DC: IFPRI.

Devaux, A., Torero, M., Donovan, J. & Horton, D. (2017). Agricultural innovation and inclusive value-chain development: a review. *Journal of Agribusiness in Developing and Emerging Economies, 8*(1), 99-123.

Diao, X., Hazell, P. & Thurlow, J. (2010). The role of agriculture in African development. *World Development, 38*(10), 1375–1383.

Emran, M.S., Robano, V. & Smith, S.C. (2014). Assessing the Frontiers of ultrapoverty Reduction: Evidence from challenging the frontiers of poverty reduction/targeting the ultra-poor, an innovative program in Bangladesh. *Economic Development and Cultural Change, 62*(2), 339-380.

Fafchamps, M. (2004). *Market Institutions in Sub-Saharan Africa*, Cambridge, MA: MIT Press.

FAO (2018). Transforming food and agriculture to achieve the SDGs. Rome: FAO. http://www.fao.org/3/I9900EN/i9900en.pdf.

Feyaerts, H., Van den Broeck, G., & Maertens, M. (2019). Global and local food value chains in Africa: A review. *Agricultural Economics*, *51*(1), 143-157.

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

Frölich, M., 2007. Nonparametric IV estimation of local average treatment effects with covariates. *Journal of Econometrics, 139*(1), 35–75.

Frölich, M., & Melly, B. (2010). Quantile treatment effects in the regression discontinuity design: process results and gini coefficient. IZA Discussion Paper 4993. Institute for the Study of Labor, IZA.

Goyal, A. & Nash, J. (2016). *Reaping Richer Returns: Public Spending Priorities for African Agriculture Productivity Growth*. Washington DC: The World Bank Group. https://openknowledge.worldbank.org/handle/10986/25996.

Hazell, P. & Rahman, A. (2014). *New Directions for Smallholder Agriculture*, Oxford: Oxford University Press

IAO (2010). AVCPO Project Implementation Document – Annex A. Firenze: Overseas Agronomic Institute (IAO). http://openaid.esteri.it/media/documents/VTE_ISVCDO-Final.pdf.

IDC (2016). Agricultural Value Chain in Oromia Evaluation Report. AID 9374, Italian Development Cooperation, Ministry of Foreign Affairs and International Cooperation, Rome. https://www.esteri.it/mae/resource/doc/2018/03/2016_ethiopia_evaluation_report_agricultural_programme.pdf.

IFAD (2016). *Rural Development Report 2016. Fostering Inclusive Rural Transformation*. Rome: IFAD.

Imai, K., Keele, L., & Yamamoto, T. (2010). Identification, inference and sensitivity analysis for causal mediation effects. *Statistical Science*, *25*(1), 51–71.

Ivanic, M. & Martin, W. (2018). Sectoral productivity growth and poverty reduction: National and global Impacts. *World Development*, *109*, 429-439. https://doi.org/10.1016/j.worlddev.2017.07.004.

Jayne, T.S., Chamberlin, J. & Benfica, R. (2018). Africa's unfolding economic transformation, *Journal of Development Studies*, *54*(5), 777-787.

Ligon, E. & Sadoulet, E. (2018). Estimating the relative benefits of agricultural growth on the distribution of expenditures. *World Development, 109*, 417–428. http://dx.doi.org/10.1016/j.worlddev.2016.12.007.

Lowder, S.K., Sánchez, M.V. & Bertini, R. (2019). Farms, family farms, farmland distribution and farm labour: What do we know today? FAO Agricultural Development Economics Working Paper 19-08. Rome: FAO. http://www.fao.org/3/ca7036en/ca7036en.pdf.

Loayza, N., & Raddatz, C. (2010). The composition of growth matters for poverty alleviation. *Journal of Development Economics*, *93*, 137–151.

Markelova, H., Meinzen-Dick, R., Hellin, J., & Dohrn, S. (2009). Collective action for smallholder market access. *Food Policy*, *34*, 1–7. doi:10.1016/j.foodpol.2008.10.001.

McCullough, E. (2017). Labor productivity and employment gaps in Sub-Saharan Africa. *Food Policy*, *67*, 133-52. https://doi.org/10.1016/j.foodpol.2016.09.013.

Nilsson, M., Griggs, D., & Visback, M. (2016). Map the interactions between Sustainable Development Goals. *Nature*, *534*(15), 320–322.

Pace, N., Daidone, S., Davis, B., Handa, S., Knowles, M. & Pickmans, R. (2017). One Plus One can be Greater than Two: Evaluating Synergies of Development Programmes in Malawi. *Journal of Development Studies, 54*(11)*,* 2023-2060.

Palinkas, L.A. Mendon, S.J. & Hamilton, A.B. (2019). Innovations in mixed methods evaluations. *Annual Review of Public Health*, *40*, 423–42. https://doi.org/10.1146/annurev-publhealth-040218-044215.

Patton, M. (2011). *Developmental Evaluation*, New York: The Guilford Press.

Poulton, C., Dorward, A., & Kydd, J. (2010). The future of small farms: new directions for services, institutions, and intermediation. *World Development 38*(10), 1413–1428. https://doi.org/10.1016/j.worlddev.2009.06.009.

