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The Role of Agricultural Market Information System on Farmers' Agricultural Outcomes: Evidence from Smallholder Coffee Producers in Ethiopia

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Abstract

Using data from 466 smallholder coffee farmers in Ethiopia, this paper examines the effect of a public agricultural market information system (AMIS) on production. Our findings confirm that providing market price information via an AMIS is positively related to coffee sales, the ratio of sales to production, and coffee revenue. In addition, our study considered market heterogeneity by comparing two zones with different market characteristics. The AMIS was positively associated with increasing coffee sales, the ratio of sales to production, and coffee revenue in only one zone with lower market participation. The sales and revenue of AMIS users in the other zone with higher market participation did not increase, although the selling price did. While public information provided through information and communication technology (ICT) is beneficial to underdeveloped markets, we suggest correcting other market imperfections, which is important to maximize the utility of AMISs, would be of greater utility.

Discipline: Social Science
Additional key words: coffee farmer, ICT4D, IPWRA

Introduction

Information asymmetry between farmers and buyers is a classic source of market inefficiency (Stigler 1961). This is more important in rural areas in developing countries than in developed countries because of high transportation costs, poor infrastructure, and a limited number of buyers (Fafchamps & Hill 2008, Mérel et al. 2009, Osborne 2005). To reduce this, after marketing boards were abolished in the 1980s, many Sub-Saharan African governments introduced agricultural market information systems (AMISs), which publish price information on commodities in various markets (Tollens 2006, USAID 2013). However, these donor-funded first-generation AMISs did not function effectively because of operational difficulties. Information and communication technology (ICT) developments and the penetration of mobile technologies in the 2000s led to second-generation AMISs (Courtois & Subervie 2015, USAID 2013). The new AMISs were available through media such as radio, television, short messaging services (SMS), and websites. Private AMIS providers also emerged. The types of information expanded to include not only agricultural prices but also technical advice, input information, and weather forecasts.

Following the rapid penetration of mobile phones in developing countries in the 2000s, the number of studies on the effects of mobile phones, which are believed to reduce information asymmetry, on agricultural markets expanded (Aker & Mbiti 2010, Nakasone et al. 2014). Earlier studies by Jensen (2007), Aker (2010), and Aker & Fafchamps (2015) showed that introducing mobile phones narrowed price dispersions across markets in India and Niger. Since then, the impact of mobile phones on agricultural outcomes has been analyzed, including agricultural prices (Fafchamps & Minten 2012, Shimamoto et al. 2015, Svensson & Yanagizawa 2009), market participation (Aker & Ksoll 2016, Muto &

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Yamano 2009), farmers' income (Fafchamps & Minten 2012, Muto & Yamano 2009), technology adoption (Aker 2011, Cole & Fernando 2012), and crop diversification (Aker & Ksoll 2016). While most studies found that introducing mobile technology led to reduced price dispersion across markets and greater market integration, the findings on the impact on agricultural outcomes have been mixed (Nakasone et al. 2014). Positive effects on selling prices have been found in Cambodia (Shimamoto et al. 2015) and on input use and agricultural productivity in Kenya (Ogutu et al. 2014). However, heterogeneous effects due to age, farm size, and types of crops have also been found (Fafchamps & Minten 2012, Mitra et al. 2018, Muto & Yamano 2009). This heterogeneity suggests the need for more studies to clarify what drives the results.

Most AMISs analyzed in current studies were privately managed and fee-based, with a few exceptions (Svensson & Yanagizawa 2009). These private AMIS were accessed primarily by wealthier farmers due to their financial advantage. In contrast, public AMIS offers free access via radio, television, SMS, and websites and can reach a much broader audience.

The study of public AMIS makes an important academic contribution for two main reasons. First, public AMIS can potentially serve a much wider audience, particularly benefiting farmers who might otherwise be excluded from fee-based systems due to financial constraints. This is particularly important in developing countries, where many smallholder farmers cannot afford private services. Second, research has focused primarily on private AMIS, leaving a significant gap in understanding how public AMISs affect agricultural outcomes. The study of public AMISs provides critical insights into how these systems can mitigate information asymmetries and improve market outcomes for a wide range of farmers, thereby filling a significant gap in the AMIS literature.

In this context, we evaluated the effects of a public AMIS on farmers' production data using primary data collected from 466 coffee farmers in Ethiopia in 2014. Our findings confirm that providing wholesale market price information via an AMIS is positively related to coffee sales, the ratio of sales to production, and coffee revenue. In addition, we considered market heterogeneity by comparing two zones with different market characteristics. The AMIS is positively associated with increasing coffee sales, the ratio of sales to production, and coffee revenue in only one zone with lower market participation. However, the sales and revenue of AMIS users who reported using coffee price information provided by the ECX through such channels such as radio, TV, and electronic tickers in the other zone with higher market participation did not increase, although the selling price increased. These findings indicate the need to address other market imperfections, such as the high transportation costs that discourage traders from entering the market and farmers from participating, in addition to information asymmetry. This is consistent with the findings of Aker & Ksoll (2016), who found that while reducing information asymmetry through mobile phones and information systems led to better agricultural outcomes, structural barriers like inadequate infrastructure and limited market access constrained its overall impact.

Hypothesis development

With the rapid development of ICT allowing farmers in developing countries to provide market price information more easily, there has been growing interest in providing market information for bargaining power and market participation. We focused on the relationship between market information and farmers' bargaining power. Theoretically, predicting removing information asymmetry by providing farmers with more market information raises their bargaining power with traders (Stigler, 1961). Many empirical studies have also provided evidence for this. For example, Jensen (2007) found that using market information through mobile phones helps fishers choose the fish market with the highest price. Svensson & Yanagizawa (2009) also found that farmers better informed about agricultural prices have higher bargaining power over traders. Courtois & Subervie (2015) evaluated the impact of a private AMIS-based program in Ghana on farmers' marketing. They found that AMIS users sell maize 10% higher than non-AMIS users. This implies that using AMIS increases farmers' bargaining power. However, their target program was operated privately, so the effect of public AMIS on farmers' bargaining power remains unknown. Thus, we first tested the following:

Hypothesis 1. *Providing market information to farmers through a public AMIS increases their bargaining power so they can sell at a higher price.*

