IFPRI Discussion Paper 01833

April 2019

Dairy Contract Farming in Bangladesh

Implications for Welfare and Food Safety

Abu Hayat Md. Saiful Islam

Devesh Roy

Anjani Kumar

Gaurav Tripathi

P. K. Joshi

South Asia Regional Office

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. IFPRI's strategic research aims to foster a climate-resilient and sustainable food supply; promote healthy diets and nutrition for all; build inclusive and efficient markets, trade systems, and food industries; transform agricultural and rural economies; and strengthen institutions and governance. Gender is integrated in all the Institute's work. Partnerships, communications, capacity strengthening, and data and knowledge management are essential components to translate IFPRI's research from action to impact. The Institute's regional and country programs play a critical role in responding to demand for food policy research and in delivering holistic support for country-led development. IFPRI collaborates with partners around the world.

AUTHORS

Abu Hayat Md. Saiful Islam (saiful_bau_econ@yahoo.com) is an Associate professor, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

Devesh Roy (d.roy@cgiar.org) is a senior research fellow in the Agriculture for Nutrition and Health (A4NH) of the International Food Policy Research Institute (IFPRI), New Delhi, India.

Anjani Kumar (anjani.kumar@cgiar.org) is a research fellow in the South Asia Office of IFPRI, New Delhi, India.

Gaurav Tripathi (g.tripathi@cgiar.org) is a senior research analyst in the South Asia Regional Office of IFPRI, New Delhi, India.

P. K. Joshi (p.joshi@cgiar.org) is director of the South Asia Office of IFPRI, New Delhi, India.

Contents

Tables

Figures

ABSTRACT

Contract farming is emerging as an important institutional innovation in the high value food chain in developing countries including Bangladesh, and its socioeconomic implications are topic of interest in policy debates. This study is an empirical assessment to explore the determinants of participation and the impact of contract farming on welfare and adoption of food safety practice in Bangladesh. Our analysis indicates that contract farmers are more likely to have better access to agricultural extension services, attended proportionately more community meetings, households members are member of organizations, access more credit, are located farther from output market, and have larger herd sizes. We also find that network variables such as time spent with cooperatives and other institutions and price fluctuation and average prices received experience before participation in contract are strongly associated with participation in contract farming. We find that contract farming has a robust positive impact on welfare measured by expenditure, farm profit and farm productivity, and food safety practice adoption even after innovatively controlling for observed and unobserved heterogeneity among dairy farmers. More specifically results indicate that a one unit increase in the likelihood of participating in contract farming is associated with a 42, 35,34 and 9 percent increase in household expenditure, gross margin and net margin per cow, and food safety practice adoption rate respectively, among other positive impacts.

Keywords: Contract farming, dairy, welfare, treatment regression model, food safety, Bangladesh.

JEL classification: O33; Q12; Q13; Q18

ACKNOWLEDGMENTS

We are grateful to the United States Agency for International Development (USAID) for extending financial support to this study through the Policy Reform Initiative Project in Nepal. We thank Md. Sazzadur Rahman for valuable research assistance with the data management, and for helping to coordinate the field survey in Bangladesh. The authors are also grateful to the individual farmers from Sirajganj and Pabna districts, who participated in the field survey interviews. Last but not the least, we express our sincere gratitude to the Dean's Office and the Bureau of Socio-Economic Research and Training (BSERT) at Bangladesh Agricultural University (BAU) for their support that facilitated successful conduct of the primary survey. The opinions expressed here belong to the authors, and do not necessarily reflect those of IFPRI, CGIAR, USAID, or BSERT, BAU.

This work was undertaken as part of the CGIAR Research Program on Policies, Institutions, and Markets (PIM) and the Research Program on Agriculture for Nutrition and Health (A4NH), led by the International Food Policy Research Institute (IFPRI).

ABBREVIATIONS

AI	Artificial Insemination
AMUL	Anand Milk Union Limited
BBS	Bangladesh Bureau of Statistics
BRAC	Bangladesh Rehabilitation Assistance Committee
BSERT	Bureau of Socio-Economic Research and Training
BMPCUL	Bangladesh Milk Producers' Cooperative Union Ltd.
CGIAR	Consultative Group on International Agricultural Research
DANIDA	Danish International Development Agency
DLS	Department of Livestock Services
e. g.	Exempli gratia (for example)
Eqn	Equation
et al.	et alia (and other)
etc.	et cetera (other and so forth)
FAO	Food and Agriculture Organization
FIML	Full Information Maximum Likelihood
FSAI	Food Safety Adoption Index
FSPs	Food Safety Practices
GO	Government Organization
GM	Gross Margin
HIES	Household Income and Expenditure Survey
HYV	High Yielding variety
i.e	id est (that is)
IV	Instrumental Variable
Kg	Kilogram
MMT	Million Metric Tonne
NGO	Non-Government Organization
No	Number
NR	Net Return
OLS	Ordinary Least Squares
PDUSS	Prathomic Dugdha Utpadonkari Samabaya Samity
PRAN	Programme for Rural Advancement Nationally
PSM	Propensity Score Matching
SNF	Solid Non-fat
Std. Dev.	Standard Deviation
Std. Err.	Standard Error
Tk	Taka (Bangladesh Currency)
UHT	Ultra-high Temperature
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
%	Percentage
2sls	Two Stage Least Squire