Prato, B. & Longo, R. (2012). "Empowerment of poor rural people through initiatives in agriculture and natural resource management". In OECD. Poverty Reduction and Pro-Poor Growth: The Role of Empowerment. Paris: OECD. https://doi.org/10.1787/9789264168350-en.

Rapsomanikis, G. (2015). The economic lives of smallholder farmers: An analysis based on household data from nine countries. Rome: FAO. http://www.fao.org/3/a-i5251e.pdf.

Reardon, T., Swinnen, J.F.M., Barrett, C.B. & Berdegué, J. (2009). Agrifood industry transformation and small Farmers in developing Countries. *World Development, 37*(11), 1717-1727.

Ricketts, K., Turvey, C. & Gomez, M. (2014). Value chain approaches to development: smallholder farmer perceptions of risk and benefits across three cocoa chains in Ghana, *Journal of Agribusiness in Developing and Emerging Economies, 4*(1), 2-22.

Rodrik, D., McMillan, M. & Sepúlveda, C. (2016). *Structural change, fundamentals, and growth*. Washington DC: IFPRI. https://www.ifpri.org/publication/structural-change-fundamentals-and-growth-framework-and-case-studies.

Roodman, D. (2011). Fitting fully observed recursive mixed-process models with cmp. *The Stata Journal*, *11*(2), 159-206.

Sall, A.T., Chiari, T., Legesse, W., Seid-Ahmed, K., Ortiz, R., van Ginkel, M. & Bassi, F.M. (2019). Durum wheat (*Triticum durum* Desf.): Origin, cultivation and potential expansion in Sub-Saharan Africa. *Agronomy, 9*, 263. doi: 10.20944/preprints201904.0149.v1.

Shiferaw, B., Hellin, J. & Muricho, G. (2011). Improving market access and agricultural productivity growth in Africa: what role for producer organizations and collective action institutions? *Food Security* 3, 475–489. DOI 10.1007/s12571-011-0153-0.

Schipmann, C. & Qaim, M. (2010). Spillovers from modern supply chains to traditional markets: Product innovation and adoption by smallholders. *Agricultural Economics*, *41*, 361–371.

Schut, M., Andersson, J., Dror, I., Kamanda, J., Sartas, M., Mur, R., Kassam, S., Brouwer, H., Stoian, D., Devaux, A., Velasco, C., Gramzow, A., Dubois, T., Flor, R.J., Gummert, M., Buizer, D., McDougall, C., Davis, K., Homann-Kee Tui, S. & Lundy, M. (2017). *Innovation Platforms in Agricultural Research for Development: Guidelines for Research, Development, and Funding Agencies on how to Design, Budget, and Implement Successful Innovation Platforms*, International Institute of Tropical Agriculture and Wageningen University under the CGIAR Research Program

on Roots Tubers and Banana, Kigali. http://biblio1.iita.org/bitstream/handle/20.500.12478/1748/schut_guidelines_IP_2017.pdf?sequence=1.

Stoian, D., Donovan, J., Fisk, J. & Muldoon, M. (2012). Value chain development for rural poverty reduction: a reality check and a warning, *Enterprise Development & Microfinance, 23*(1), 54-69.

Stür,W., Tan Khanh, T. & Duncan, A. (2013). Transformation of smallholder beef cattle production in Vietnam, *International Journal of Agricultural Sustainability, 11*(4), 363-381.

Swindale, A. & Bilinsky, P. (2006). Household Dietary Diversity Score (HDDS) for measurement of household food access: Indicator Guide (v.2). Washington, DC: FHI 360/FANTA. https://www.fantaproject.org/sites/default/files/resources/HDDS_v2_Sep06_0.pdf.

Swinnen, J.F.M. (2007). *Global Supply Chains, Standards and the Poor: How the Globalization of Food Systems and Standards Affects Rural Development and Poverty*. Wallingford: CAB International.

Swinnen, J.F.M. (2018). Inclusive Value Chains to Accelerate Poverty Reduction in Africa. Ferdi-AFD workshop on Agricultural Value Chain Development and Smallholder Competitiveness, Paris.

Swinnen, J.F.M. & Kuijpers, R. (2020). Inclusive Value Chains to Accelerate Poverty Reduction in Africa. Jobs Working Paper Issue No. 37. Washington, DC: The World Bank Group. http://documents.worldbank.org/curated/en/983221582592327153/Inclusive-Value-Chains-to-Accelerate-Poverty-Reduction-in-Africa.

Swinnen, J.F.M. & Maertens, M. (2007). Globalization, privatization, and vertical coordination in food value chains in developing and transition countries. *Agricultural Economics*, *37*(1), 89-102.

Swinnen, J.F.M., Vandeplas, A. & Maertens, M. (2010). Liberalization, endogenous institutions, and growth: A comparative analysis of agricultural reforms in Africa, Asia, and Europe. *World Bank Economic Review*, *24*(3), 412–45.

Taffesse, A.S, Dorosh, P.A. & Gemessa, S.A. (2013). Crop Production in Ethiopia: Regional Patterns and Trends. In P.A. Dorosh and S. Rashid (Eds.). *Food and Agriculture in Ethiopia. Progress and Policy Challenges*. Washington, DC: IFPRI.

UN (2019). *Global Sustainable Development Report 2019: The Future is Now – Science for Achieving Sustainable Development*. New York: United Nations. https://www.ifpri.org/publication/food-and-agriculture-ethiopia.