We turned to sales volume. Several studies have examined the effect of farmers' use of market information on market participation. Muto & Yamano (2009) suggested that crop marketing costs decrease as information flow increases, raising farmers' market participation in remote areas. They interpreted this result as follows: farmers and traders bear the cost and risk of product transportation if both parties know the volume and price that they can trade in advance. Courtois & Subervie (2015) claimed that asymmetric information about market prices may collapse negotiations between farmers and traders. When the market price falls sharply due to external factors, uninformed farmers may refuse to sell their products to traders because the payoff for selling products is lower than expected, even if traders offer prices that minimize their gains. This study proposed using AMISs by farmers and expected transaction success rates to improve when farmers subscribe to an AMIS—even when the market price fluctuates due to unexpected external factors. Hence,

Hypothesis 2. *Providing market information to farmers through a public AMIS reduces sales price and travel cost uncertainty so that farmers can sell in larger quantities or at a higher ratio of sales to production.*

To provide evidence of the potential benefit of the Ethiopian AMIS, Getnet et al. (2011) used a quasi-rational expectation formation and found that the AMIS helps farmers make unbiased price forecasts. The positive impact of the AMIS on price predictions may improve their production decision-making and the market behavior related to coffee and marketing; thus, the AMIS would increase farmers' revenue. However, the study did not estimate its effect on revenue. Hence, empirical evidence of a positive effect of the AMIS on farmers' revenue is still lacking. Thus, we tested the following:

Hypothesis 3. *Providing market information to farms through a public AMIS improves farmers' decision-making and market behavior related to coffee production and marketing to earn higher revenue.*

We further assumed that the impact of AMISs changes with the different elasticities of demand and supply, depending on the market structure. For instance, when the market structure is close to an oligopsony, it is usually difficult for farmers to negotiate with traders. Even if farmers are aware of the prevailing market, they may not benefit from such information if they lack access to other buyers. Farmers can only choose between selling their products below market price or not selling them at all. In contrast, if there are many buyers, farmers can search for those willing to pay closer to the market price. Providing market information to farmers is expected to induce them to sell more in such a market. Thus,

Hypothesis 4. *The effects of providing market price information to farmers vary based on market structure, with a stronger impact in competitive markets than oligopsonistic ones.*

In addition to examining the impact of ICT-based AMISs on farmers' bargaining power and market participation, we examined two types of heterogeneity: individual ability and location. While many previous studies have found that AMISs are effective at changing farmers' behavior, it remains unclear whether smallholder farmers would benefit from them. In other words, because an individual's ability to interpret information depends on his/her cognitive skills, the benefits of receiving information are greater for those with higher levels of education than those with lower levels. Thus,

Hypothesis 5. *The effects of providing market price information to farmers depend on their ability to interpret information.*

We tested these hypotheses using primary data on coffee farmers collected in Ethiopia to verify whether the AMIS enhances farmers' bargaining power and market participation and how its effects depend on the individual's level of education and the market structure.

AMIS in Ethiopia

1. Coffee industry

There are more than one million coffee-growing households in Ethiopia, and the livelihood of over 15 million people directly and indirectly depends on the coffee industry (Labouisse et al. 2008, LMC 2000, Petit 2007). Since liberalizing its agricultural market in 1990, the Ethiopian government has striven to improve the productivity, quality, and market efficiency of domestic coffee crops (Petit 2007). Consequently, in 2018, Ethiopia was ranked the largest coffee exporter in Africa and the 10th largest exporter globally (ICO 2020, Minten et al. 2019). Figure 1 shows Ethiopia's coffee export volume and value between 1990 and 2018. During this period, Ethiopian coffee exports increased from 64 thousand tons to 215 thousand tons; in U.S. dollars, it rose from $129 million to $759 million. This is a 340% increase in volume and a 590% increase in value (FAO 2020).

To ensure the development of an efficient and modern trading system, the Ethiopian government established the Ethiopian Commodity Exchange (ECX) in Addis Ababa in May 2008 with $29 million in funding from official development assistance and international organizations. It also changed the hub of its coffee distribution from auction centers to the ECX (Gabre-Madhin 2012). Currently, nine cash crops, including coffee, are traded on the exchange. In 2009, the year after ECX was established, Ethiopia's coffee exports decreased by 60 thousand tons from 2008 levels, but they began to recover in 2010 and nearly doubled in 2018, as shown in Figure 1. This increase may be partially due to growing demand for coffee, as coffee exports from coffee-producing countries rose by nearly 130% from 5.7 million tons to 7.4 million tons between 2009 and 2018 (FAO 2020). The modernized trading system under the ECX also contributed to the remarkable growth achieved by the Ethiopian coffee industry.

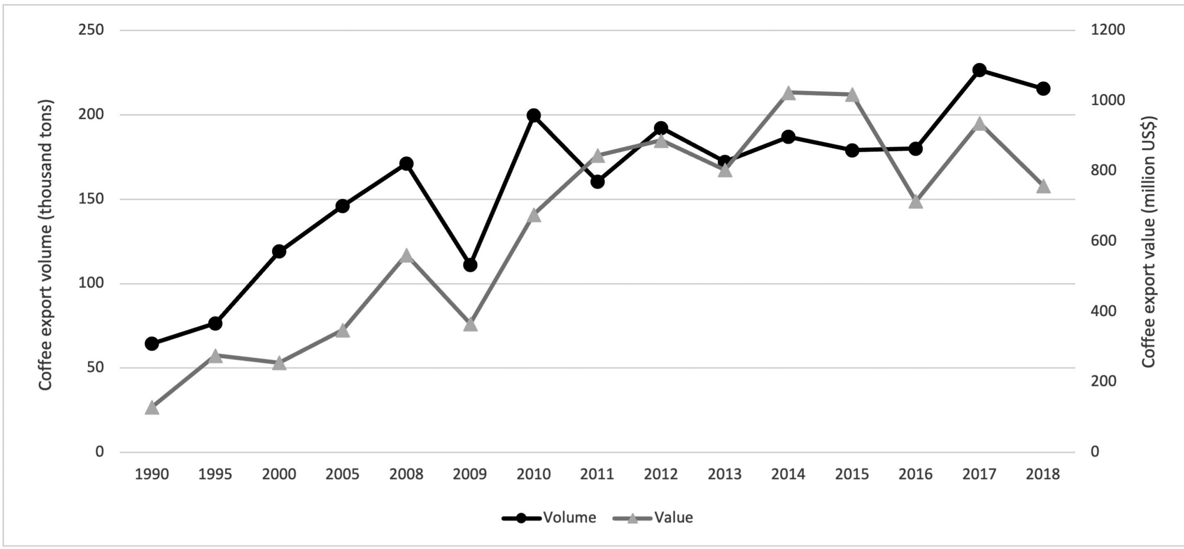

Fig. 1. Ethiopian coffee export volume and value
Source: FAO (2020)

