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Notices

The Impact of Ethiopia's Direct Seed Marketing Approach on Smallholders' Access to Seeds, Productivity, and Commercialization*

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Abstract

Several factors contribute to the low level of improved variety use in Ethiopia. Among those, on the supply side, is the limited availability of seed in the volumes, quality, and timeliness required by farmers, which is partly a result of limited public and private investment in the sector. Beginning in 2011, the Government of Ethiopia introduced a novel experiment-the Direct Seed Marketing (DSM) approach-to reduce some of the centralized, state-run attributes of the country's seed market and rationalize the use of public resources. DSM was designed to incentivize private and public seed producers to sell seed directly to farmers rather than through the state apparatus. This study is the first quantitative evaluation of DSM's impact on indicators of a healthy seed system: access to quality seeds, on-farm productivity, and market participation of smallholders. Using a quasi-experimental difference-in-differences approach, the study finds that DSM led to a 26 percent increase in maize yields and a 5 percent increase in the share of maize harvest sold. DSM also led to improvements in seed availability for all three of Ethiopia's major cereals: maize, wheat, and teff. However, DSM's effects on yields and share of harvest sold are not statistically significant for wheat and teff. These crop-specific differences in performance are likely explainable by biological differences between hybrid maize and openly pollinated varieties of wheat and teff that incentivize private sector participation in maize seed markets over wheat and teff seed markets. These differences demand different policies and perhaps even institutional approaches to accelerating adoption between hybrids and OPVs.

Keywords: Seed system, direct seed marketing, productivity, commercialization, Ethiopia

JEL classification: Q120; Q130

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Acronyms

ACC Agricultural Commercialization Cluster

ACLED Armed Conflict Location and Event Data Project

ATA Agricultural Transformation Agency

BoA Bureau of Agriculture

CGIAR Consultative Group on International Agricultural Research

DID Difference-in-Differences

DSM Direct Seed Marketing

EEA Ethiopian Economic Association

EEPRI Ethiopian Economic Policy Research Institute

EIAR Ethiopian Institute of Agricultural Research

ESA Ethiopian Seed Association

ESE Ethiopian Seed Enterprise

FDRE Federal Democratic Republic of Ethiopia

IFPRI International Food Policy Research Institute

ISSD Integrated Seed Sector Development

MoA Ministry of Agriculture

OPV Openly Pollinated Variety

SNNP Southern Nations, Nationalities, and Peoples

SSA Sub-Saharan Africa

WB World Bank

WUR Wageningen University & Research

1 Introduction

Like in much of Africa South of the Sahara (SSA), agriculture is a critical sector in the Ethiopian economy. One of the key challenges faced by the sector are low levels of crop productivity and commercialization. Among other factors, this is largely due to the low adoption of improved crop technologies (Dorosh and Rashid, 2013), particularly improved varieties and quality seeds of those varieties. Although Ethiopia experienced an increase in improved variety adoption for its main cereal crops between 2010 and 2015, only about a quarter of all smallholders were using improved varieties in 2015, with relatively higher concentration among maize producers (32%). Even where improved varieties are prevalent, as among wheat producers, the use of certified seed is low (9%), which is well below recommended replacement rates. Both improved variety adoption and seed replacement rates are lower for most other crops in Ethiopia (Mekonen et al., 2019). The same trend is observed in terms of area planted with improved varieties or certified seed (Alemu, 2010; Alemu, Rashid, and Tripp, 2010; Spielman and Mekonnen, 2013).

Low rates of improved variety adoption and seed replacement rates are often associated with supply and demand constraints in the seed market. On the supply side, improved varieties or quality seeds are either not available at all or not supplied at the right quantity, time, or location, or do not embody the traits desired by the farmer (Spielman and Mekonnen, 2013; Alemu and Tripp, 2010; EIAR, 2020). On the demand side, seed market performance is often constrained by farmers' limited awareness of traits embodied in an improved variety, or by other well-documented factors such as credit and liquidity constraints, their perceptions of production and market risks or climate uncertainty, and a range of behavioral factors

(Alemu, 2010; Alemu, Rashid, and Tripp, 2010; Spielman and Mekonnen, 2013).

Like many developing countries, Ethiopia's seed market was largely state controlled, with public organizations charged with managing breeding, multiplication, and distribution to farmers - an end-to-end system that offered few opportunities for private investment anywhere in the supply chain (Spielman and Mekonnen, 2013). The Government of Ethiopia, working closely with Wageningen UR and other partners, began experimenting with seed market liberalization in 2011 in an intentional effort to allow seed producers to market seed directly to farmers, rather than through the state's rural administrative apparatus. This "Direct Seed Marketing (DSM)" approach aimed to increase the supply of improved varieties and quality seed to farmers while rationalizing the use of public resources allocated to the distribution of seed to fragmented, spatially dispersed, resource-poor smallholders that make up the vast majority of farmers in Ethiopia (MoA/ATA, 2016). Since its launch in 2011, the DSM has been promoted and closely monitored by a number of government entities (e.g., the ATA, regional BoA) and their development partners (e.g., ISSD). Benson, Spielman, and Kasa (2014) undertook an operational evaluation of the pilot DSM program and found encouraging results, ultimately recommending that the government stay the course and advance the seed sector reform process. Mekonen et al. (2019) undertook a descriptive analysis of DSM's key performance indicators such as seed availability, quality, sufficiency, price competitiveness, supply timeliness, and accountability. Mixed results were documented, including differences in performances between regions as well as across crops.

But to date, there has been no rigorous assessment of DSM's impact on these first-order performance indicators. Nor has there been an assessment of DSM's impact on secondary and tertiary level outcomes such as changes on productivity and commercialization. The availability of three rounds of a nationally representative household-level panel dataset from DSM and non-DSM *woredas* in 2012 (the beginning of DSM's pilot phase), 2016 and 2019 (after the program has reached more than two hundred *woredas* (districts)) provides an opportunity to fill this gap in the evaluative literature on DSM.