UNIDO (2011). Pro-poor value chain development: 25 guiding questions for designing and implementing agroindustry projects. Vienna: UNIDO. https://www.unido.org/sites/default/files/2011-12/Pro-poor_value_chain_development_2011_0.pdf.

Yirga, C., & Alemu, D. (2016). Adoption of crop technologies among Smallholder Farmers in Ethiopia: Implications for Research and Development. *Ethiopian Journal of Agricultural Science*, EIAR 50th Year Jubilee Anniversary Special Issue, 1-16.

WHO (2008). Indicators for assessing infant and young child feeding practices: part 1: definitions: conclusions of a consensus meeting held 6-8 November 2007 in Washington DC. Geneva: WHO. https://www.who.int/maternal_child_adolescent/documents/9789241596664/en/.

Wiggins, S., Kirsten, J. & Lambi, L. (2010). The Future of small farms. *World Development*, *38*(10), 1341–1349.

Winters, P., Davis, B., Carletto, G., Covarrubias, K., Quiñones, E.J., Zezza, A., Azzarri, C & Stamoulis, K. (2009). Assets, Activities and Rural Income Generation: Evidence from a Multicountry Analysis. *World Development*, *37*(9), 1435–1452.

Wollni, M. & Zeller, M. (2007). Do farmers benefit from participating in specialty markets and cooperatives? The case of coffee marketing in Costa Rica. *Agricultural Economics, 37*(2-3), 243–248.

World Bank (2007). *World Development Report. Agriculture for Development*. Washington, DC: The World Bank Group.

World Bank (2012). *Agricultural Innovation Systems: An Investment Sourcebook*, Washington, DC: The World Bank Group.

World Bank (2016). *Linking Farmers to Markets Through Productive Alliances*. Washington, DC: The World Bank Group.

Table 1. SDGs, targets and indicators analyzed in the study

SDGs	SDG Targets	SDG Indicators
SDG2	**T2.1:** end hunger and ensure food access by all people	• Household Food Insecurity Access Scale (HFIAS) • HFIAS components
	T2.2: end all forms of malnutrition … in children under 5 years of age	• Household Dietary Diversity Index (HDDS) • Children Dietary Diversity Index (CDDS)
	T2.3: double the agricultural productivity and incomes of small-scale food producers, in particular … family farmers … through … markets and opportunities for value addition and non-farm employment	• Growth in cereal production value • Returns to family labor • Share of cereal production sold through cooperative
SDG4	**T4.1:** ensure that all girls and boys complete primary and secondary education	• Enrollment ratio, by gender • Time spent in education, by gender
SDG16	**T16.6:** develop effective, accountable and transparent institutions at all levels **T16.7:** ensure responsive, inclusive, participatory and representative decision-making at all levels	• Collective Action – Participation in coop activities – Participation in other formal meetings – Participation in other social activities • Social Capital – Have a say in cooperative decisions – Trust in the cooperative management – Satisfaction of being farmer – Respect within the community

Table 2. Major bottlenecks addressed by the AVCPO

Bottlenecks	Actions	Actors
Small farm size (and low per-farm production)	- Strengthening cooperatives - Creation of cooperative's unions - Construction of new storage facilities at cooperative/*kebele* level	- Farmers - Cooperatives - Unions - Regional and Zonal Institutions
Farmers' high risk-aversion	- Contract farming schemes to link farmers to processing industries - Quality premium in price setting - Peer learning	- Cooperatives & Unions - Pasta producers - Sinana Agricultural Research Center (quality lab checks) - Regional and Zonal Institutions
Low quality of production (i.e. low protein content)	- Training of farmers (fertilization, appropriate farming practices, etc.) - Selecting new (patented by research institutions) durum wheat varieties adapted to the intervention area - Creating a seed value chain involving seed multiplier cooperatives and agricultural research centers - Providing seed grading machines to cooperatives (not operating yet at the time of evaluation)	- Farmers (for training) - Selected farmers (for the seed production cycle) - Cooperatives - Sinana Agricultural Research Center - Oromia Agriculture Research Center
Insufficient coordination among actors along the VC	- Sharing experience and creating awareness among farmers and cooperative managers - Capacity building of cooperatives by strengthening technical and managerial skills - Involving local institutions in the value chain	- Cooperatives & Unions - Pasta producers - Regional and Zonal Institutions - International donors

Source: Adapted from Biggeri et al., 2018.

Table 3. Treatment status classified by typology

Treatment status	Treatment level	Treatment description	N	%
Not treated	t=0	Control	485	65.72%
Treated	t=1	Training	43	5.83%
	t=2	Training + Storage	39	5.28%
	t=3	Training + durum wheat VC	57	7.72%
	t=4	Training + Storage + durum wheat VC	61	8.27%
	Other[a]	Combinations other than above	53	7.18%
	Total		738	100.00%

[a] This includes all the units in a category of treatment whose size was too small to be considered in the multivalued treatment impact assessment (see section 4.3.2). This category was not considered in the analyses.

Source: author's elaboration.