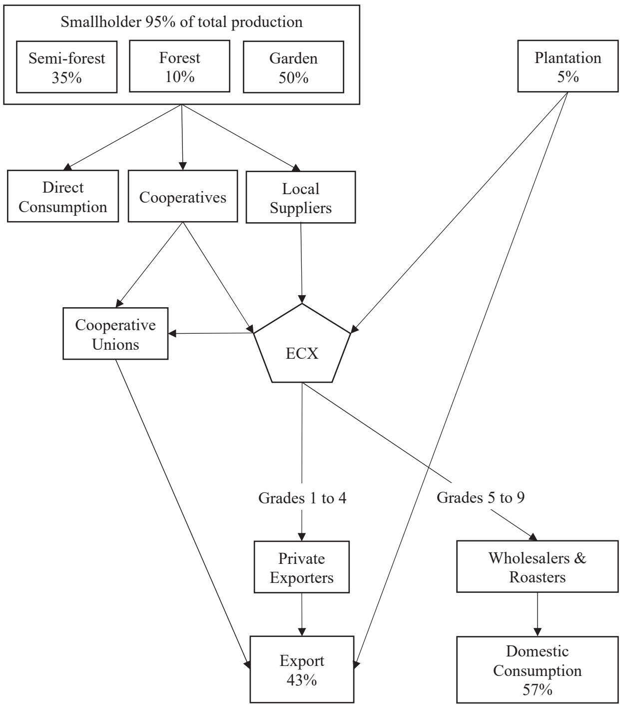

Fig. 2. Ethiopian coffee supply chain after the establishment of the ECX
Source: Based on Tamirat (2013) and Duguma & Van deer Meer (2018)

Figure 2 shows the Ethiopian coffee supply chain after the ECX system was introduced in 2008. Most of the coffee produced by smallholder farms is traded on the ECX because the government revised the laws on coffee trading for export and domestic distribution to ban coffee transactions outside the ECX (Gelaw et al. 2017). Since the Ethiopian government banned unauthorized collectors and brokers' business activities by establishing the ECX, most smallholder coffee farms sell their products directly to cooperatives or licensed local suppliers rather than brokers (Minten et al. 2019). According to ECX (2020), the coffee collected by cooperatives and suppliers is sent to national ECX warehouses and graded by experts. Coffee of grades 1 to 4 is exported overseas, while grade 5 or lower coffee is distributed to domestic markets (Duguma & Van deer Meer 2018, ECX 2020, Tamirat 2013).

2. Market information provided by the ECX

Smallholder coffee farms in Ethiopia produce about 95% of the country's coffee output. However, they have difficulty accessing information on wholesale prices since most are geographically isolated from central markets (Getnet et al. 2011, Labouisse et al. 2008). Hence, many obtain market information from unofficial sources such as neighbors, friends, and traders and make marketing decisions such as selling prices and sales volume based on sometimes incorrect or outdated information (Getnet et al. 2011). An environment where producers rely on unofficial market information causes information asymmetries between producers and traders trying to lower selling prices. Since neighbors also obtain market information from traders and other unofficial sources, the asymmetry problem persists despite an active exchange among producers (Osborne 2005).

Since 2008, the ECX has adopted an AMIS and disseminated information on the wholesale price of the coffee sold at the ECX to all market actors, including smallholder farms, through its website, electronic tickers in 250 rural markets, SMS, interactive voice response services, radio broadcasts (three times a day), television programs (twice a day), newspapers, and newsletters (daily, monthly, and semi-annually) (ECX 2020). Given the Ethiopian coffee industry's supply chain structure in which most coffee is traded at the ECX, the AMIS is expected to provide more accurate price information than other channels.

Data and summary statistics

To assess the impact of the AMIS on coffee producers' bargaining power and market participation, we interviewed the farmers of 466 smallholder coffee farms in 19 kebeles (wards) in the Jimma and Sidama zones in 2014. We collected recall data on coffee production and sales in 2012 and 2013 and restricted respondents to household heads. The kebeles and respondents were chosen randomly using lists from the Oromia Coffee Farmers Cooperative Union and the Sidama Coffee Farmers Cooperative Union. These two zones are Ethiopia's largest coffee producers and exporters: In 2013, the Jimma zone exported about 20% of Ethiopia's coffee exports, while the Sidama zone exported about 40% (Minten et al. 2014). Another reason for choosing these zones was to compare the effects of the AMIS under different market structures. According to Minten et al. (2015), 80% of the farmers in Sidama could choose from multiple traders, but only 63% of farmers in Jimma could select their trading partners. While only 2.2% of the farmers in Sidama stated they had no choice, 11.2% in Jimma said so, suggesting that there were more traders in Sidama than in Jimma. Owing to the differences in the market structure of the two zones, we expected the benefits of the price information obtained from the AMISs to differ.

Table 1 presents the number of sample households and AMIS users in each kebele in the two sample years. Between 2012 and 2013, the number of AMIS users remained the same in all kebeles except for kebeles K and O, which showed increases of two and one, respectively.

Table 1. Number of sample households and AMIS users in each kebele

Zone	Woreda	Kebele	Households	AMIS Users			
				2012		2013	
			#	#	%	#	%
Jimma			245	50	20.41	50	20.41
	Gera	A	29	10	34.48	10	34.48
		B	19	2	10.53	2	10.53
		C	37	7	18.92	7	18.92
	Limu Seka	D	24	13	54.17	13	54.17
		E	23	1	4.35	1	4.35
		F	39	1	2.56	1	2.56
	Kersa	G	36	2	5.56	2	5.56
		H	26	7	26.92	7	26.92
		I	12	7	58.33	7	58.33
Sidama			221	88	39.82	91	41.18
	Dale	J	25	17	68.00	17	68.00
		K	34	28	82.35	30	88.24
		L	8	3	37.50	3	37.50
	Aleta Wendo	M	27	3	11.11	3	11.11
		N	27	18	66.67	18	66.67
		O	26	8	30.77	9	34.62
	Shebedino	P	29	4	13.79	4	13.79
		Q	23	5	21.74	5	21.74
		R	22	2	9.09	2	9.09
N			466	138	29.61	141	30.26

"AMIS" is an abbreviation for agricultural market information system.
% of AMIS users in each year = # of AMIS users in each year / # of observations in each kebele
Source: Authors' survey (2014)

Table 2. Types of price information sources (Multiple answers are allowed)