1. Introduction

Contracts, cooperatives and different forms of coordination arrangements are emerging as institutional innovations in the global agri-food supply chains, especially in developing countries, and its socioeconomic implications are attracting considerable attention in public policy debates (Glover, 1984, 1990; Warning and Key, 2003; Miyata *et al.,* 2009; Oya, 2012; Grosh, 1994; Key and Runsten, 1999; Little and Watts, 1994; Reardon and Timmer, 2005; Warning and Key, 2002). Empirical evidence on impact of contract and cooperatives on farmers is mixed (Cornelis and Van der Meer, 2006). Small holders particularly in developing countries face multiple constraints such as high transaction costs, less access to services including extension, technologies, information and rural credit that impede taking advantage of market opportunities (Jia and Huang, 2011; Fischer and Qaim, 2012), and proponents of contract farming seeing that it is an institutional solution to these problems (Grosh, 1994; Key and Runsten, 1999). It provides an opportunity for producers to secure immediate market outlets (Reardon et al. 2004; Gulati *et al.,* 2007; Dries *et al.,* 2009; Miyata et al. 2009; Abebe *et al.*, 2013). On the other hand to increase efficiency, synergies, inter-firm pooling of resources, customer responsiveness to food quality and safety and risk, market imperfection and transaction cost encourage agribusiness farms to form such contract farming mechanism (Besanko, *et al.,* 2009; Boger, 2001; Key and Runsten, 1999; Zhang and Hu, 2011).

An emerging body of literature finds that participation in contract farming increase income and welfare and reduce poverty (Minten *et al.,* 2009; McCulloch and Ota, 2002; Minten *et al.,* 2006; Maertens and Swinnen, 2009; Warning and Key, 2002; Singh, 2002; Miyata *et al.,* 2009; Morrison *et al*., 2006). On other outcomes, Key and Bride (2008) assess the impact on productivity , farm profit (Narayanan, 2014), efficiency (Ramaswami *et al.,* 2006; Begum *et al.,* 2012), women's farm labour and employment (Singh, 2002; Raynolds, 2002), link to domestic and global chain (Glover and Kusterer, 1990), reduction in market imperfections and transaction costs (Key and Runsten, 1999; Hellin and Higman, 2003), enhanced access to credit, technology, management skills, market information and/or inputs (Glover and Kusterer, 1990; Key and Runsten, 1999; Singh, 2002; Masakure and Henson, 2005; Shiferaw *et al.,* 2008), commercialization of agriculture (Bijman, 2008) and reduced risk and work as insurance (Hennessey & Lawrence, 1999; Rhoades, 1995; Fukunaga and Huffman, 2009). Bolwig et al. (2009) showed contract enhance adoption of organic farming and affect revenue positively in Uganda. Masakure and Henson (2005) found four factors namely market uncertainty, indirect benefits (e.g., knowledge acquisition), income benefits, and intangible benefit motivate small scale vegetables farmers to participate in contract in Zimbabwe. Transaction costs and collective action are also significant determinants of farmer participation in contract (Blandon *et al.,* 2009; Birthal *et al.,* 2005).

In terms of income effects, results from Madagascar show that a 1-percent increase in the likelihood of participating in contract farming is associated with an average 0.6-percent increase in a household's total income, a 0.5-percent increase in a household's income per adult equivalent,

and a 0.5-percent increase in a household's income net of contract farming revenues (Bellemare, 2012). Recent study on HYV seed production contract farming in Nepal shows that contract has a significant positive impact on revenues, profits, and yield, and a significant negative impact on total costs of production (Mishra *et al.,* 2016). Another recent study from Madagascar shows that contract farming reduces food insecurity problems measured by duration of a household's hungry season (Bellemare and Novak, 2017).

While there is much evidence indicating that smallholders successfully participate in contract, critics argue that such type of institutional innovation has raised concerns about their fairness for farmers and they see contract farming as an institution for exploitation of small-scale producers by agro-industrial firms (Glover and Kusterer, 1990; Clapp *et al.,* 1994; Porter and Phillips- Howard, 1997; Steven Wu, 2003; Fold and Pritchard, 2005). From an extensive literature review of contract farming Oya (2012) suggests that contract farming is contributing to processes of social differentiation and capitalist development. It also leads to impoverishment, dependency, and economic differentiation (Eckel and Grossman, 1996). Singh (2000) and Ito *et al.* (2012) find that contractors tend to deal with large farms only and small and marginal producers are excluded. There are also examples where participants exit from contract due to many problems (Markelova et al., 2009; Poulton *et al.,* 2010). Narayanan (2013) presents that poorer farmers are more likely to exit from contract with economic losses from contracting often stated as the single most important reason for the exit. In addition contract farming has quite diverse impacts on income (Barrett, 2008; Narayanan, 2014). World Bank (2007) expressed strong support for contract farming arrangements, as it can work as a vehicle for agriculture commercialization and poverty reduction by resolving multiple market failures that smallholder face. Overall the evidence on farmers of contract farming is mixed.