Table 4. Output indicators t-test of mean differences

	Indicators	Total		Treated		Control		Treated - Control		
		mean	SD	mean	SD	mean	SD	t-test	p	
SDG2	**T2.1 - End hunger and ensure food access by all people**									
	[I.1] HFIAS	0.28	0.94	0.07	0.48	0.40	1.09	4.59	0.00	***
	[I.2] HFIAS - Eating smaller meals	0.15	0.48	0.03	0.20	0.21	.56	5.00	0.00	***
	[I.3] HFIAS - Eating fewer meals	0.13	0.47	0.03	0.19	0.19	.55	4.29	0.00	***
	T2.2 - End all form of malnutrition […] in children under 5 y.o.									
	[I.4] HDDS	9.59	1.97	9.73	1.80	9.52	2.04	-1.36	0.17	
	[I.5] CDDS – Low dietary index	0.42	0.49	0.39	0.48	0.43	.49	0.83	0.40	
	[I.6] CDDS – Ratio	0.25	0.09	0.27	0.09	0.24	.09	-3.38	0.00	***
	T2.3 - Double the agricultural productivity and incomes […] of small-scale food producers									
	[I.7] Growth of cereal production value	0.09	0.99	0.39	0.42	-0.06	1.15	-6.01	0.00	***
	[I.8] Ln Return to family labor	8.75	1.71	9.42	1.18	8.40	1.80	-7.97	0.00	***
	[I.9] Share of cereal production sold through cooperatives	0.09	0.17	0.20	0.21	0.03	0.09	-15.04	0.00	***
SDG4	**T4.1 - Ensure that all girls and boys complete primary and secondary education**									
	[I.10a] Enrollment ratio - Boys	0.82	0.31	0.84	0.31	0.83	0.30	-0.12	0.90	
	[I.10b] Enrollment ratio - Girls	0.89	0.26	0.89	0.28	0.92	0.22	-1.46	0.14	
	[I.10c] Enrollment ratio – All children	0.86	0.26	0.87	0.26	0.85	0.26	0.35	0.72	
	[I.11a] Time spent in education - Boys	31.68	0.73	31.32	1.21	31.87	0.92	0.36	0.71	
	[I11.b] Time spent in education - Girls	32.09	16.29	33.54	15.09	31.31	16.87	-1.48	0.14	
	[I11.c] Time spent in education – All children	32.54	15.68	32.67	15.14	32.48	15.99	-0.15	0.88	
SDG16	**T16.6 - Develop effective, accountable and transparent institutions at all levels**									
	T16.2 - Ensure responsive, inclusive, participatory and representative decision making at all levels									
	Collective Action									
	[I.12] Participation in cooperative activities/other formal meetings[a]	0.42	0.49	0.48	0.51	0.38	0.49	-2.58	0.01	***
	[I.13] Participation in activities of cooperatives	0.84	0.37	0.92	0.26	0.79	0.41	-4.72	0.00	***
	[I.14] Participation in other formal meetings[a]	0.82	0.38	0.92	0.28	0.77	0.42	-4.93	0.00	***
	[I.15] Participation in other social activities[b]	0.86	0.34	0.94	0.23	0.82	0.38	-4.65	0.00	***
	Social capital									
	[I.16] Have a say in cooperative decisions	0.88	0.32	0.91	0.28	0.86	0.34	-1.86	0.06	**
	[I.17] Trust in the cooperative management	0.90	0.30	0.91	0.29	0.89	0.31	-0.78	0.44	
	[I.18] Satisfaction of being farmer	0.96	0.19	0.99	0.11	0.95	0.22	-2.70	0.01	***
	[I.19] Respect within the community	0.99	0.10	1.00	0.06	0.99	0.12	-1.31	0.19	

[a] Other formal meetings include field days, crop plot visits, demo trials, etc.

[b] Other social activities include memberships in: religious organizations, producer groups, NGOs, self-help groups, savings or credit groups, village committees.

Note: * p < 0.1, ** p <0 .05, ***p < 0.001.

Table 5. Impact of AVCPO on SDG 2 outcomes with PSM+IV strategy

	Indicators	β	t	Obs.
[I.7]	Growth of cereal production value	0.86***	[6.24]	598
[I.8]	Ln Return to family labor	1.37***	[6.17]	599
[I.9]	Share of cereal production sold through cooperatives	0.17***	[10.04]	598
[I.1]	HFIAS	-0.56***	[-4.48]	599
[I.2]	HFIAS - Eating smaller meals	-0.29***	[-4.51]	599
[I.3]	HFIAS - Eating fewer meals	-0.26***	[-4.16]	599
[I.4]	HDDS	-0.10	[-0.42]	599
[I.5]	CDDS – Low dietary index	0.02	[1.19]	343
[I.6]	CDDS – Ratio	0.03	[0.37]	343

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets. Demographic Household and agricultural assets, agricultural production variables, agro-ecological characteristics are included as additional controls in the regression. Full estimates available on request.

Table 6. Impact of AVCPO on SDG 4 outcomes with PSM+IV strategy

	Indicators	β	t	Obs.
[I.10a]	Enrollment ratio - Boys	-0.01	[-0.31]	472
[I.10b]	Enrollment ratio - Girls	0.08*	[1.96]	406
[I.10c]	Enrollment ratio – All children	0.03	[0.84]	515
[I.11a]	Time spent in education - Boys	-0.47	[-0.19]	472
[I11.b]	Time spent in education - Girls	7.26***	[2.86]	406
[I11.c]	Time spent in education – All children	1.10	[0.52]	515

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets. Demographic Household and agricultural assets, agricultural production variables, agro-ecological characteristics are included as additional controls in the regression. Full estimates available on request.