	Jimma (n= 245)		Sidama (n= 221)		Total (n= 466)	
	#	%	#	%	#	%
From unofficial channels						
Family member	163	66.53	27	12.22	190	40.77
Friends and neighbors	226	92.24	109	49.32	335	71.89
Relative	187	76.33	15	6.79	202	43.35
From buyers						
Broker	24	9.80	2	0.90	26	5.58
Private trader	179	73.06	8	3.62	187	40.13
Collector	46	18.78	23	10.41	69	14.81
Exporter	38	15.51	1	0.45	39	8.37
From official channels						
Cooperative	21	8.57	193	87.33	214	45.92
Extension agent	25	10.20	5	2.26	30	6.44
AMIS	50	20.41	91	41.18	141	30.26

% of users in each channel = # of users in each channel / # of observations in each zone
Source: Authors' survey (2014)

Table 3. Types of AMIS channels (Multiple answers are allowed)

	Jimma (n= 50)		Sidama (n= 91)		Total (n= 141)	
	#	%	#	%	#	%
Radio	49	98.00	91	100.00	140	99.29
SMS	9	18.00	14	15.38	23	16.31
TV	3	6.00	12	13.19	15	10.64
Electronic ticker	0	0.00	7	7.69	7	4.96
IVR	1	2.00	0	0.00	1	0.71
Newspaper	1	2.00	0	0.00	1	0.71
Website	0	0.00	0	0.00	0	0.00

% of users in each channel = # of users in each channel / # of observations in each zone
Source: Authors' survey (2014)

In the full sample, the share of AMIS users increased marginally from 29.61% in 2012 to 30.26% in 2013. This stagnant trend may be attributed to the low awareness of farmers of the system. Farmers might also be reluctant to use the AMIS, as its benefits at the time of the survey might not have been visible.

Table 2 shows the types of information sources used by smallholder coffee farms to obtain price information in 2013. Altogether, 72% of respondents answered that they obtained information from friends or neighbors, 43% from relatives, and 46% from cooperatives. Only 30% of respondents, or 141 of the 466 farmers, used the AMIS provided by the ECX. Overall, farmers in Jimma relied on informal information from family members, friends, and private traders, while most farmers in Sidama obtained prices from formal information sources, such as cooperatives. In addition, AMIS is the third most popular information source in Sidama after cooperatives, friends, and neighbors (41.18% of the sample). In turn, the user ratio of the AMIS in Jimma is only half that of Sidama, and the AMIS is only the fifth most popular information source among the 10 types surveyed there.

Table 3 displays the AMIS channels used by coffee farmers in 2013. Virtually all respondents (140 of 141) using the AMIS obtained information from radio broadcasts. Although 85% of the farmers in the sample owned mobile phones, using the costly SMS subscription and interactive voice response systems was relatively low. Instead, farmers used the radio features on their mobile phones in addition to radio receivers, which are owned by 73% of the farmers, making radio the most popular AMIS channel. While ownership statistics for mobile phones and radios are not included in Table 3, they are discussed in the text to provide context for the

Table 4. Socioeconomic characteristics of respondents

Variables	Unit	Jimma			Sidama			Total		
		AMIS Mean	Non-AMIS Mean	Difference	AMIS Mean	Non-AMIS Mean	Difference	AMIS Mean	Non-AMIS Mean	Difference
HH's age	years	44.88	45.55	−0.67	47.31	46.72	0.58	46.45	46.02	0.43
		[12.81]	[11.53]	(1.87)	[9.18]	[11.21]	(1.43)	[10.63]	[11.40]	(1.13)
HH's gender	= 1 male	0.98	0.97	0.01	0.98	1.00	−0.02*	0.98	0.98	−0.00
		[0.14]	[0.17]	(0.03)	[0.15]	[0.00]	(0.01)	[0.14]	[0.13]	(0.01)
HH's schooling	years	2.84	3.09	−0.25	5.38	4.78	0.61	4.48	3.77	0.72**
		[2.97]	[2.88]	(0.46)	[3.06]	[3.33]	(0.44)	[3.25]	[3.18]	(0.32)
Household size	#	5.68	5.96	−0.28	5.76	5.81	−0.05	5.73	5.90	−0.17
		[2.04]	[1.61]	(0.27)	[2.08]	[2.05]	(0.28)	[2.06]	[1.80]	(0.19)
Adults in the household	#	2.84	3.05	−0.21	4.29	4.13	0.15	3.77	3.48	0.29
		[1.18]	[1.22]	(0.19)	[2.11]	[2.17]	(0.29)	[1.96]	[1.74]	(0.18)
Total assets	birr	55,373.72	31,317.94	24,055.78**	31,276.02	31,724.18	−448.16	39,821.30	31,480.44	8,340.87*
		[76,614.28]	[56,204.60]	(9,649.59)	[26,948.34]	[28,917.38]	(3,844.10)	[51,527.78]	[47,164.09]	(4,893.07)
AMIS informants	#	0.48	0.02	0.46***	2.03	1.70	0.33*	1.48	0.69	0.79***
		[1.16]	[0.14]	(0.09)	[1.28]	[1.46]	(0.19)	[1.44]	[1.24]	(0.13)
N		50	195		91	130		141	325	

Standard deviations are in brackets. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
"HH" and "AMIS" are abbreviations for the head of household and agricultural market information system.
Total assets = fixed assets + saving − loan

widespread use of radio broadcasts as the primary source of information among farmers. None of the farmers accessed the ECX website to check price information because the website targeted foreign buyers rather than local coffee farmers and most smallholder farms did not have a device or network to view the website. Seven farmers in Sidama obtained price information through electronic tickers, whereas the number in Jimma was zero.

Table 4 outlines respondents' socioeconomic characteristics from the 2013 data. The AMIS and non-AMIS user groups were divided according to the answers of the household heads who participated in the interview. This grouping does not reflect the usage of other household members, as household heads have the strongest bargaining power. Thus, we considered only the household head's characteristics in the following analysis. The average age of the household head was 46 years old and 98% were men. There was no significant difference between AMIS and non-AMIS users. However, significant differences were found in the years of schooling, total assets, and number of AMIS informants (i.e., the number of people who use the AMIS with whom respondents discuss market prices), which are higher for AMIS users than non-users. The number of AMIS informants is the only characteristic that significantly differs between the user and non-user groups in both Jimma and Sidama, as well as in the total sample. The AMIS user group in both zones has more informants who use the AMIS around them than the non-user group.