This study exploits the staggered approach of DSM's scale-up over time in both spatial reach and crop coverage. This staggered scale-up allows us to analyze the impact of DSM on key indicators of a healthy seed system: access to seeds, crop productivity, and market participation of smallholders as measured by share of harvest sold to the market. Using a quasi-experimental difference-in-differences econometric approach, the study finds that DSM led to a 26 percent increase in maize yields and a 5 percent increase in the share of maize harvest marketed. DSM also led to improvements in seed availability for all the three major grains studied: maize, wheat, and teff. In addition, compared to 2012, DSM has led to a 27 kg increase in wheat seed purchased per hectare in 2019, which is equivalent to 108 percent of the average wheat seed purchased per hectare in non-DSM *woredas* in 2019. However, the effects of DSM on yield and share of harvest sold are not statistically significant for wheat and teff. The results suggest caution in the scaling of the DSM approach, particularly for self- and -open pollinated varieties (as opposed to hybrid maize), and particularly in the time period when DSM is first introduced to the *woreda*. While the pro-market dimension of these findings are fairly straightforward for maize—DSM for hybrid maize succeeds because farmers need to purchase fresh seed each season to capture the yield gains conferred by heterosis, which is a characteristic not present in other major crops in Ethiopia—it raises important questions about how markets for other crops will attract private investment and allow the government to reallocate budgetary resources to other development priorities.

This paper is structured as follows. Section 2 describes the conventional public seed distribution system and the direct seed marketing (DSM). Section 3 defines the data and undertakes a descriptive analysis. Section 4 outlines the econometric model underlying the evaluation and section 5 presents the empirical results. Section 6 discusses the findings, and section 7 closes with a discussion of policy implications and concluding remarks.

2 Public Seed Distribution and Direct Seed Marketing in Ethiopia

Following reforms to agricultural inputs systems and markets that began in the 1990s in Ethiopia (Dorosh and Rashid, 2013), seed production and distribution was opened to the private sector, at least in principle. In reality, however, Ethiopia's seed sector remained heavily dominated by public actors such that, by 2004, no more than eight firms were active in seed production (Spielman et al., 2007), with most of them involved exclusively in hybrid maize seed multiplication and not in distribution or retail activities (Langyintuo et al., 2008). Even Pioneer, a multinational company, produced its hybrids locally and relied primarily on the public distribution system to reach farmers (Spielman and Mekonnen, 2013). Federal and regional extension and input supply agencies accounted for 80 percent of total sales of seed of improved varieties, mostly paid for with credit disbursed against public guarantees (WB, 2006). Most private seed producers were merely subcontractors to the state-owned Ethiopian Seed Enterprise (ESE) which then distributed seed through the regional extension system, cooperatives, and local administration.

The entire seed system supplied seed to farmers based on official demand projections that were formally estimated at the local administrative level and then aggregated upwards and transmitted through official channels to the regional levels, after which they were further aggregated to the national level and used to determine the type of varieties and quantity of seed that was to be produced by ESE and distributed back down to farmers (Spielman et al., 2007).

Likewise, the promotion and marketing of new varieties and commercial seed were largely the mandate of public extension and administrative entities at the *woreda* and *kebele* level (Spielman and Mekonnen, 2013; Alemu and Bishaw, 2016).[1] Many studies of Ethiopia's seed system highlight the myriad bottlenecks and issues created by this system of intensive state management, including inaccurate and often ad hoc demand assessments resulting in persistent mismatches between demand and supply, large carryovers of unsold seed between seasons and years, late supply of seed to farmers, high seed prices relative to farmers' purchasing power, and seed quality issues, among other problems (Sahlu and Kahsay, 2002; DSA, 2006; EEA/EEPRI, 2006; Alemu, Rashid, and Tripp, 2010; Atilaw and Korbu, 2012; Spielman and Mekonnen, 2013; EIAR, 2020).

Despite policies favorable to private sector development, including a plant breeder's law that came into effect in 2006 (FDRE, 2006), efforts to attract private investors to Ethiopia's seed sector as a way of addressing the public sector's shortcomings have been severely constrained by several factors. The primary constraint to attracting private investment is the continued existence of the state-led seed system–including the introduction of several

[1] A *kebele* or peasant association (PA) is the lowest administrative unit below the *woreda* (district) level, and corresponds roughly to a cluster of villages.

state-owned regional seed enterprises in the early 2010s, in addition to ESE−which effectively crowds out private sector participation. Private investors must contend with the high costs of building distribution and marketing networks that can compete with the public sector's own system, the low nominal prices (and declining real prices) for ESE seed, and the indirect costs of navigating the regulatory system, accessing financing from a risk-averse banking sector, and meeting high collateral requirements in financial markets (Spielman et al., 2010; Husmann, 2015; ESA, 2018).

Cognizant of these many constraints and the burden that the state-run system was imposing on scarce public budgetary resources, the Government of Ethiopia began experimenting with the DSM approach beginning in the early 2010s. The DSM approach was piloted by the Integrated Seed Sector Development (ISSD) initiative, a project led by Wageningen UR, in two *woredas* of Amhara region[2]. In 2012, there were seven additional *woredas* under DSM, while the two original *woredas* in Amhara region briefly interrupted the program in 2012 but restarted again in 2013 (Mekonen et al., 2019). The approach was later expanded in 2013 by the Ethiopian Agricultural Transformation Agency (ATA) and the Ministry of Agriculture (MoA). DSM aims to develop a dynamic, effective, efficient, and well-regulated seed sector that provides farmers with timely access to varied, sufficient, affordable, and high-quality seeds at competitive prices (Benson et al. 2014). As of 2016, the number of DSM *woredas* has reached 100. In 2019, the number of DSM *woredas* in the country has reached 290, located in Ethiopia's four main agricultural regions (Amhara, Oromia, Southern Nations, Nationalities, and Peoples' (SNNP), and Tigray regions). Since inception, DSM has grown considerably both in terms of the number of private agents (individual input dealers) participating and

[2]There are currently about 670 rural *woredas* in Ethiopia.

the crops covered by the program (Table 1).

Table 1: *The evolution of the Direct Seed Marketing (DSM) program (2011 - 2019)*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of woredas	2	6	33	54	83	100	132	228	290
Number of agents	n/a	29	124	294	456	650	800	1163	1400
Number of crops	1	1	1	4	6	6	7	8	10

Source: ATA (2020).
Note: n/a = not available.