Table 7. Impact of AVCPO on SDG 16 outcomes using PSM+IV: Marginal Effects

	Indicators	δx/δy	t	Obs.
[I.12]	Participation in cooperative activities/other formal meetings	0.14***	[2.81]	604
[I.13]	Participation in activities of cooperatives	0.19***	[3.59]	604
[I.14]	Participation in other formal meetings	0.12**	[2.23]	604
[I.15]	Participation in other social activities	0.07	[1.05]	604
[I.16]	Have a say in cooperative decisions	0.09	[1.56]	604
[I.17]	Trust in the cooperative management	0.06	[1.13]	605
[I.18]	Satisfaction of being farmer	0.17***	[3.20]	603
[I.19]	Respect within the community	0.09*	[1.72]	606

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets. Demographic Household and agricultural assets, agricultural production variables, agro-ecological characteristics are included as additional controls in the regression. Full estimates available on request.

Table 8. Non-parametric LATE estimates of the impact of AVCPO on SDG 2 outcomes

	Indicators	β	t	Obs.
[I.7]	Growth of cereal production value	0.81***	[5.68]	598
[I.8]	Ln Return to family labor	1.25***	[6.57]	599
[I.9]	Share of cereal production sold through cooperatives	0.18***	[4.43]	598
[I.1]	HFIAS	-0.49***	[-4.33]	599
[I.2]	HFIAS - Eating smaller meals	-0.25***	[-3.75]	599
[I.3]	HFIAS - Eating fewer meals	-0.23***	[-3.54]	599
[I.4]	HDDS	-0.10	[-0.42]	599
[I.5]	CDDS – Low dietary index	0.03	[0.58]	343
[I.6]	CDDS – Ratio	-0.04	[-0.44]	343

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets.

Table 9. Non-parametric LATE estimates of the impact of AVCPO on SDG 4 outcomes

	Indicators	β	t	Obs.
[I.10a]	Enrollment ratio - Boys	-0.02	[-0.35]	472
[I.10b]	Enrollment ratio - Girls	0.06	[1.08]	406
[I.10c]	Enrollment ratio – All children	0.02	[0.29]	515
[I.11a]	Time spent in education - Boys	-0.17	[-0.07]	472
[I11.b]	Time spent in education - Girls	6.16***	[2.81]	406
[I11.c]	Time spent in education – All children	1.33	[0.70]	515

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets.

Table 10. Non-parametric LATE estimates of the impact of AVCPO on SDG 16 outcomes

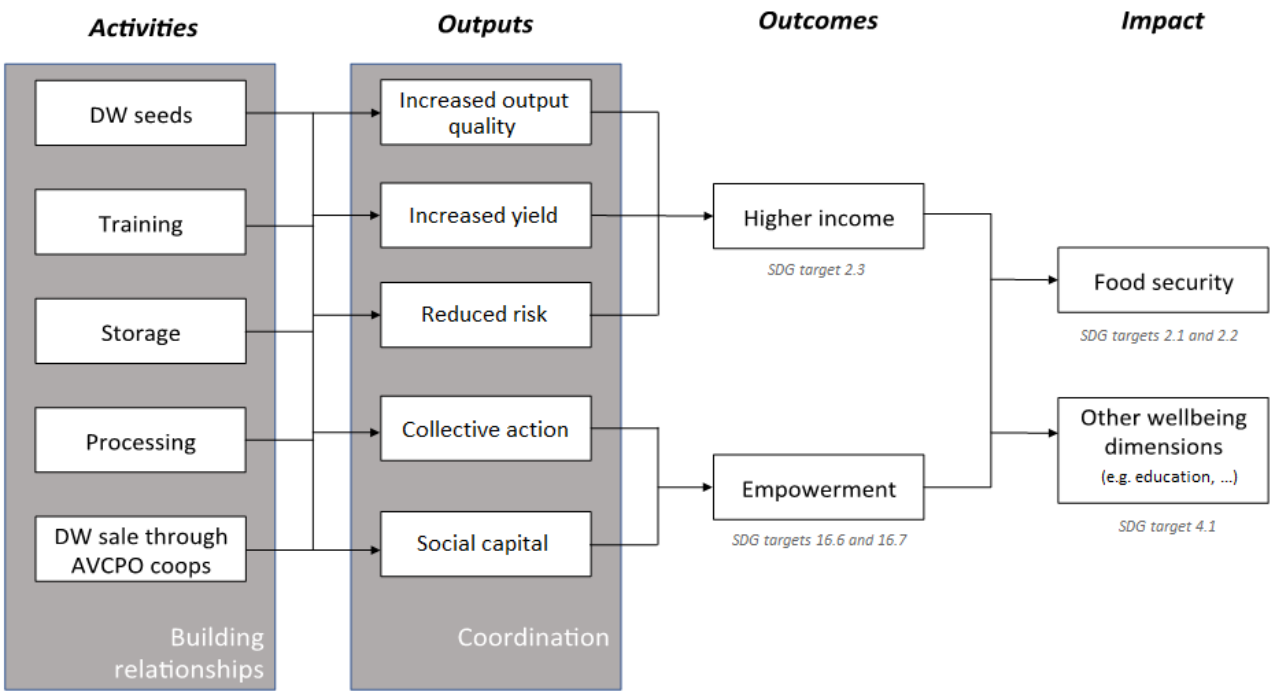
	Indicators	β	t	Obs.
[I.12]	Participation in cooperative activities/other formal meetings	0.11**	[2.09]	604
[I.13]	Participation in activities of cooperatives	0.13**	[2.21]	604
[I.14]	Participation in other formal meetings	0.11*	[1.85]	604
[I.15]	Participation in other social activities	0.13*	[1.73]	604
[I.16]	Have a say in cooperative decisions	0.06	[0.90]	604
[I.17]	Trust in the cooperative management	0.06	[0.95]	605
[I.18]	Satisfaction of being farmer	0.19***	[2.86]	603
[I.19]	Respect within the community	0.07	[1.19]	606