Table 5 shows coffee production, cost, and sales in 2013. The AMIS user group had a statistically higher harvest volume, sales volume, ratio of sales to production, total coffee cost, and labor cost than non-AMIS users. The difference in total coffee cost between the two groups was due to the AMIS user group's labor cost being 926 birr ($24.75) more than that of the non-AMIS group. Since AMIS users could reduce market price uncertainty, the users in Sidama appear to have actively hired workers as an investment strategy to increase revenue. However, the difference in the labor cost between the groups in Jimma was not statistically significant. In addition, the AMIS group harvested about 264 kg more and sold about 294 kg more than the non-AMIS group despite the different land sizes not being statistically significant. Owing to the higher sales volume for AMIS users, they earn 3,903 birr ($104.29) more coffee revenue than non-AMIS users. Higher revenue may not result from the higher selling price because the difference between the two groups is not statistically significant. We can infer that the effect of the AMIS may differ in the two zones since the difference in the average prices between users and non-users in Jimma was negative, while that in Sidama was positive. Further, sample farmers in Sidama harvested more, sold more, sold at a higher price, earned

Table 5. Coffee production and sales performance of farms

Variables	Unit	Jimma			Sidama			Total		
		AMIS Mean	Non-AMIS Mean	Difference	AMIS Mean	Non-AMIS Mean	Difference	AMIS Mean	Non-AMIS Mean	Difference
Coffee farm size	ha	0.83	0.94	−0.11	0.69	0.61	0.08	0.74	0.81	−0.07
		[0.57]	[0.63]	(0.10)	[0.39]	[0.36]	(0.05)	[0.46]	[0.56]	(0.05)
Harvest volume	kg	795.00	554.10	240.90***	1,114.18	1,011.15	103.02	1,000.99	736.92	264.07***
		[470.37]	[404.12]	(66.31)	[544.83]	[665.58]	(84.58)	[540.14]	[569.61]	(56.56)
Sales volume	kg	725.00	434.74	290.26***	960.11	804.23	155.88**	876.74	582.54	294.20***
		[514.11]	[360.97]	(62.87)	[532.87]	[461.00]	(67.22)	[536.46]	[442.15]	(47.66)
Ratio of sales to production	%	86.81	74.72	12.09***	83.33	82.66	0.67	84.56	77.89	6.67***
		[17.43]	[18.11]	(2.85)	[12.49]	[17.72]	(2.16)	[14.47]	[18.35]	(1.74)
Sales price/kg	birr	10.39	12.80	−2.41***	14.71	13.10	1.61***	13.18	12.92	0.26
		[4.17]	[4.46]	(0.70)	[4.16]	[4.45]	(0.59)	[4.63]	[4.45]	(0.45)
Total coffee revenue	birr	6,399.90	5,307.80	1,092.10	13,848.90	10,300.05	3,548.85***	11,207.41	7,304.70	3,902.71***
		[3,639.65]	[4,853.12]	(734.59)	[8,071.70]	[6,448.60]	(978.67)	[7,701.29]	[6,054.69]	(665.05)
Total coffee cost	birr	368.58	460.01	−91.43	2,230.14	966.53	1,263.61***	1,570.01	662.62	907.40***
		[1,476.41]	[1,480.65]	(234.58)	[1,979.71]	[2,492.08]	(313.73)	[2,020.20]	[1,961.41]	(199.60)
Fertilizer	birr	22.58	41.44	−18.86	8.79	0.00	8.79***	13.68	24.86	−11.18
		[116.35]	[506.82]	(72.26)	[32.14]	[0.00]	(2.82)	[73.80]	[392.70]	(33.34)
Pesticide	birr	0.00	0.00	0.00	0.66	0.00	0.66	0.43	0.00	0.43
		[0.00]	[0.00]	(0.00)	[6.29]	[0.00]	(0.55)	[5.05]	[0.00]	(0.28)
Herbicide	birr	0.00	14.70	−14.70*	1.47	0.00	1.47**	0.95	8.82	−7.87**
		[0.00]	[56.59]	(8.01)	[8.25]	[0.00]	(0.72)	[6.65]	[44.38]	(3.76)
Labor	birr	346	403.87	−57.87	2,219.22	966.53	1,252.69***	1,554.96	628.94	926.02***
		[1,419.30]	[1,393.43]	(221.72)	[1,968.16]	[2,492.08]	(313.18)	[2,001.01]	[1,926.53]	(196.57)
N		50	195	245	91	130	221	141	325	466

Standard deviations are in brackets. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
“AMIS” is an abbreviation for agricultural market information system.
Total coffee revenue = sales volume × sales price/kg
Total coffee cost = fertilizer + pesticide + herbicide + labor

more, and invested more even though they had less farmland than farmers in Jimma.

Econometric strategies

Using the 466-farmer dataset from the household survey mentioned in the ‘Data and Summary Statistics’ section, we empirically examined the impact of the AMIS on farmers’ bargaining power and market participation. Although we collected two years of panel data from each farmer, the primary analysis of the study was cross-sectional because the number of AMIS users in 2012 and 2013 was almost the same, as shown in Table 1. As alternatives, we employed a pooled regression model, a fixed effect model, and a random effect model using panel data in a robustness check. The following econometric model was estimated:

$$Y_{ik13} = \alpha + \beta_1 MIS_{ik13} + \beta_2 MIS\ informant_{ik13} + X_{ik13}\beta_k + \gamma Y_{ik12} + \delta_k + \varepsilon_{ik} \quad (1)$$

where Y_{ik13} is the outcome (log selling price per kg, log sales volume, ratio of sales to production, and log farm revenue) for farmer i in zone and woreda k in 2013; MIS_{ik13} is a dummy variable that indicates whether farmer i was an AMIS user in 2013; and $MIS\ informant_{ik13}$ is the number of informants who used the AMIS and exchanged price information with farmer i in 2013. This variable allows for potential treatment spillover effects because the price information obtained from the AMIS can easily spill over to farmers who do not use the AMIS. Since the decision to use the AMIS is made independently and the final decision to share information lies individually, we classified $MIS\ informant_{ik13}$ as an exogenous variable in our estimation. X_{ik13} accounts for farmer i’s age and years of schooling, farm size, total coffee costs, and types of coffee price information sources in 2013. A lagged dependent variable Y_{ik12} is included to estimate the extent to which MIS usage is associated with a higher growth of the outcome. δ_k refers to the zone or woreda dummies, and ε_{ik} is an error term. As mentioned in sub-section 1, within the 'AMIS in Ethiopia' section, most of the coffee harvested by smallholders was traded on the regional trading centers managed by the ECX. Since the centers are located at the woreda level and the coffee cultivation method varies by zone, the heterogeneity across woredas or zones is likely to be greater than across kebeles. Thus, to capture unobserved heterogeneity across zones or woredas, the regression model included zone and woreda dummies instead of kebele dummies.