In assessing the impact of contract farming on incomes researchers have to confront the challenge of identification emanating from selection problems. It is possible that outcomes would be similar for those farmers who get into contract even when they were not part of the arrangement. There could be either positive or negative selection. Finding an instrument for participation in contract farming for outcomes such as incomes or profits is extremely difficult since factors that bear on joining contracts are also likely to be related to profits or incomes from contract farming, for example the commercial orientation or entrepreneurial spirit of the farmer. We appeal to theory of contract farming as a risk sharing mechanism for developing instruments that can help us identify the causal impact of contract farming. The incentive compatibility constraints dictate that those farmers who faced greater variability in prices and/or income are likely to pick up contract farming. We do find this to be the case.

Here we explore the scope for small-scale dairy producers to participate in evolving of production- and market-oriented contract arrangements in Bangladesh. Apart from addressing the issue of identification with theory based instruments, we make a number of contributions to the literature. Most of the current literature on contracts centers on coordinated systems that link smallholders

with global food chains, but with little emphasis on local food chains. Focusing on dairy farmers in Northern Bangladesh, this paper explores the impacts of contracts in local food chains as more attention is now being given to the transformation of domestic agri-food markets and the rise of demand for high value products in developing countries as incomes increase alongside other socio-demographic changes such as rapid urbanization, market liberalization and globalization (Reardon and Berdegue, 2002; Pingali and Khwaja 2004; Berdegue´ *et al.,* 2005; Dev and Rao, 2005; Henson and Reardon, 2005).

We extend the focus of the impacts of participation in contract by looking at expenditure, productivity, farm profit effects and adoption of quality and food safety standards. Sykuta and Cook (2001) state that little attention has been paid to the identity or nature of the contracting organization when examining the structure of agricultural contracts. The literature on contract farming in Bangladesh is largely anecdotal possibly because of lack of data. In this paper, we contribute to the literature by undertaking an empirical case study of production and market oriented contract farming in the Bangladesh dairy sector. Given the domestic shortfall of production and high income elasticity of demand for milk this sector has high potential to reduce poverty through increasing income and employment. Yet, the problem remains to identify, develop and test appropriate institutional arrangements for linking production, marketing and processing activities to improve smallholder's access to urban markets at competitive cost (Asaduzzaman, 2000; Omore *et al.,* 2002; Jabbar, 2009).

The dairy sector in Bangladesh is characterized by a great number of small scale dairy farmers who are contracted by a large scale private milk processing company (World Bank, 2008; Shamsuddin, 2011; Raha, 2009). Our analysis is based on a cross-section survey of participants and nonparticipants of contract dairy farmers. Unobservable factors may cause contracting farmers to earn higher benefits than noncontracting farmers, resulting in an overestimation or underestimation of the contract farming effect (Greene, 2008). To that end for the impact assessment, we use treatment regression model to control for possible sample selection bias and two stages least squire regression (2sls) and Heckman two step selection model.

The remainder of the article is organized as follows. In Section 2, we briefly discuss the background of dairy sector in Bangladesh and the evolution of contract and cooperative as a form of vertical coordination in the marketing and production of dairy in Bangladesh. In Section 3, we describe the survey data and the analytical approaches including theoretical and conceptual basis. The section 4 briefly discusses the outcome variables used for the analysis. The estimated results are presented and discussed in Section 5, while Section 6 presents conclusions and policy implications of the findings of this study including further research scope.

2. Overview of Dairy Farming and Evolution of Dairy Contract Farming in Bangladesh

Historically in Bangladesh dairying is part of mixed crop farming system where most rura1 households keep cow for draft power and produce milk for family consumption (Saadullah, 2002; Zaedi *et al.,* 2009; Mian *et al.,* 2007). Bangladesh has three types of dairy farmers: landless and small holders who keeps 1-3cows (local/crossbreed); smallholders who keep 1-5 crossbreed cows; and small to medium holders who keep 10-20 crossbreed cows (World Bank, 2008; Uddin *et al.,* 2011). Dairy animals include cows, buffaloes, sheep and goats. Bangladesh has one of the highest cattle densities (Karim, 1997). There are about 24 million cattle, 1.46 million buffaloes and 25.44 million goats in the country (Table 1). Among the total cattle population, about 6 million are dairy cattle of which about 85-90% are indigenous and 10-15% are crossbred. Indigenous cattle consist of (a) Non-descript Deshi, (b) Red Chittagong cattle, (c) Pabna cattle, (d) North Bengal Gray and (e) Munshigonj White cows (DLS, 2012).

Milk production primarily takes place mainly in two seasons-the lean season, from July to October, and the pick season, from November to June. Over the year dairying growth shows an increasing trend. The country has achieved a tripling of milk production during the last decade (Table 1). However, the growth rate has fluctuated considerably over the years – the main reasons for this are natural disasters, regular flooding, the severity of the monsoon, *Sidr* (like a tsunami) and prevalence of diseases such as anthrax (Hemme and Uddin, 2010).