Under DSM, both public and private seed producers are authorized to directly market their seeds through multiple channels such as primary cooperatives, individual or private agents, and their own trading outlets. The model distinguishes itself from the conventional seed marketing system in many ways. First, it is designed to allow both public and private seed producers to conduct their own demand assessments and then multiply and market seed according to these assessments. This is intended to overcome the demand and supply mismatch and costly inventory carryovers. Second, DSM aims to considerably shorten the seed distribution chain by allowing seed producers to market directly to farmers, thereby reducing both the direct and indirect transaction costs of distributing through the public system. Third, DSM seeks to create a competitive seed market at the last mile by allowing seed producers to promote their seed and to compete with other seed producers based on seed price, traits, quality, timeliness of delivery, and other attributes. Fourth, DSM potentially improves seed traceability, thereby providing an accountability mechanism that renders seed producers (instead of extension agents) directly responsible to farmers for seed quality. This accountability mechanism is as important for extension agents as it is for farmers and seed providers: by removing extension agents from the seed exchange equation, extension agents reduce their exposure to reputational risks that accompany the distribution of poor-quality seed to farmers under the conventional state-led distribution system (Benson, Spielman, and Kasa, 2014; Mekonen et al., 2019).

DSM's commercial orientation also aims to free up scarce public resources and expert time that can be better used to improve the overall seed system and extension service in Ethiopia (Mekonen et al., 2019). For instance, DSM removes extension agents from the task of assessing seed demand and distributing seed to farmers, thereby allowing them to focus on the provision of better quality and more timely advisory services to farmers. Similarly, DSM removes seed system experts in the public sector from similar tasks, providing opportunities to reassign them to varietal development, quality assurance, and other necessary functions. In effect, DSM offers an opportunity to reallocate scarce public resources to those activities that are necessary to make seed markets work effectively and efficiently for both farmers and seed producers.

The performance of the DSM program has been monitored and assessed frequently since its inception to gauge its impact on the timely provision of quality seed to farmers in appropriate quantities and at competitive prices. While results from operational assessments have been critical in informing government actors who were initially hesitant to concede seed marketing responsibilities to private agents and facilitate the program's expansion, its impact on higher order outcomes such as crop productivity and commercialization have not yet been studied. This study aims to fill this empirical gap.

3 Data and descriptive statistics

This analysis uses data from the three household surveys conducted in 2012, 2016, and 2019 by Ethiopia Agricultural Transformation Agency (ATA) and the International Food Policy Research Institute (IFPRI).

Table 2 shows the panel structure of the ATA/IFPRI survey data at the *woreda* level. A total of 63 *woredas* were sampled in all three rounds of the survey, while 29 *woredas* were sampled in the 2012 and 2016 rounds, and 30 in 2016 and 2019 rounds. A total of 122 *woredas* were thus included in at least two of the three survey rounds. Once we account for the 99 *woredas* that appeared in only one round each, there are a total of 221 distinct *woredas* in the sample.

Table 2: *Woreda level panel structure*

Panel Structure	Survey Year			
	2012	2016	2019	Total
Only in 2012	7	0	0	7
Only in 2016	0	31	0	31
Only in 2019	0	0	61	61
Only in 2012 & 2016	29	29	0	29
Only in 2016 & 2019	0	30	30	30
In all years	63	63	63	63
Total	99	153	154	221

At the household level (Table 3), a total of 1,899 households were sampled in all three rounds of the survey, while 889 households were sampled in both the 2012 and 2016 rounds, and 1,136 households in both the 2016 and 2019 rounds. This provides us with 3,935 households that were interviewed in at least two rounds of the survey. Including those interviewed only in one of the survey rounds, the total number of households in the sample is 5,697. Over the three rounds of the survey, the number of household observations totals 13,302.

Table 3: *Household level panel structure*

Panel Structure	Survey Year			
	2012	2016	2019	Total
Only in 2012	201	0	0	201
Only in 2016	0	1067	0	1067
Only in 2019	0	0	2265	2265
Only in 2012 & 2016	889	889	0	1778
Only in 2012 & 2019	11	0	11	22
Only in 2016 & 2019	0	1136	1136	2272
In all years	1899	1899	1899	5697
Total	3000	4991	5311	13302

The DSM rollout beginning in 2011 varied in terms of crop and *woreda* coverage. At inception in 2011, the pilot focused on hybrid maize seed in just two *woredas* in Amhara region. In 2012, the program expanded into SNNP region with hybrid maize in one *woreda* and wheat in four *woredas*. In 2014, the expansion to Tigray region led to the introduction of open-pollinated varieties of wheat, teff, and barley (Mekonen et al., 2019).

Table 4 shows that only one of the *woredas* in the 2012 ATA/IFPRI survey was part of the DSM program for maize. Unfortunately, this *woreda* cannot be included in our analysis owing to the absence of pre-intervention data. In the 2016 and 2019 survey rounds, the number of *woredas* under the DSM approach for hybrid maize increased to 21 and 57, respectively. While none of the *woredas* were under DSM for wheat and teff in the 2012 survey, the coverage increased in subsequent years. Specifically, the number of *woredas* under DSM for wheat in the survey increased to 14 and 34 in 2016 and 2019, respectively. Likewise, the number of *woredas* under DSM for teff has increased to 3 and 19 in 2016 and 2019, respectively.

Table 4: *DSM Status of woredas over survey years, by crop*

Crop Type	DSM status	Survey Year			
		2012	2016	2019	Total
Maize	0	92	112	66	270
	1	1	21	57	79
Wheat	0	69	91	74	234
	1	0	14	34	48
Teff	0	68	99	93	260
	1	0	3	19	22

Table 5 shows that 2,912 households sampled in the ATA/IFPRI survey produced maize in *woredas* that were not part of the DSM program in any of the three survey rounds, while 1,960 households produced maize in *woredas* that were part of the program in at least one of the survey years.