To test Hypothesis 4, this study employed an interaction term between AMIS usage and residential areas, which was estimated. The benefit of the price information obtained from the AMIS was expected to differ in the two zones due to differences in their markets, as described in the 'Data and Summary Statistics' section.

Another interaction effect between AMIS usage and years of schooling is a proxy for revealing the differences in the outcomes among AMIS users depending on their ability to interpret market price information. If the impact of the AMIS on the outcome variables is higher for more educated farmers than less educated ones, Hypothesis 5 is supported. In other words, the effects of the AMIS are greater when price information is provided to individuals with better understanding and higher cognitive skills.

Because our sample farmers freely chose whether to use the AMIS, self-selection bias may have arisen in the analyses. Thus, as a quasi-experimental method, this study adopted the inverse probability-weighted regression adjustment (IPWRA) estimator and estimated the average treatment effect (ATE) to measure the differences in the average outcomes between the AMIS and non-AMIS user groups. Since the estimator is a doubly robust estimator that combines a logistic model for the treatment (i.e., the IPW component) and a linear model for the outcome (i.e., the RA component), it provides asymptotically unbiased estimates even if one of the models is misspecified (Bourguignon et al. 2007, Robins et al. 2007, Wooldridge 2007):

$$\widehat{ATE_{IPWRA}} = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{MIS_i Y_i}{\hat{\pi}(Z_i)} - \frac{(1-MIS_i)Y_i}{1-\hat{\pi}(Z_i)}\right] \quad (2)$$

where n is the number of individuals in our sample and $\hat{\pi}(Z_i)$ is the estimated propensity score, which is the estimated conditional probability of using the AMIS given Z_i. Appendices 1 to 3 show the variables used to estimate the probability.

Results

1. Effects of the AMIS on farmers' agricultural outcomes

We first analyzed the effect of the AMIS on farmers' agricultural outcomes using the full sample. In addition to ordinary least squares (OLS) data, which might have been biased by the endogenous nature of AMIS adoption, the IPWRA results are presented in this paper. We used the household and farm characteristics for matching, which passed the covariate balance tests (Table A.1) and overidentification tests (Table 6).

Table 6 shows the effects of the AMIS to be consistent under both the OLS and the IPWRA specifications for all four dependent variables, except for the ratio of sales to production. The AMIS user dummy does not show statistically significant effects on the selling price per kg in either OLS or IPWRA. However, the AMIS dummy shows positive, statistically significant effects on the user's sales volume, ratio of sales to production, and farm revenue in both the OLS and IPWRA columns. The sales volume of AMIS users is 10% higher (column (iv)) than that of non-AMIS users, and the ratio of sales to production is about 3% higher for AMIS users, implying that they increased their sales in absolute and relative terms. Consequently, AMIS users also have statistically higher farm revenue, as presented in columns (vii) and (viii). We concluded that farmers who used the AMIS enjoyed higher revenue from coffee because of more active market participation rather than higher selling prices.

2. Heterogeneous effects of the AMIS on farmers' agricultural outcomes

We investigated the regional heterogeneity between the Jimma and Sidama zones. Since IPWRA is not well-suited for handling interaction terms between AMIS and zones, the analysis of regional heterogeneity was conducted using OLS exclusively. Based on the differences in Table 4, we see that farmers in the two zones were different in terms of both coffee production and marketing. Table 7 captures the differences in the effect of the AMIS between Jimma and Sidama by including the Jimma dummy and the interaction term. While farmers in Jimma have a sales-to-production cost ratio 5.12% lower and earn 19% less on average compared to those in Sidama, the effects of using the AMIS are much greater for farmers in Jimma. If Jimma farmers used the AMIS, the ratio of sales to production and farm revenue increased by 0.8% points and 0.05%, respectively, over those in Sidama. These figures were calculated by adding the coefficient of the Jimma dummy to the

Table 6. Effects of the AMIS on farmers' agricultural outcomes

	ln(sales price/kg)		ln(sales volume)		Ratio of sales to production		ln(coffee farm revenue)	
	OLS (i)	IPWRA (ii)	OLS (iii)	IPWRA (iv)	OLS (v)	IPWRA (vi)	OLS (vii)	IPWRA (viii)
= 1 AMIS user	0.002	0.01	0.08**	0.10***	2.17	3.44**	0.12***	0.16***
	(0.03)	(0.02)	(0.04)	(0.04)	(1.33)	(1.58)	(0.05)	(0.04)
= 1 info. from unofficial channels	−0.06	−0.10**	0.14*	0.09	1.12	−0.49	0.01	−0.12
	(0.04)	(0.05)	(0.07)	(0.08)	(2.15)	(2.12)	(0.09)	(0.08)
= 1 info. from buyers	0.003	0.07	−0.03	−0.17	0.27	−6.00	−0.04	−0.23
	(0.04)	(0.09)	(0.06)	(0.18)	(2.16)	(3.68)	(0.07)	(0.22)
= 1 info. from extension agents	−0.09**	−0.09*	0.19***	0.06	1.85	−4.21	0.17**	0.04
	(0.04)	(0.05)	(0.05)	(0.07)	(1.49)	(2.88)	(0.07)	(0.09)
= 1 info. from coop.	−0.0003	0.15**	−0.01	−0.10	−3.97**	−1.66	0.02	0.08
	(0.04)	(0.08)	(0.06)	(0.10)	(1.82)	(3.35)	(0.08)	(0.14)
# of AMIS informants	−0.02*	−0.02	0.06**	0.04**	1.55**	−0.18	0.04	0.01
	(0.01)	(0.02)	(0.02)	(0.02)	(0.70)	(0.89)	(0.03)	(0.03)
Y_{t-1}	0.67***	0.63***	0.88***	0.93***	0.78***	0.79***	0.74***	0.75***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)	(0.07)	(0.07)	(0.07)
Jimma dummy (= 1 live in Jimma)	−0.03	−0.002	−0.07	0.19	−3.42	7.70*	−0.13	0.28
	(0.06)	(0.13)	(0.07)	(0.19)	(2.40)	(4.63)	(0.10)	(0.21)
Constant	1.11***	1.36***	0.62*	0.09	29.96***	23.91	2.24***	1.99***
	(0.20)	(0.35)	(0.35)	(0.44)	(9.16)	(18.50)	(0.62)	(0.75)
Over. (Prob>F)		0.33		0.33		0.33		0.33
R^2	0.55		0.79		0.48		0.72	
N	466	466	466	466	466	466	466	466

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All regressions include control variables for the household head's age, age^2, schooling, and coffee farm size.

interaction term between AMIS and the Jimma dummy. The larger effects of the AMIS among users in Jimma were attributed to the lower sales volume, ratio of sales to production, and farm revenue compared to farmers in Sidama. The effects of the AMIS on selling price remain insignificant even in Jimma, where the selling price per kg is lower than in Sidama.