Note: * p <0.1, ** p<0.05, ***p<0.001, t statistics in brackets.

Table 11. OLS estimates of ACME and ADE

	Indicators		Mediators: SDG 16							
			[I.12] Participation in cooperative activities/ other formal meetings	[I.13] Participation in activities of cooperatives	[I.14] Participation in other formal meetings	[I.15] Participation in other social activities	[I.16] Have a say in cooperative decisions	[I.17] Trust in the cooperative management	[I.18] Satisfaction of being farmer	[I.19] Respect within the community
SDG2	[I.7] Growth of cereal production value	ACME							(+) **	
		ADE	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***
	[I.8] Ln Return to family labor	ACME	(+) **	(+) **						
		ADE	(+) ***	(+) ***	(+) ***	(+) *	(+) ***	(+) ***	(+) ***	(+) ***
	[I.9] Share of cereal production sold through cooperatives	ACME	(+) **	(+) ***						
		ADE	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***	(+) ***
	[I.1] HFIAS	ACME	(-) *		(-) *					
		ADE	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) *
	[I.2] HFIAS - Eating smaller meals	ACME	(-) *		(-) *					
		ADE	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***
	[I.3] HFIAS - Eating fewer meals	ACME			(-) *					
		ADE	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) ***	(-) **
	[I.4] HDDS	ACME							(+) ***	
		ADE								
	[I.5] CDDS – Low dietary index	ACME								
		ADE					(+) *			
SDG4	[I.10b] Enrollment ratio - Girls	ACME								
		ADE	(+) **	(+) *	(+) *	(+) **	(+) **	(+) **	(+) **	
	[I11.b] Time spent in education - Girls	ACME			(+) **				(+) **	(+) *
		ADE	(+) **	(+) **	(+) *	(+) **	(+) *	(+) **		

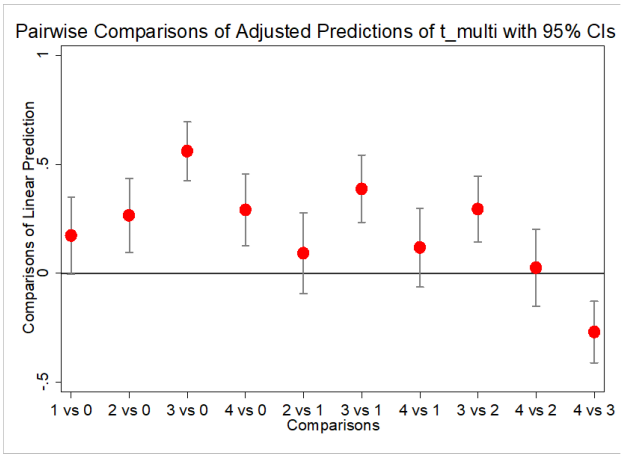
Note: * p <0.1, ** p<0.05, ***p<0.001; Grey area: ATE not statistically significant.
Full estimates including β coefficients, t-tests and statistical significance for ACME, ADE, ATE available in Table A4 and A5, Appendix 3.



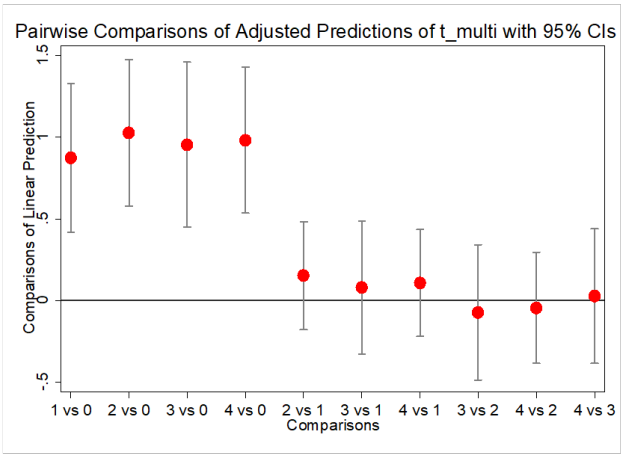
Source: Adapted from Biggeri et al. (2018)