Table 5: *Household DSM panel by crop type*

Crop Type	DSM crop_panel	Survey Year			
		2012	2016	2019	Total
Maize	0	912	1288	712	2912
	1	272	452	795	1519
	2	99	171	171	441
Wheat	0	570	901	947	2418
	1	140	246	335	721
	2	78	132	132	342
Teff	0	531	792	817	2140
	1	36	96	267	399
	2	26	42	42	110

Descriptive statistics of key observable characteristics among households is presented by the DSM status of the household's *woreda* in Table 6, along with the mean value of the whole sample in the baseline year (2012). While DSM and non-DSM sub-groups are comparable in certain years on observable characteristics such as number of oxen owned, conflict-related fatalities, rainfall during the kiremt (the long rainy season period that runs from June to September), and access to market, they significantly differ on other dimensions such as household size and agricultural input use. In particular, households in the DSM group are relatively larger and use more chemical fertilizer, manure, and pesticides (Table 6). Our impact estimates presented later in the paper control for these variables.

Table 6: *Summary statistics of independent variables*

Variables*	2012	2016				2019			
	Mean	Non DSM	DSM	dif	p-val	Non DSM	DSM	dif	p-val
Household size	1.857	1.905	1.938	-0.034	0.020	1.855	1.91	-0.055	0.000
Number of oxen owned	0.863	0.925	0.922	0.003	0.907	0.913	0.991	-0.077	0.000
Fatalities	0.634	7.54	8.616	-1.075	0.456	1.02	0.837	0.182	0.298
Average kiremt rainfall	6.628	6.276	6.368	-0.092	0.001	6.556	6.553	0.003	0.819
Time to weekly market	4.113	3.899	3.746	0.153	0.001	3.788	3.828	-0.04	0.215
Chemical fertilizers (kg)	2.475	2.983	4.035	-1.052	0.000	3.910	4.530	-0.620	0.000
Manure used (kg)	2.209	2.433	2.861	-0.429	0.002	1.142	1.794	-0.651	0.000
pesticides use (yes=1)	0.278	0.373	0.530	-0.158	0.000	0.327	0.448	-0.121	0.000
N	1969	2342	628			1661	1462		

* Except the number of fatalities and pesticide use, other variables are in logarithmic transformations.

The descriptive statistics of our main outcome variables are provided in Table 7, again by DSM status of the household's *woreda*. The figures for seed purchases show a substantial difference between DSM and non-DSM households across the three crops considered. Specifically, DSM households purchased significantly more maize and wheat seeds during both the 2016 and 2019 survey rounds. In contrast, non-DSM households purchased relatively more teff seed in 2016 compared to their non-DSM counterparts. Figures for yield and the share of harvest sold show similar patterns, especially with respect to maize and teff. While maize yields and share of harvest sold are significantly higher for DSM households, non-DSM households performed relatively better in teff yield and share of harvest marketed in some of the survey years. There is not much difference between DSM and non-DSM households on wheat yield and marketed surplus, except in 2019 where households in DSM *woredas* marketed a larger share of their harvest. However, at this juncture, we cannot make any observations about causality that links the DSM program to these differences without accounting for potentially confounding factors.

Table 7: *Summary Statistics of Yield (kg/ha), Share of crop sold and Seed purchased*

	2012	2016				2019			
Crops	All mean	Non-DSM	DSM	dif	p-val	Non-DSM	DSM	dif	p-val
Yield in kg/ha									
Maize	2417.456	2351.785	2950.063	-598.278	0.000	2187.192	3074.481	-887.290	0.000
Wheat	2095.776	1967.258	2086.405	-119.147	0.311	2401.336	2509.428	-108.091	0.278
Teff	1233.891	1266.654	1033.950	232.703	0.080	1403.137	1427.900	-24.763	0.706
Share of harvest sold									
Maize	0.126	0.117	0.185	-0.069	0.000	0.131	0.182	-0.051	0.000
Wheat	0.168	0.163	0.182	-0.020	0.228	0.152	0.197	-0.045	0.001
Teff	0.222	0.304	0.248	0.056	0.191	0.264	0.215	0.049	0.011
Seed purchased in kg/ha									
Maize	13.367	12.808	18.516	-5.708	0.000	12.100	17.512	-5.412	0.000
Wheat	42.305	35.912	67.627	-31.715	0.000	25.493	63.978	-38.486	0.000
Teff	9.781	8.470	3.050	5.420	0.035	8.335	8.974	-0.639	0.682
Observations									
Maize	1283	1522	389			712	966		
Wheat	788	1039	240			947	467		
Teff	593	876	54			817	309		

4 Empirical Model

The econometric approach exploits differences in the rollout of the DSM progam for a specific crop across *woredas* over time. The 2012 ATA/IFPRI survey was implemented before the introduction of DSM in the sample *woredas*, while the 2016 and 2019 survey rounds correspond with increasing coverage of DSM. The presence of DSM and non-DSM *woredas* in each year provide an opportunity to employ a quasi-experimental difference-in-differences (DID) approach in which we compare key program outcomes (i.e., yields and market sales by crop) between households residing in DSM and non-DSM *woredas* before and after the *woreda*'s inclusion in the DSM program. Formally, the DID method is represented in equation 1:

$$Y_{hwt} = \alpha_w + \beta_t + \delta_{wt} + \gamma_{hwt} + \theta_{rt} + \phi_{wt} + \omega_w + \epsilon_{hwt} \tag{1}$$

where Y_{hwt} is the log of yield and the share of crop sold by household h in *woreda* w and year t either for wheat, maize, or teff; α_w is a treatment indicator showing whether the *woreda* is included in the DSM program for a given crop; β_t are time fixed effects; δ_{wt} are interaction terms of time fixed effects and the treatment indicator, capturing the treatment effects of the DSM program in 2016 and 2019; γ_{hwt} denotes a vector of household-specific control variables for household h in *woreda* w at time t; θ_{rt} are the region and time interactions to control for region-specific trends; ω_w denotes time-invariant *woreda* fixed effects; ϕ_{wt} are time-varying *woreda*-level control variables; and ϵ_{hwt} is the error term. Standard errors are clustered at the *woreda* level given that DSM is a *woreda* level intervention. The region and time interactions (θ_{rt}) are needed as state-owned regional seed enterprises and research organizations play a key role in seed multiplication, and unparalleled trends across regions may cause biases in estimation if left uncontrolled for in the estimations. The time fixed effects (β_t) refer to 2012, 2016, and 2019, with 2012 referencing the period before the DSM program began.