To further distinguish the difference between the effects of the AMIS in Jimma and Sidama, we divided the sample into halves and ran separate regressions. Table 8 summarizes the results using OLS and IPWRA. We used the household and farm characteristics for matching, which passed all the covariate balance tests (Tables A.2, A.3) and overidentification tests. Under both OLS and IPWRA, we found that the significance level of the four dependent variables varied by region. The AMIS variable showed a positive, statistically significant effect on the selling price for farmers in Sidama, but the effects on the other three dependent variables were insignificant. The opposite case was true for Jimma. The coefficients of the AMIS dummy were positive and statistically significant for sales volume, the ratio of sales to production, and farm revenue, but not the selling price (OLS). The results using IPWRA showed similar trends to the OLS results, except for the effect on the selling price for farmers in Jimma. This contradiction was likely due to differences in the market structure of the zones. As explained in the 'Data and Summary Statistics' section, farmers in Sidama had a better choice of buyers than farmers in Jimma, meaning that additional access to the official price information through the AMIS increased prices. Nonetheless, a higher selling price does not contribute to a statistically significant increase in farm revenue. In Jimma, the AMIS encourages farmers to sell more coffee to the market, leading to higher farm revenue.

Next, we examined whether the effect of the AMIS differed with the users' education level, using OLS instead of IPWRA due to the limitations of IPWRA in handling interaction terms. Table 9 shows that neither the AMIS dummy nor the interaction term is statistically significant. Hence, the education level of AMIS users did not affect users' performance, perhaps because the price information that farmers obtained from the AMIS was sufficiently simple that even those with an elementary education could understand it easily. Since all the models in this table fail the joint significance test, those without interaction terms seem to be more appropriate for measuring the effects of the AMIS.

Table 7. Regional heterogeneity of the AMIS effects: OLS

	ln(sales price/kg) (i)	ln(sales volume) (ii)	Ratio of sales to production (iii)	ln(coffee farm revenue) (iv)
= 1 AMIS user	0.02	−0.01	−0.40	0.01
	(0.04)	(0.05)	(1.38)	(0.06)
= 1 info. from unofficial channels	−0.06	0.16**	1.74	0.04
	(0.04)	(0.07)	(2.10)	(0.09)
= 1 info. from buyers	0.01	−0.04	−0.19	−0.06
	(0.04)	(0.06)	(2.16)	(0.07)
= 1 info. from extension agents	−0.08**	0.16***	1.03	0.13**
	(0.04)	(0.05)	(1.63)	(0.06)
= 1 info. from coop.	0.003	−0.01	−4.15**	0.01
	(0.04)	(0.06)	(1.79)	(0.08)
# of AMIS informants	−0.02*	0.06**	1.61**	0.04
	(0.01)	(0.02)	(0.71)	(0.03)
Y_{t-1}	0.67***	0.87***	0.77***	0.75***
	(0.05)	(0.05)	(0.06)	(0.07)
Jimma dummy (= 1 live in Jimma)	−0.02	−0.14*	−5.12**	−0.19*
	(0.06)	(0.08)	(2.55)	(0.10)
AMIS × Jimma dummy	−0.04	0.22***	5.94**	0.24***
	(0.05)	(0.08)	(2.88)	(0.09)
Constant	1.12***	0.65	30.58***	2.20***
	(0.20)	(0.35)	(9.27)	(0.61)
Joint. (Prob>F)	0.38	0.004***	0.04**	0.007***
R^2	0.55	0.80	0.48	0.71
N	466	466	466	466

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All regressions include control variables for the household head's age, age^2, schooling, and coffee farm size.

3. Robustness check

As a robustness check, we ran fixed, random, and pooled effect models using the two-year panel data from 2012 and 2013. The results in Table 10 are consistent with those using OLS and IPWRA. The coefficients of the AMIS dummy are insignificant for selling prices in all columns but statistically significant and positive for sales volume, the ratio of sales to production, and farm revenue.

Policy implications and conclusions

1. Policy implications

This study evaluated the impact of the AMIS in Ethiopia on smallholder farms' agricultural outcomes using data collected from 446 coffee farmers. Moreover, we examined whether the AMIS's effect depended on the market structure and the farmer's level of education. Based on our results, we concluded that AMIS users experienced a significant increase in farm revenue compared to non-AMIS users, primarily driven by increased sales volume. Such differences in farm revenue between AMIS and non-AMIS users were attributed to increased sales volume by AMIS users rather than a rise in their selling prices. Moreover, the ratio of sales to production is about 3% higher for AMIS users, suggesting that the Ethiopian AMIS may enhance farmers' market participation; this finding is consistent with other studies (Courtois & Subervie 2015, Mabota et al. 2003, Muto & Yamano 2009). However, unlike many studies (Courtois & Subervie 2015, Jensen 2007, Muto & Yamano 2009), our full sample analysis does not reveal any statistically significant effects of the AMIS user dummy on farmers' selling price per kg.

One reason for not impacting the selling price is the regional heterogeneity in our data. By region, the AMIS dummy shows a positive, significant effect on the price per kg in Sidama, whereas the other dependent variables are statistically insignificant. However, the AMIS dummy showed positive, statistically significant effects on sales prices, sales volume, the ratio of sales to production, and farm revenue in Jimma, perhaps because of its difference in market structure from Sidama. According to Minten et al. (2015), coffee farmers in Sidama had more choices of traders and options to sell to cooperatives than those in Jimma, which created more intense competition among buyers, resulting in higher

Table 8. Effects of the AMIS by region

	OLS		IPWRA	
	Jimma (i)	Sidama (ii)	Jimma (iii)	Sidama (iv)
ln(sales price/kg)	0.03	0.11***	0.08*	0.10***
	(0.03)	(0.04)	(0.04)	(0.04)
ln(sales volume)	0.22***	0.05	0.21***	0.03
	(0.07)	(0.07)	(0.07)	(0.07)
Ratio of sales to production	8.03***	0.07	8.20***	0.30
	(2.65)	(1.94)	(2.73)	(1.71)
ln(coffee farm revenue)	0.29***	0.11	0.34***	0.10
	(0.07)	(0.10)	(0.08)	(0.08)
N	245	221	245	221

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All regressions include woreda dummies and the same control variables as in Table 6, except for the Jimma dummy.