Figure 1. The AVCPO Theory of Change and expected impacts on SDGs

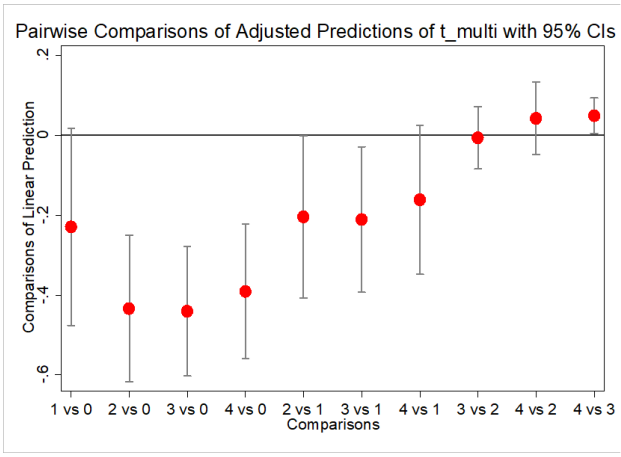
a. SDG2: % Growth of cereal production value



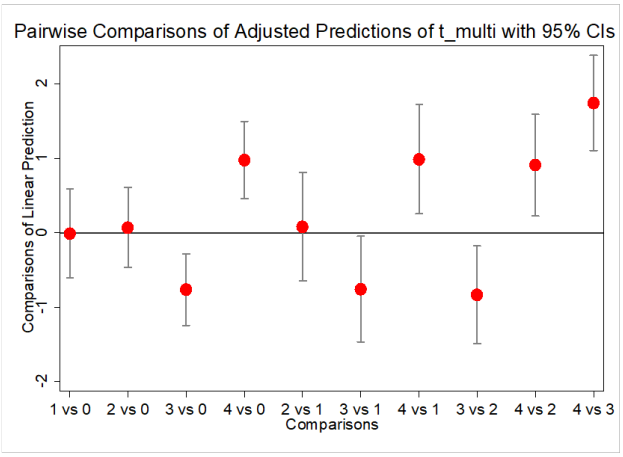
b. SDG2: Return to family labour (ln)



c. SDG2: HFIAS



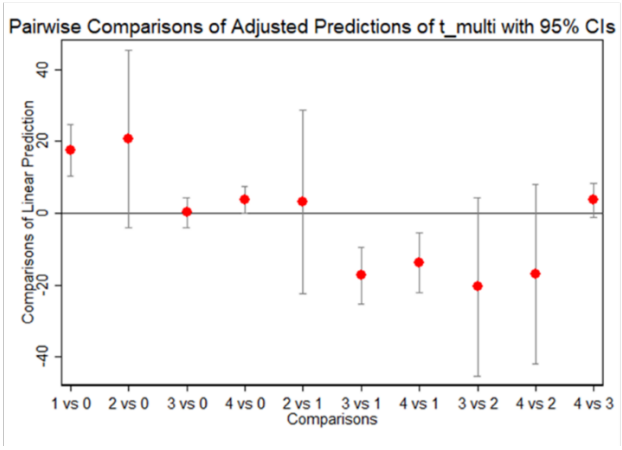
d. SDG2: HDDS



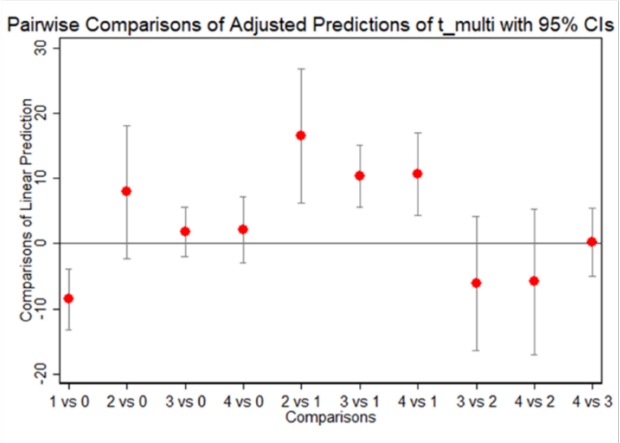
Note: Multivalued treatment effects are estimated using the Efficient-influence function (EIF) estimator proposed by Cattaneo (2010) using the '*poparms'* command in STATA 14. Estimates for all SDG2 outcomes available on-line as Supplementary material.

Figure 2. Pairwise contrasts of adjusted prediction of multi-level treatment: SDG2 selected outcomes

a. SDG4: Boys 6-18, avg weekly hours spent in education



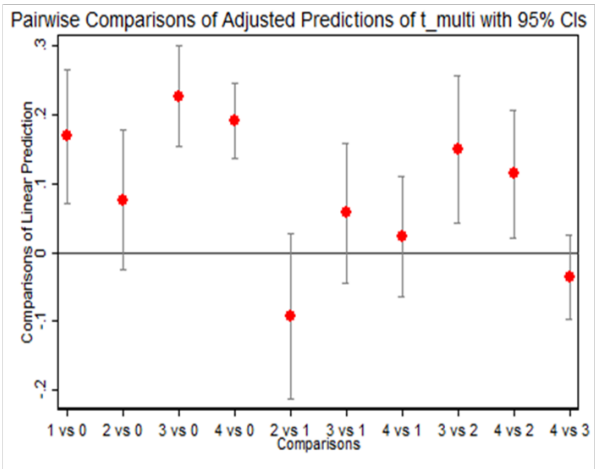
b. SDG4: Girls 6-18, avg weekly hours spent in education