The household-specific control variables (γ_{hwt}) include household size, size of land ownership, number of oxen owned, time to weekly markets, and use of chemical fertilizers, manures, and pesticides. The control variables include size of land owned by the household in the commercialization equation, though this is not needed for the yield equation given the dependent variable is measured on a per-hectare basis. The *woreda* level time-varying control variables (ϕ_{wt}) include average rainfall in the main production season (*Meher*), whether the *woreda* is part of ATA's agricultural commercialization cluster (ACC) program, and the number of reported conflict-related fatalities in the *woreda* in the survey years and the year before.[3] Note that Ethiopia witnessed significant civil unrest in the years preceding the 2018 government reform. The *woreda*-level conflict-related fatalities data, obtained from the Armed Conflict Location and Event Data Project (ACLED), is used as a proxy for the level of civil unrest and conflict intensity in the *woreda*, and accounts for the likely destabilizing effects that unrest potentially has on input supply systems and market participation by farmers.

Different versions of equation 1 were also fit to understand the mechanisms through which DSM affects yield and commercialization of crops. The first estimation to understand mechanisms uses quantity of seed purchased per hectare and fits the same model as in equation 1 with the change in the dependent variable. The other two estimations to understand mechanisms of the effect of DSM on yield and commercialization of crops deals with changes in seed availability and seed quality compared to the year preceding the survey as this is how the questions were asked in the survey. Farmers were given three response options when asked about seed availability and quality compared to last year: whether quality or availability has worsened, remained the same, or improved. This required three changes to

[3]ACC is the flagship program of the ATA and it promotes geographic farming clusters specializing in priority commodity to facilitate integrated and targeted support towards accelerating the agricultural transformation process. It is also intended to serve as models for learning as the country scales up best intensification and commercialization practices across the board.

our estimation of equation 1. First, given that farmers were asked to respond to changes only compared to the preceding year, *woredas* in which DSM has started more than a year ago are likely to get a no-change response even if the program led to changes in availability or quantity. Thus, we restricted the data to *woredas* where DSM for a specific crop was introduced in the survey year. Second, given the ordinal responses of "worse, the same, and better than last year", we fit the model using ordered probit estimations. Third, changes in seed availability and quality have less to do with household characteristics but with *woreda* level characteristics such as DSM and ACC status, distance to markets, rainfall, and conflicts along with time dummies and region specific trends. Hence, we excluded γ_{hwt} – the vector of household specific control variables – from the estimating equation for seed availability and quality.

5 Results

Table 8 presents the DID results for the *woreda*-level impact of DSM on maize, wheat, and teff yields. Results show that DSM led to a significant improvement in maize yields. Households in DSM *woredas* show a 26 percent increase in maize yields in 2019 compared to 2012 (the pre-DSM period).[4] However, the impact of DSM on wheat and teff yields is not statistically significant, indicating no discernible impact of DSM on these crops. The full set of regression coefficients is provided in Table A.1 in the appendix.

[4]The 26% yield change is computed by converting the coefficient on log yield to yield, i.e, exp(0.231) - 1 = 0.26.

Table 8: *Crop Productivity impact of DSM*

	Maize	Wheat	Teff
DSM status =1	-0.0187	0.248***	0.214*
	(0.084)	(0.084)	(0.120)
2016	-0.195	-0.234**	
	(0.126)	(0.117)	
2019	-0.124	-0.122	-0.136
	(0.108)	(0.152)	(0.129)
DSM status =1 × 2016	0.0644	-0.0549	
	(0.080)	(0.103)	
DSM status =1 × 2019	0.231***	0.0432	0.0745
	(0.085)	(0.123)	(0.105)
Observations	4845	3476	2056

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9 presents the DID results on the impact of DSM on the intensity of market participation of maize, wheat, and teff, where market participation is measured as the share of harvest sold in the market. The results show that DSM has led to a 4.8 percentage point increase in the share of maize harvest sold to the market in 2019. The results on the impact of DSM on the share of wheat and teff harvest sold are not statistically significantly different from zero. The full set of regression coefficients is provided in Table A.2 in the appendix.

Table 9: *Crop Commercialization (Share of Harvest) Impact of DSM*

	Maize	Wheat	Teff
DSM status =1	-0.000180	0.0325	0.00590
	(0.022)	(0.032)	(0.052)
2016	-0.0172	-0.0199	
	(0.014)	(0.035)	
2019	-0.0185	-0.0421	-0.172***
	(0.017)	(0.033)	(0.049)
DSM status =1 × 2016	0.00825	0.000487	
	(0.020)	(0.026)	
DSM status =1 × 2019	0.0476**	0.0303	-0.0607
	(0.021)	(0.030)	(0.037)
Observations	4814	3461	2036

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10 presents the impact of DSM on seed availability and seed quality as well as on the quantity of seed purchased per hectare of area planted for maize, wheat, and teff. The results are important in understanding the first order effects of DSM on indicators of a healthy seed system and shed light on the mechanisms through which DSM affects yield and market participation of households. The results show that DSM has led to significant improvements in seed availability for maize, wheat, and teff in 2019. In addition, DSM has led to a 27 Kg increase in wheat seed purchased per hectare in 2019, compared to 2012. This impact is equivalent to 108 percent of the average wheat seed purchased per hectare in non-DSM *woredas* in 2019. However, the effect of DSM on seed quality for all the three crops and its effect on quantity of seed purchased per hectare for maize and teff, are not statistically significantly different from zero. As such the result indicates that the main mechanism through which DSM led to improved maize yield and commercialization in Ethiopia is primarily through improving seed availability. It appears that the improvements in seed availability and seed quantity purchased due to DSM in wheat and seed availability in teff are not big enough to be reflected in improved yield and commercialization for these two crops.