Table 9. Educational heterogeneity of the AMIS effects: OLS

	ln(sales price/kg) (i)	ln(sales volume) (ii)	Ratio of sales to production (iii)	ln(coffee farm revenue) (iv)
= 1 AMIS user	−0.01	0.08	2.05	0.12
	(0.04)	(0.06)	(2.24)	(0.08)
= 1 info. from unofficial channels	−0.06	0.14*	1.13	0.01
	(0.04)	(0.07)	(2.16)	(0.09)
= 1 info. from buyers	0.004	−0.03	0.27	−0.04
	(0.04)	(0.06)	(2.16)	(0.07)
= 1 info. from extension agents	−0.09**	0.19***	1.86	0.17**
	(0.04)	(0.05)	(1.53)	(0.07)
= 1 info. from coop.	−0.00004	−0.01	−3.97**	0.02
	(0.04)	(0.06)	(1.83)	(0.08)
# of AMIS informants	−0.02*	0.06**	1.55**	0.04
	(0.01)	(0.03)	(0.71)	(0.03)
Y_{t-1}	0.67***	0.88***	0.78***	0.74***
	(0.05)	(0.05)	(0.06)	(0.07)
HH's schooling	0.01**	−0.01	−0.50**	0.005
	(0.01)	(0.01)	(0.24)	(0.01)
AMIS × schooling	0.003	0.0001	0.03	0.0001
	(0.01)	(0.01)	(0.37)	(0.01)
Jimma dummy	−0.03	−0.07	−3.42	−0.13
(= 1 live in Jimma)	(0.06)	(0.07)	(2.41)	(0.10)
Constant	1.11***	0.62*	29.99***	2.24***
	(0.20)	(0.35)	(9.16)	(0.62)
Joint. (Prob>F)	0.42	0.57	0.70	0.47
R^2	0.66	0.99	0.94	0.99
N	466	466	466	466

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All regressions include control variables such as the household head's age, age^2, and coffee farm size.

prices for farmers. We conclude that in a market dominated by a small number of traders, even with the price information gained from the AMIS, farmers' selling prices increase only by small margins. In addition, in a market where farmers sell less actively, the AMIS may enhance their sales-to-production ratio, as shown in Table 5. These findings suggest that unless other market imperfections are addressed, which discourage more

Table 10. Robustness check

	FE (i)	RE (ii)	Pooled (iii)
ln(sales price/kg)	0.01	0.03	0.03
	(0.05)	(0.03)	(0.03)
ln(sales volume)	0.16**	0.28***	0.29***
	(0.08)	(0.06)	(0.05)
Ratio of sales to production	2.31**	3.71***	3.76***
	(1.04)	(1.37)	(1.11)
ln(coffee farm revenue)	0.18***	0.30***	0.31***
	(0.05)	(0.06)	(0.05)
# of observations	932	932	932
# of groups	466	466	466

traders from entering the market and more farmers from participating (e.g., high transportation costs), farmers may not benefit fully from the AMIS.

In addition, we found no difference in outcomes among AMIS users according to their years of schooling. There are two reasons for this. First, because the average education level is only four years and variance across farmers is minor, the benefits of using the AMIS do not differ markedly. Second, farmers can obtain only simple market prices from the AMIS. These require little knowledge to process and do not lead to a statistically significant difference in how farmers use such information in their decision-making. If the information provided by the AMIS becomes more complex, the difference in benefits will widen according to the individual's ability to interpret such price data.

2. Conclusions

In conclusion, this paper presents the findings relevant to the Ethiopian AMIS that can influence policies for public AMISs in developing countries to improve smallholder farms' agricultural outcomes. This study contributes to the literature by examining the impact of the AMIS on farmers' agricultural outcomes and considering the heterogeneity among farmers, but there are several limitations.

One is that the data used in this study were not obtained from a random assignment of the treatment. Second, our sample size was only 466, and we estimated heterogeneous effects across regions using data collected in only two zones. Another limitation is that the study focused exclusively on the household head's use of AMIS, omitting the analysis of how information might be exchanged or utilized by other household members. This oversight may obscure the full impact of AMIS on decision-making processes and the agricultural outcome at the household level. Further, determining the effect of the AMIS on farmers' long-term profit maximization decisions is beyond the scope of our data. Farmers may use AMIS information to decide such inputs as farm size, the number of coffee trees, and fertilizers, which can affect the performance of the next cropping year. Using AMIS to obtain information on market trends may positively and significantly affect farmers' profits eventually. Therefore, future studies should use data from a random assignment over a longer period.

Our paper contributes to the discussion on the effect of ICT on mitigating information asymmetry in agricultural markets by providing empirical evidence on the effects of using a public AMIS on smallholder farms' agricultural outcomes. In contrast, most current studies analyze the impact of ownership or privately managed AMISs. Our findings show that the effect of AMIS depends on the competitiveness of the market structure and suggest correcting other market imperfections and information asymmetry to benefit fully from using AMISs.

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Table A.1. Covariate balance test: the full sample

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
HH's age	0.04	−0.01	0.87	0.93
HH's schooling	0.22	−0.01	1.05	1.02
Adults in the household	0.16	−0.01	1.27	1.02
Coffee farm size	−0.13	−0.04	0.69	0.87
Total assets	0.26	0.02	0.98	1.01
Info. from traders	−0.38	0.01	1.01	1.00
Info. from extension agents	0.19	0.01	1.92	1.03
Kebele dummies	0.17	0.06	0.71	0.89

Table A.2. Covariate balance test: Jimma

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
Coffee farm size	−0.19	0.00	0.83	1.05
Total assets	0.37	0.01	1.58	1.22
Info. from unofficial channels	−0.05	0.03	1.31	0.87
Info. from traders	0.36	0.06	0.21	0.83
Info. from extension agents	0.49	0.01	2.98	1.03

Table A.3. Covariate balance test: Sidama

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
Coffee farm size	0.22	0.01	1.14	0.90
Total assets	0.07	0.01	0.70	0.75
Info. from unofficial channels	0.49	−0.01	0.92	1.00
Info. from traders	−0.19	0.04	0.66	1.08
Info. from extension agents	−0.01	0.00	0.96	0.99