Table 1. Dairy animal Population, milk production and growth rate in Bangladesh

Year	Milk		Cattle		Buffalo		Goat		Sheep	
	Production (MMT)	Growth rate (%)	Number (million)	Growth (%)	Number (million)	Growth (%)	Number (million)	Growth (%)	Number (million)	Growth (%)
2002-03	1.82	-	22.58	-	1.01	-	17.71	-	2.29	-
2003-04	1.99	9.34	22.60	0.44	1.06	4.95	18.40	3.95	2.38	3.93
2004-05	2.14	7.54	22.67	0.44	1.11	4.72	19.23	4.35	2.47	3.78
2005-06	2.27	6.07	22.80	0.44	1.16	4.50	19.92	3.65	2.57	4.05
2006-07	2.28	0.44	22.87	0.44	1.21	4.31	20.75	4.52	2.68	4.28
2007-08	2.65	16.23	22.90	0.00	1.26	4.13	21.56	3.85	2.78	3.73
2008-09	2.29	-13.58	22.98	0.35	1.30	3.17	22.40	3.70	2.88	3.60
2009-10	2.36	3.06	23.05	0.30	1.35	3.85	23.28	3.93	2.98	3.47
2010-11	2.95	25.00	23.12	0.30	1.39	2.96	24.15	3.74	3.00	0.67
2011-12	3.46	17.29	23.2	0.35	1.44	3.60	25.12	4.02	3.08	2.67
2012-13	5.07	46.53	23.34	0.60	1.45	0.69	25.28	0.64	3.14	1.95
2013-14	6.09	20.12	23.99	2.78	1.46	0.69	25.44	0.63	3.21	2.23
Average (%)		12.55		0.59		3.42		3.36		3.12

Source: BBS, 2006, 2011 and 2014

Average annual per capita milk consumption in Bangladesh rose over the last decade (from 10.45 litters in 1995/96 to 11.2 liters in 2004/05) but remains very low compared with regional levels (for example, 85 liters per capita in India). According to HIES data, total milk consumption grew by about 3 percent per year between 1995/96 and 2004/05, but national milk production grew at an average rate of only 1.2 percent per year from 1995 to 2005 (BBS, 2007). To compensate for the deficits in supply, Bangladesh has relied heavily on imported milk (World Bank, 2008). During the last three decades, significant changes in the livestock sector in general and dairy sector in particular are also taking place in the organization of production, procurement of supply, processing and the distribution of products (Jabbar *et al.,* 2005).

Until 1990s Milk Vita, the trade name of a government cooperative – Bangladesh Milk Producers' Cooperative Union Ltd. (BMPCUL), was the only formal sector that processed and marketed milk from the cooperative producers of Bangladesh. After liberalization and market reforms in 1990s, increases in per capita income, increases in population (1.8% annually), rapid urbanization (15% annually) and consequently increase in the demand for animal products (mostly milk and milk products) and infrastructural growth attracted a number of private sector to participate in dairy sector such as Pram, BRAC- Aarong, AFTAB dairy as a formal channel (Table 2) (World bank, 2008; Jabbar *et al.*, 2005; Hafez, 2004; Shamsuddin, 2011; Raha, 2009). About 15 percent domestically produced milk is consumed by the producer households and the 81 percent marketed through traditional market (unorganized/informal market) and the rest 4 percent enter into the contact farming channel (organized/formal channel) (Figure 1). However, milk sales through contract channel is increasing as the contractor/milk processor provides improved dairy breeds, improved inputs, and marketing facilities for milk and milk products (Curtis, 2011).

Table 2. Market share of milk among the different enterprises

Processing companies	Establishment year	Average milk collection ('000 liter/day)	Market share (%)	No. of producers supplying milk
BMPCUL (Milk Vita)	1973	200	52.08%	150,000
BRAC Dairy (Aarong)	1988	80	20.83%	70,000
Pran Dairy	2001	40	10.42%	30,000
Amo milk	1996	10	2.60%	5,000
Bikrompur Dairy	1998	10	2.60%	6,000
Ultra Shelaide Dairy	1998	10	2.60%	4,000
Aftab Dairy	1998	8	2.08%	4,000
Tulip Dairy	1998	3	0.78%	2,000
Grameen/CLDDP	1999	7	1.32%	6,000
Grameen-Damone	2007	1	0.03%	-
Rangpur Dairy	2007	8	2.08%	7,000
Akij Dairy	2007	4	1.04%	500
Savar Dairy	1974	6	1.54%	Government farm
Total milk collection/day		387,000 Liter	100%	284,500

Source: Raha (2009)