Table 10: *Seed Availability and seed quality improvement perceptions*

	Seed Availability			Seed Quality		
Indicators	Maize	Wheat	Teff	Maize	Wheat	Teff
DSM status =1	-0.144	0.094	-0.208	-0.125	-0.019	-0.388
	(0.173)	(0.206)	(0.304)	(0.155)	(0.297)	(0.346)
2016	-0.425*	0.173		-0.443**	0.107	
	(0.220)	(0.512)		(0.197)	(0.520)	
2019	-1.197***	-0.841**	-1.288**	-1.167***	-1.273***	-0.417
	(0.175)	(0.367)	(0.536)	(0.217)	(0.346)	(0.585)
DSM status =1 × 2016	-0.110	0.035		0.017	0.081	
	(0.221)	(0.211)		(0.186)	(0.286)	
DSM status =1 × 2019	0.531*	0.752**	1.119**	0.323	0.498	0.802
	(0.307)	(0.334)	(0.522)	(0.255)	(0.383)	(0.513)
Observations	1145	818	556	1143	818	557
	Quantity of seed purchased (kg/ha)					
DSM status=1	-3.562	-6.361	-3.784			
	(4.517)	(9.485)	(3.174)			
2016	0.272	-17.26				
	(2.119)	(17.049)				
2019	-0.327	-59.78***	3.237			
	(2.352)	(13.664)	(3.002)			
DSM status=1 × 2016	2.491	11.29				
	(2.323)	(9.731)				
DSM status=1 × 2019	0.257	27.07**	-0.104			
	(2.590)	(11.832)	(2.152)			

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: DSM status ≡ households in treatment *woredas=1, and 0 otherwise)*

Note: Seed availability and seed quality indicators are dummy variables with a value of 2 if respondents perceived seed availability/seed quality has improved relative to the previous year, a value of 1 if it remained the same, and a value of 0 if it has gotten worse.

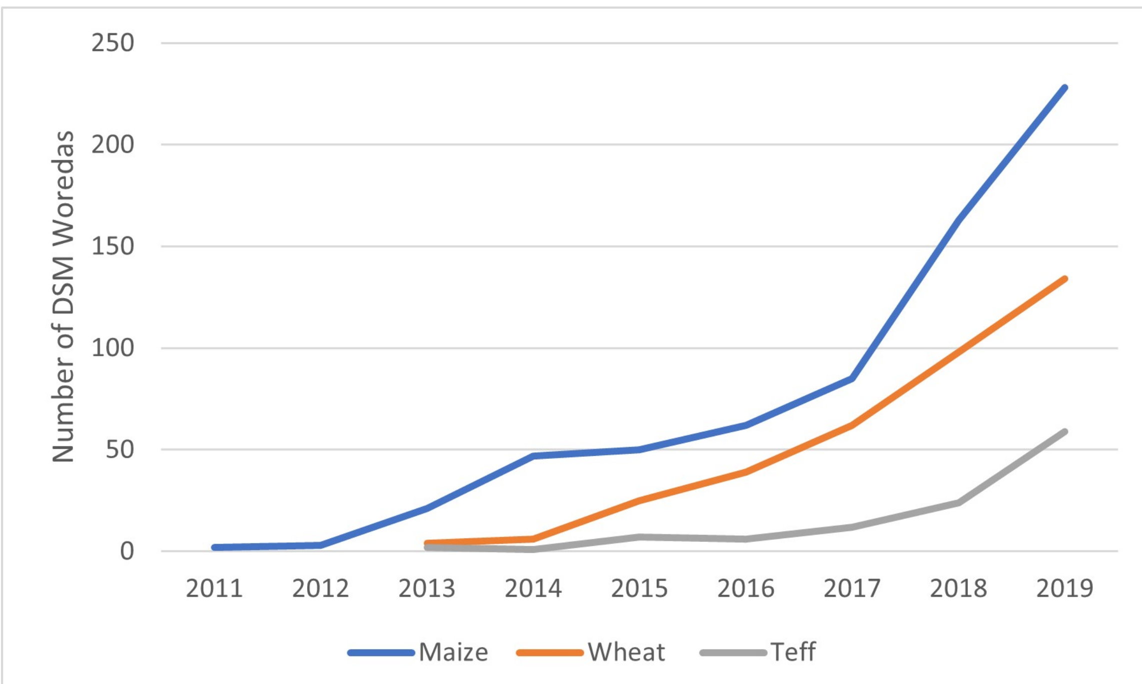
6 Discussion

This study finds that the rolling out of the DSM approach has led to increased yield and commercialization of maize primarily through improving maize seed availability. On the other hand, it finds no impact of DSM on the yield and commercialization levels of wheat and teff. There may be several explanations that can be put forward as to why we observe a positive impact of DSM on maize but not on wheat and teff.

The main argument is based on fundamental differences in incentive compatibility with respect to the provision of hybrid maize seed versus seed for open-pollinated varieties (OPVs) such as wheat and teff. The biological properties of maize hybrids require that farmers purchase fresh seed each season (rather than use saved seed) in order to realize the productivity gains conferred by hybrid vigor (also referred to as heterosis). Fresh seed purchases provide private, profit-maximizing firms with the financial incentive to aggressively produce and market hybrid seed to farmers. This incentive may also apply to state-owned seed enterprises that use the revenues from hybrid seed sales to cover losses in other areas, including OPV seed sales. OPVs, on the other hand, offer fewer opportunities to the profit-maximizing firm in terms of volume or value because farmers can readily rely on either farmer-to-farmer exchanges or saved seeds for several years without observable deterioration in yields or output (Belay, 2004; Benson, Spielman, and Kasa, 2014). Prior to the DSM program, these incentives were weak or non-existent given that the public extension system and local administrative services were entirely responsible for seed distribution and marketing. The entry of the private sector under the DSM program encourages seed producers to gauge farmers' revealed preferences and sell seed directly to them, with a focus on those seeds that are most profitable. This comes at the expense of less-profitable seeds such as wheat and teff, ultimately creating supply problems either in quality, quantity, timeliness, or availability of OPVs.