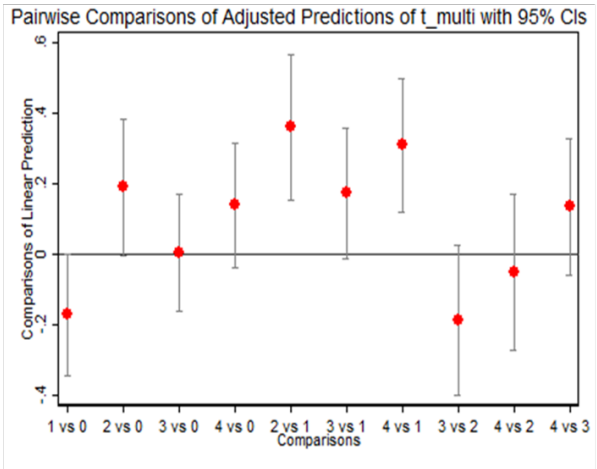
Note: Multivalued treatment effects are estimated using the Efficient-influence function (EIF) estimator proposed by Cattaneo (2010) using the '*poparms'* command in STATA 14. Estimates for all SDG4 outcomes available on-line as Supplementary material.

Figure 3. Pairwise contrasts of adjusted prediction of multi-level treatment: SDG4 selected outcomes

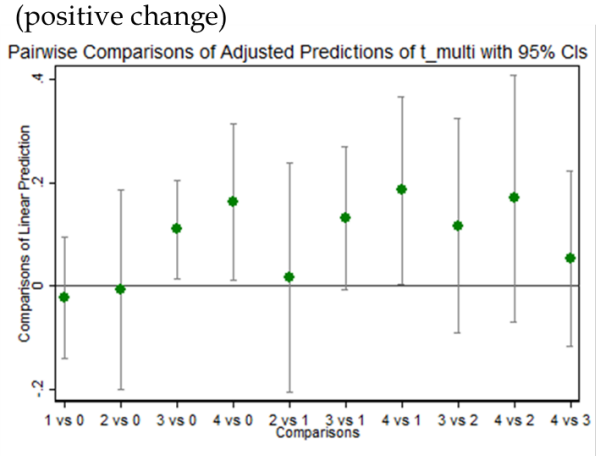
a. SDG 16: Participation in coop activities (positive change)



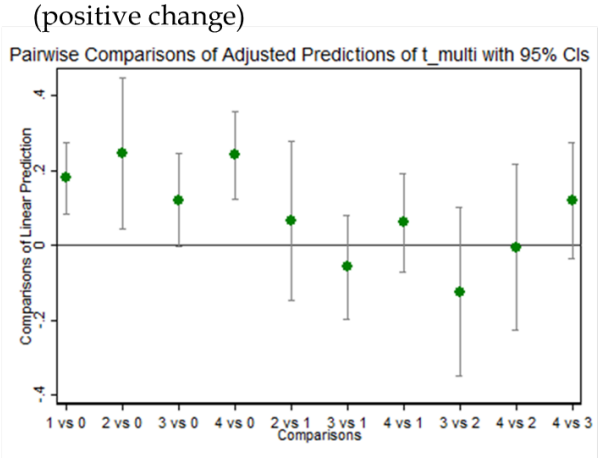
b. SDG 16: Participation in social activities (positive change)



c. SDG 16: Trust towards the coop management (positive change)



d. SDG 16: Satisfaction about being a farmer (positive change)



Note: Multivalued treatment effects are estimated using the Efficient-influence function (EIF) estimator proposed by Cattaneo (2010) using the '*poparms'* command in STATA 14. Estimates for all SDG16 outcomes available on-line as Supplementary material.

Figure 4. Pairwise contrasts of adjusted prediction of multi-level treatment: SDG16 selected outcomes

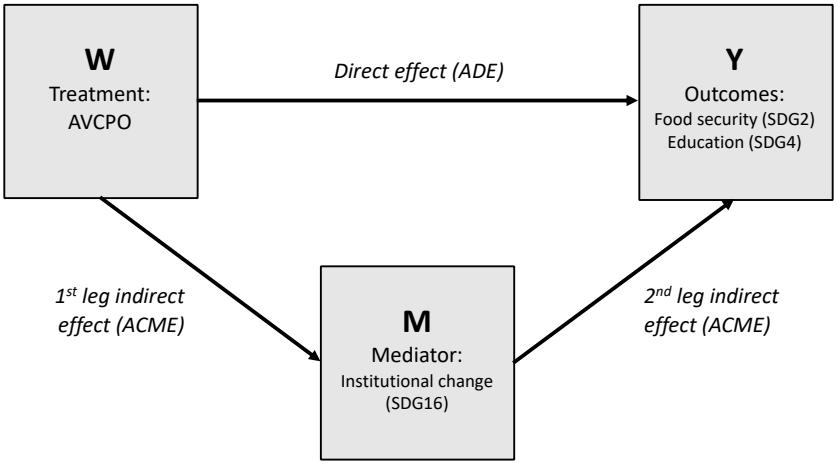


Figure 5. Causal mediation analysis of the AVCPO