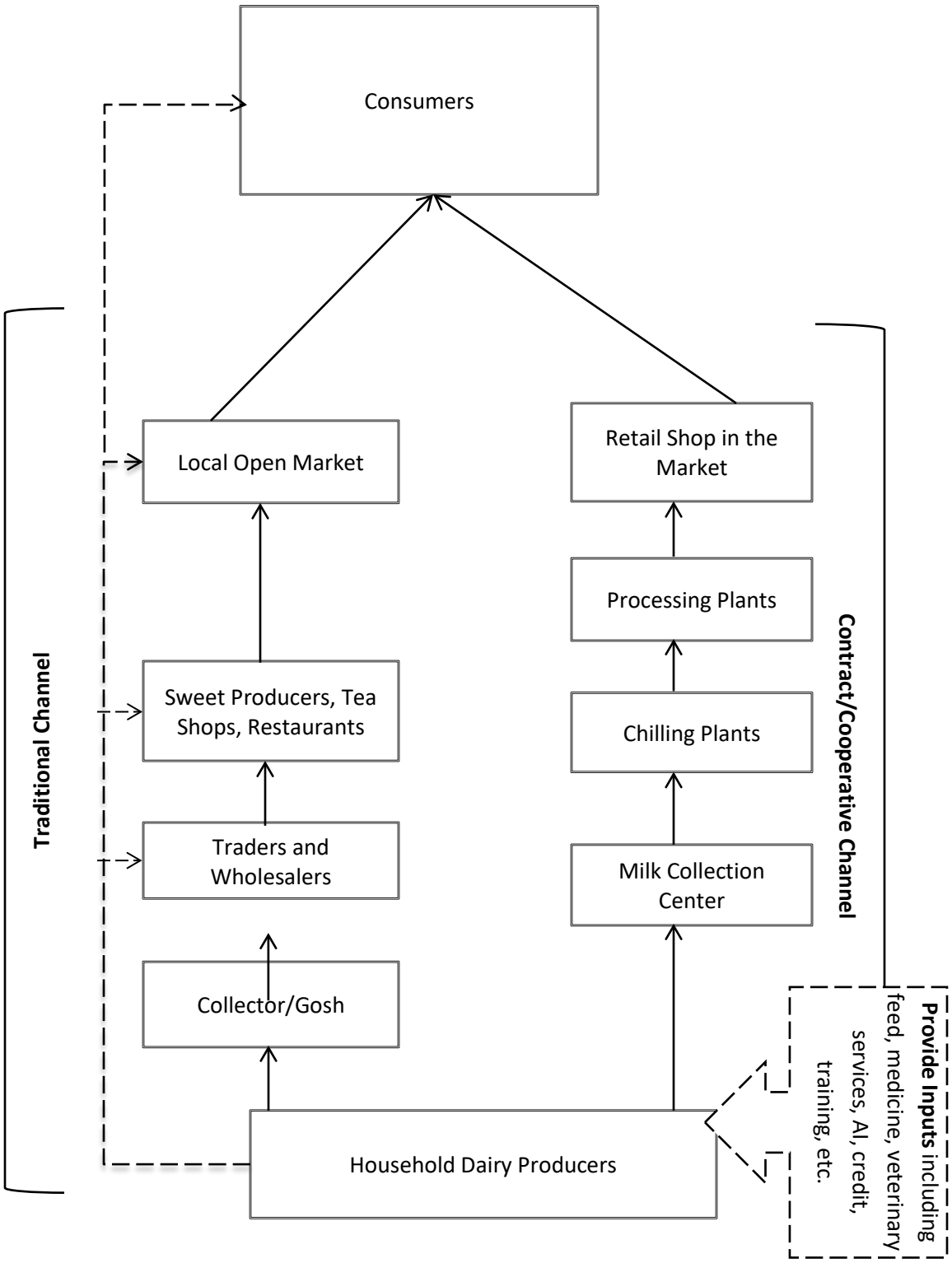

Figure 1. Contract (organized) and independent (unorganized) milk/dairy Marketing channel in Bangladesh

Source: Author's illustration based on field observation, survey with dairy farmers, contract and cooperative processors.

Both the formal (contract/cooperative) and informal (independent) milk marketing channels coexist in Bangladesh. Formal channel includes public and private sector milk processor and cooperative such as BMPCUL and informal channels include selling milk directly to consumer or rural market or to small village traders. Figure 1 shows how the milk passes through producer to consumer in both channels. In the informal channel, the smallholders normally sell their milk to the nearby markets or directly to the neighboring consumers or to the local trader who again sell to the local market or sometimes to the formal channel if it is available in the surrounding areas. Sometimes in the informal channel smallholders sell their milk to the local processors who make dairy products such as sweetmeats, ghee, which are the main dairy products produced in the informal sector (Hemme, Garcia, and Khan, 2004). In this channel stallholder dairy producers do not get any support for their dairy production except the government livestock extension support and most producers rear their dairy through grazing and sometimes additional concentrate stall feeding particularly in the off season. On the other hand in the contract or cooperative channel dairy farmers get technology, marketing and extension supports. In this channel the dairy farmers supply their milk to the contractor/cooperative firm then they process the milk and sell it to the consumers in different forms (Figure 1).