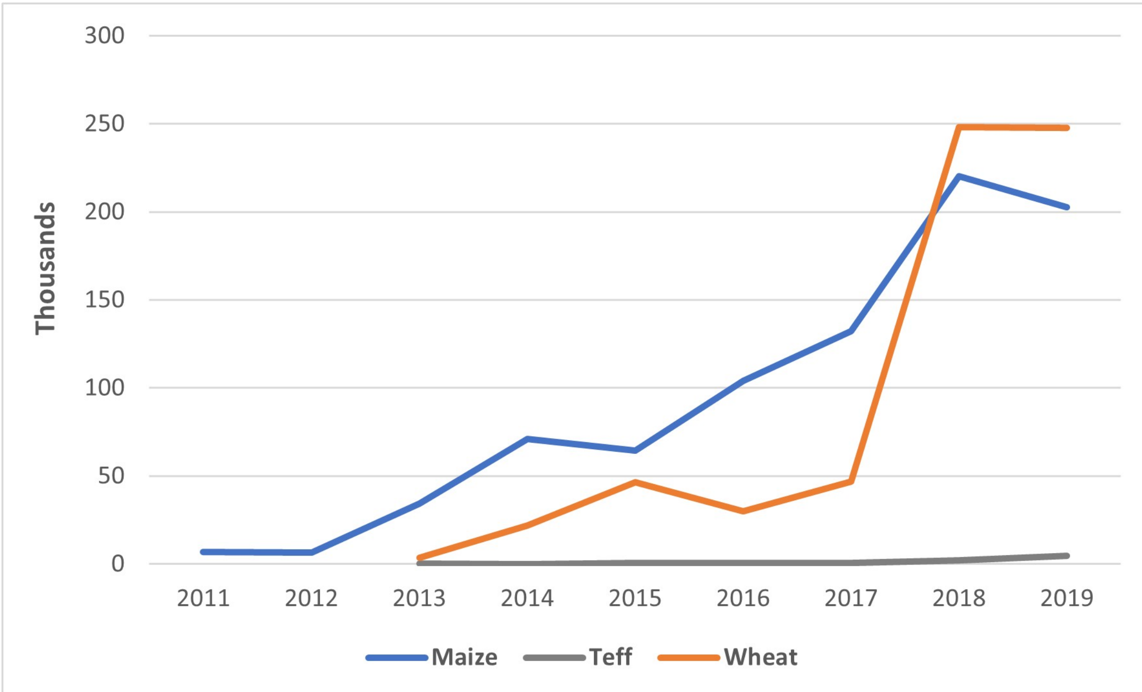
A related explanation is based on the historical evolution of DSM in Ethiopia. Even prior to the DSM program's outset, there was considerable accumulated experience with maize production and marketing, as well as revealed preferences from farmers for high-quality traits and seeds. While farmer demand for similarly high-quality traits and seeds for wheat and teff are also well understood, willingness to pay may be significantly lower.

Figure 1: *Trends of the number of DSM woredas by crop type*



As shown in Figure 1, Ethiopia–and the DSM program itself–has relatively greater experience with direct seed marketing of maize, which began in 2011, relative to wheat and teff, which started later. Figure 2 shows that maize seed supply responses occurred earlier than for wheat and teff: the inflection point capturing the increased quantity of wheat seed

Figure 2: *Trends of total quantity of seed supplied (in quintals) in DSM woredas by crop type*



supply under DSM occurred as late as 2018, and is still in its infancy for teff. First, private firms need time to gauge and respond to increased demand: seed bulking and multiplication can take two years or more depending on the availability and quality of early generation seed. This may be particularly true in Ethiopia due to limited availability and use of irrigation for off-season (dry season) seed production that allows for more rapid supply responses. Second, private firms may need time to establish their distribution channels, marketing strategies, and logistics operations to directly reach farmers as the market shifts away from public provision. In the short run, as seed suppliers establish their production systems and their supporting strategies, channels, and operations, to respond to increased demand, there is the potential for a stagnation or even deterioration in the availability, quality, and timeliness of seed delivery, with potentially detrimental outcomes for yields and commercialization. The fact that the positive results of DSM on maize seed availability, yields, and commercialization were all observed in 2019 but not in 2016, suggesting that even for maize it took some time for DSM to show statistically significant effects, gives credence to this hypothesis. In addition, it should be noted that the first hypothesis on hybrid seed maize versus mostly OPV varieties of wheat and teff can influence the time with which private and state-owned seed multipliers respond to satisfy seed demand for wheat and teff, compared to maize, as the return to agile supply response to meet seed demand is not as strong for OPVs compared to hybrid seeds.

7 Conclusions and Policy Implications

Ethiopia's seed supply system has gone through a gradual transformation over the last decade from a system where the state was predominately responsible for all aspects of the seed market – from assessing demand to organizing production to distributing seed to farmers – to a system in which private actors are playing an increasingly important role in production, marketing, and sales. This is no small feat given the history of state control over agricultural production in Ethiopia dating back to the feudal monarchy period and continuing through the socialist military dictatorship that ended in the early 1990s. The DSM program represents an important break from the past: what started with direct marketing of maize seed in two pilot *woredas* in 2011 has now expanded both in terms of crop and spatial coverage. As of 2019, DSM was being implemented in 290 *woredas*–close to half all *woredas* in the country–and covers 10 major crops. However, the absence of a rigorous evaluation of the program to highlight its impacts on key seed system indicators means that the program's proponents have had very little to show apart from achievements in coverage that can be extracted from standard monitoring data.

This study addresses this issue by examining the impact of DSM on seed availability, quality, quantity, yield, and market participation of farmers for three crops that were the initial focus of the program. It uses a quasi-experimental difference-in-differences approach to demonstrate how DSM has led to increased yield and commercialization of maize primarily through improving maize seed availability. Over all, the study finds encouraging results on the impact of DSM that include a 26 percent increase in maize yield and a 4.8 percent increase in the amount of maize harvest marketed. In addition, the approach demonstrates how DSM has led to increased seed availability for wheat and teff and seed quantity purchased per hectare has increased for wheat due to DSM, albeit without commensurate improvements in yield and commercialization for these two crops.