2.1 The settings of BMULC and PRAN dairy contact farming

In this study the sample of contract dairy farmers are from Bangladesh Milk Producers' Cooperative Union Ltd. (BMPCUL)-the trade name of this government cooperative is Milk Vita and a private dairy contract farming enterprise name PRAN dairy limited. With the financial and technical assistance of UNDP and FAO and grants-in-kind from Danish International Development Agency (DANIDA), Milkvita was established in 1974 by the Government of the Peoples Republic of Bangladesh under the cooperative principle by following the philosophy of Anand Milk Union Limited (AMUL), India to meet up the growing need of milk and milk products in Bangladesh. Under the two-tier co-operative structure MilkVita provides a package of milk production enhancing technologies, village level organizational skills and a milk collection-processing-marketing system with the aims of helping both the producers as well as consumers.

The BMPCUL is the central (apex) union and its primary society at village level is called Primary Milk Producer's Co-operative Society or *Prathomic Dugdha Utpadonkari Samabaya Samity* (PDUSS) within its two-tier system. Each PDUSS is composed of 100 to 400 dairy farmers from 3 to 6 villages. To become a member of a village primary society, a farmer has to own a milking cow and has to buy a share of Tk 10.00 and pay Tk 1.00 as entrance fee and a thrift deposit of Tk. 1.00 only. In addition, to maintain membership, a farmer has to supply at least 150 litres of milk in a year. In addition each farmer has to supply minimum 150 liters of milk in 150 days within one year. From the thrift deposit farmers can take loan if needed. PDUSS has to be the member of the BMPCUL-the central society by purchasing at least one share amounted at Tk. 1000 and has to supply 1000 liter of milk within 180 days in a year.

Besides that the central society also cut Tk 0.20. from each liter of milk sold by the member farmers of primary society for developing cattle development fund which is used for cattle development

including cattle treatment, development schemes of various services like milk collection facilities, veterinary services, artificial insemination services, balance cattle feed, loan for cattle purchase. Each society has a collection center where members supply milk twice a day and is transported to the nearest processing plant to produce liquid milk, Powder milk, butter and Ghee (butter oil), cream, ice-cream, flavored milk, sweet yogurt. Milk price is determined on the basis of fat and solid non-fat (SNF) percentage and paid on cash payment with a preferential system of weekly basis matched on the market day of each area (Dugdill *et al.,* 1995; Jabbar *et al.,* 2005; Banglapedia, 2015; Zaedi *et al.,* 2009; Mahmoud et. al, 2005).

PRAN is one of the largest private agro-processing and business companies in Bangladesh, started ultra-high temperature (UHT) treated milk production in 2002 for School Nutrition Program. It started as milk processing partner with Land- 54 O-Lakes, Tetra Pak, and the USDA. The technical expertise developed during this project was also shared with other companies to expand local commercial production of UHT milk. PRAN currently is the third largest dairy producers in Bangladesh, representing about 10 percent share of the milk market. PRAN also follows the procedure of Milk Vita. It operates through a hub system which is like chilling center of Milk vita and they also have milk collection center where farmers come to supply their milk. Like Milk vita, PRAN provides various extension services to farmers including veterinary care, animal husbandry, dairy housing, quality feed and breed improvement through artificial insemination (AI).

In addition, PRAN provides advices on better housing and feeding management of cows free of cost, de-worming and periodical vaccination, balanced feed at cost price, seeds of fodder and silage preparation training and AI services at a cost price. Every hub has a full time veterinary doctor, extension workers along with field supervisors and collection centers in almost every village that is easily accessible to local dairy farmers. They have also established a dairy academy to train the dairy farmers. Dairy farmers must register with PRAN for supplying milk and PRAN provides a register where farmer record daily milk supply along with fat percentage and price. Registered farmer has to supply milk every day and PRAN monitors the quantity of supply as a contract enforcement mechanism. If they realize farmer's average supply falls from his average daily supply then they contact that farmer and check whether that farmer is outselling his milk or not. The same enforcement mechanism is also applied by Milk vita. Same like Milk vita, milk price is determined on the basis of fat and SNF percentages and paid on cash on weekly basis (Holm and Tinnberg, 2015; Rahman *et al.,* 2013). As it is evident that basically, PRAN and Milk vita contract system including terms and conditions are more or less similar, we did not differentiate rather we count both group of respondents as contract and compare with the non-contract (independent) farmers to assess the impact of contract farming on various welfare indicators and adoption of food safety practice.

3. Data and Methods

3.1 Data and study area

The study makes use of primary survey data randomly collected in May to September 2016 by covering information from the last year preceding the survey in northern rural Bangladesh from 195 contract (49%) and 207 (51%) independent dairy farm households in 10 rural villages in two districts (Sirajganj and Pabna) (Figure 2). Within the contract sample of 195, 102 contractors are from PRAN and 93 contractors are from MilkVita. These districts are located within the same agro-ecological zone, have similar access to road infrastructure, and are classified as high-potential dairy-growing areas. We randomly sampled dairy farmers who are participants of contract as well as nonparticipants for comparison. The data were collected using a pretested structured questionnaire using Tablet administered to heads of households by trained enumerators. The survey was designed by the authors of this paper at the Bangladesh Agricultural University (BAU) and International Food Policy Research Institute (IFPRI), and the survey was implemented by the Bureau of Socio-Economic Research and Training (BSERT) at Bangladesh Agricultural University (BAU) under the direct supervision of the first author of this paper. The data collected at the farm-household level include farm and farmer socio-economic characteristics, cropping patterns and economics of dairy farming, marketing channels, and adoption of good agricultural practices.

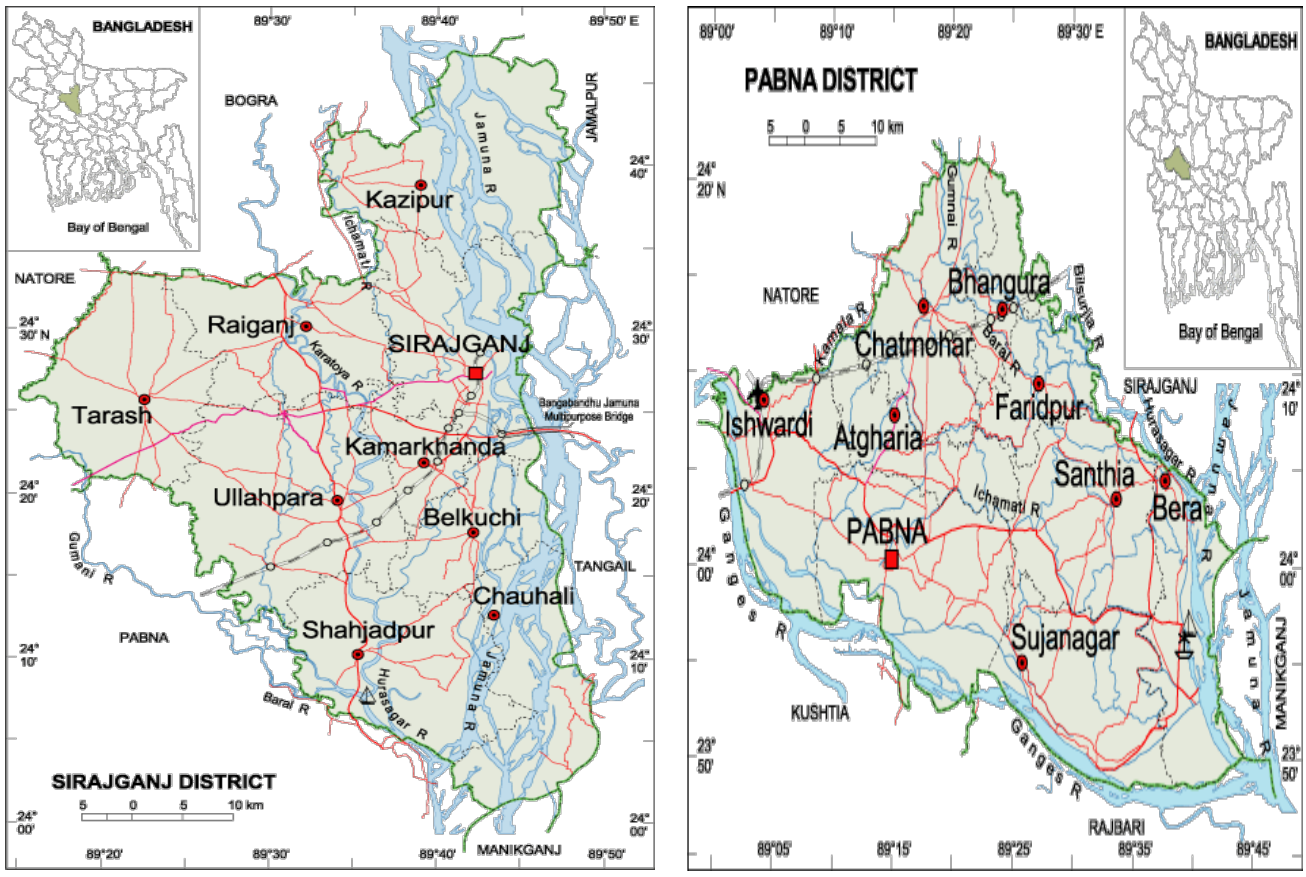

Figure 2. Study Areas (Source: BD Affairs, 2019)

These northern districts were selected due to a high concentration of dairy contract farmers. In terms of the regional share of milk production, the northern part of Bangladesh produces nearly half of the country's milk (Hemme *et al.,* 2004). The selected firms that establish vertical and horizontal coordinations with farmers included Milk vita cooperatives in the Sirajganj district and PRAN in the Pabna district.

3.2 Empirical framework

It is already indicated that the present analysis focuses on the determinants of participation in a contract farming scheme and the impact of contract participation on welfare and food safety practice by the dairy farming households in Bangladesh. The study comprises two stages. In the first stage, the objective is to identify determinants of farmer participation in contract farming. Following a random utility framework (Feder, Just, & Zilberman, 1985; Wollini and Zeller, 2007; Fischer and Qaim, 2012; Abebaw and Haile, 2013; Handschuch et al., 2013; Islam *et al.,* 2015), individual farmers decision to participate in contract farming is estimated by using probit model. For choosing the explanatory variables that included in the probit model, we rely on the existing theoretical and empirical literatures on contract and cooperative farming (e.g., Warning & Key, 2002; Simmons *et al.,* 2005; Wollini and Zeller, 2007; Roy and Thorat, 2008; Bernard *et al.,* 2008; Miyata *et al.,* 2009; Bernard and Spielman, 2009; Rao & Qaim, 2011; Francesconi and Heerink, 2011; Fischer and Qaim, 2012; Bellemare 2012; Abebaw and Haile, 2013; Handschuch et al., 2013; Narayanan, 2014; Mishra *et al.,* 2016). As presented in Table 4, we include quite a number of farmer, farm and household socio-economic variables that are hypothesized to influence the participation decision in contract farming.