These crop-specific differences may be partly attributable to biological differences between hybrid maize and OPV wheat and teff that incentivize private participation in maize seed markets over wheat and teff seed markets - calling for different policies and perhaps even institutional approaches to accelerating adoption between hybrids and OPVs. The different performances may also be attributable to Ethiopia's relatively greater experience with maize direct seed marketing, which began as early as 2011, when compared to the more recent scale-up of wheat and teff DSM. The better performance of DSM (i) with maize compared to wheat and teff, and (ii) with maize in 2019 than in 2016, suggest that differences in the performance of DSM by crop are likely associated with the adjustment period required for suppliers to establish their own seed production systems, marketing strategies, distribution channels, and logistics operations to respond to growing seed demand by farmers.

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A Appendix

Table A.1: *Crop Productivity impact of DSM*

	Maize	Wheat	WTeff
DSM status =1	-0.0187	0.248***	0.214*
	(0.084)	(0.084)	(0.120)
2016	-0.195	-0.234**	
	(0.126)	(0.117)	
2019	-0.124	-0.122	-0.136
	(0.108)	(0.152)	(0.129)
DSM status =1 × 2016	0.0644	-0.0549	
	(0.080)	(0.103)	
DSM status =1 × 2019	0.231***	0.0432	0.0745
	(0.085)	(0.123)	(0.105)
Household size	-0.0489	0.0232	0.0714
	(0.038)	(0.038)	(0.048)
Number of Oxen owned	0.104***	0.193***	0.170***
	(0.027)	(0.030)	(0.037)
Fatalities in the survey years and a year before	0.000105	-0.0000447	-0.00407
	(0.001)	(0.001)	(0.005)
Average Kiremt rainfall (mm)	0.0809	-0.198	0.682**
	(0.177)	(0.161)	(0.269)
Time to weekly market (minutes)	-0.0178	-0.0114	-0.00207
	(0.015)	(0.018)	(0.023)
Chemical fertilizers used (kg)	0.0915***	0.130***	0.118***
	(0.008)	(0.011)	(0.014)
Manure used (kg)	0.0166***	0.0276***	0.0348***
	(0.004)	(0.006)	(0.007)
pesticides use (yes=1)	-0.0258	-0.00544	-0.0441
	(0.039)	(0.041)	(0.045)
Amhara	-0.00923	0.271	-0.933***
	(0.143)	(0.214)	(0.170)
Oromia	0.388***	-0.313	-0.304*
	(0.129)	(0.201)	(0.159)
SNNP	0.229*	-0.104	0.0674
	(0.119)	(0.170)	(0.185)
Amhara × 2016	0.243*	0.211	0.193
	(0.132)	(0.129)	(0.168)
Oromia × 2016	0.167	0.103	0.318**
	(0.136)	(0.127)	(0.133)
SNNP × 2016	0.206		
	(0.160)		
Amhara × 2019	-0.0371	0.0761	
	(0.121)	(0.172)	
Oromia × 2019	0.00555	-0.157	
	(0.135)	(0.143)	
SNNP × 2019	0.0473	0.236	
	(0.158)	(0.153)	
ACC for crops (yes=1)	-0.120*	-0.00167	0.0820
	(0.061)	(0.071)	(0.074)
Constant	6.395***	7.972***	1.742
	(1.178)	(1.006)	(1.774)
Woreda fixed effects	yes	yes	yes
Observations	4845	3476	2056

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: *Crop Commercialization (Share of Harvest) Impact of DSM*

	Maize	Wheat	WTeff
DSM status =1	-0.000180	0.0325	0.00590
	(0.022)	(0.032)	(0.052)
2016	-0.0172	-0.0199	
	(0.014)	(0.035)	
2019	-0.0185	-0.0421	-0.172***
	(0.017)	(0.033)	(0.049)
DSM status =1 × 2016	0.00825	0.000487	
	(0.020)	(0.026)	
DSM status =1 × 2019	0.0476**	0.0303	-0.0607
	(0.021)	(0.030)	(0.037)
ln_farmsize	0.0257***	0.0269***	0.0203***
	(0.005)	(0.005)	(0.008)
Household size	-0.0441***	-0.0605***	-0.0139
	(0.011)	(0.013)	(0.020)
Number of Oxen owned	0.0312***	0.00999	0.00449
	(0.007)	(0.009)	(0.013)
Fatalities in the survey years and a year before	-0.000585***	0.000294*	-0.000597
	(0.000)	(0.000)	(0.001)
Average Kiremt rainfall (mm)	0.0506	-0.121*	0.0496
	(0.047)	(0.065)	(0.095)
Time to weekly market (minutes)	-0.00368	-0.00935	0.00411
	(0.004)	(0.006)	(0.008)
Chemical fertilizers used (kg)	0.0284***	0.0247***	0.00589
	(0.003)	(0.003)	(0.007)
Manure used (kg)	0.000618	-0.00186	0.00269
	(0.001)	(0.002)	(0.003)
pesticides use (yes=1)	-0.00439	0.00489	0.0542**
	(0.015)	(0.014)	(0.023)
Amhara	0.00434	0.390***	-0.136*
	(0.032)	(0.063)	(0.074)
Oromia	-0.0216	0.184***	-0.0909
	(0.031)	(0.056)	(0.074)
SNNP	0.0429	0.307***	-0.323***
	(0.027)	(0.032)	(0.071)
Amhara × 2016	0.0897***	-0.00867	-0.150***
	(0.023)	(0.039)	(0.057)
Oromia × 2016	0.0323*	-0.0463	-0.155***
	(0.019)	(0.037)	(0.048)
SNNP × 2016	-0.0755***		
	(0.026)		
Amhara × 2019	0.00610	0.0938**	
	(0.028)	(0.041)	
Oromia × 2019	-0.000525	-0.0296	
	(0.025)	(0.035)	
SNNP ×2019	-0.0389	0.00952	
	(0.038)	(0.040)	
ACC for crops (yes=1)	0.00122	-0.0142	0.000599
	(0.019)	(0.018)	(0.027)
Constant	-0.269	0.842**	-0.0561
	(0.308)	(0.416)	(0.635)
Woreda fixed effects	yes	yes	yes
Observations	4814	3461	2036

Standard errors in parentheses $^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

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