In the second stage, as already stated, the interest is to estimate the impact of contract farming on several outcome variables which are household welfare (e.g. farm profits), farm productivity and food safety practice adoption. This can be expressed as:

$$Y_i = \alpha + \beta C_i + \gamma X_i + \varepsilon_i \qquad (1)$$

where the unit of observation is household i, Y_i is an indicator of welfare, farm productivity and food safety; X_i is a vector of explanatory variables (other than contract farming status) that influence the outcome variables, and it includes household, farm and contextual characteristics such as age, educational level of household head, household size, farm size, herd size, social network variables, risk preference and union dummies; C_i is a dummy equal to one if household i participates in contract farming and equal to zero otherwise; and e_i is an error term with mean zero. The aim of this paper is to estimate β coefficient, which measures the effect of participation in contract farming on household welfare and adoption of food safety practice, as correctly as possible.

The variable C_i is potentially endogenous since participation in contract farming is not randomly distributed across households and farmers may decide whether or not to participate in contract farming (i.e. self-selection bias). In other words, who participate in contract farming may be systematically different from non-participators and these differences may obscure the true effect

of contract farming on household welfare. As noted by Stefanides and Tauer (1999) for accuracy of the impact of β on outcome variable, farmers should be assigned randomly between the two groups (participator and non-participator). However, it is possible that contract and independent farmers' outcomes are different precisely because of a process of selection by contractors or self-selection by the farmers. For example, contractors might select farmers based on certain attributes such as herd sizes or skills (e.g. education and experience). If the farmers picked up by contractors on an average are higher skilled or larger herd size farmers than the average of the independent ones, this will simply a case of positive selection. Similarly, if the pool of farmers selected (or chose to be selected) is inferior to the pool of independent farmers then there is negative selection.

Thus, estimating equation 1 with ordinary least squares (OLS) regression technique may lead to biased results. The specification in Eqn (1) if estimated using OLS can suffer from omitted variables bias. Unobserved characteristics like reputation that cannot be controlled for in the regression will lead to a selection bias. If the farmers, for example, who participate in contract farming have greater unobserved ability or skill then the estimated coefficient β captures the effect of this omitted variable and not the effect of contract farming *per se*. Similarly, it is possible that those who participate in contract farming have poor prospect outside owing to lower ability or skills or knowledge and thus the coefficient β is downward biased. In both cases the dummy C_i will be correlated with the error term ε_i.

Given the cross-sectional data , three main types of estimators i.e. propensity score matching (PSM), instrumental variable (IV) model and Heckman selection model are applied to account for endogenous selection. As PSM accounts for selection into the treatment (in our case contract farming participation) based only on the observed variable, we account for this by using a treatment effect model[1] (Heckman selection correction model) with endogenous dummy variable for each outcome indicator (Greene, 2008; Wooldridge, 2010), which involves two steps. For model estimation, we implement a full information maximum likelihood procedure, in which all parameters in both models are estimated simultaneously, thereby enhancing asymptotic efficiency, rather than as a two-step procedure (Puhani, 2000). Identification is provided by the inclusion of several variables in the selection model that are not found in the outcome equation.

Our identifying variables (exclusion restrictions) are the village participation rate in contract farming, maximum and minimum price difference two years before joining contract, maximum and minimum price difference one year before joining contract, average (three years) milk price received before joining contract, time spent per year with cooperative, time spent per year with government institutions and time spent per year with other institutions. We check for the strength

[1] Though the instrumental variable (IV) model also takes into account unobservable factors that may influence both the treatment (contract participation, in our model) and the outcome (welfare, in our model), we have used the treatment effects model as it is designed for endogenous dummy variables, while the IV approach is better suited for endogenous continuous variables (Miyata *et al.,* 2007). Though treatment effects model is more robust, particularly for small samples, it is sensitive to both model specification and distributional assumptions (Blundell & Costa Dias, 2000; Heckman, LaLonde, & Smith, 1999, Chapter 31). See a discussion of these assumptions in Bellemare (2010) and we also followed the same procedure and also reported the results of the relevant misspecification tests in the relevant tables.

of these exclusion restrictions (instruments) in the first stage by including them in the regression of the determinants of participation in contract farming. The required conditions for an instrument would be met if exclusion restrictions variables that are both (i) correlated with participation in contract farming and (ii) plausibly exogenous to the welfare outcome of interest. To check the robustness of the estimated results, we have also estimated two stage least squire regression (2sls) and Hackman two-step estimator as alternative estimators.

4. Choice of Outcome Measures

Farmers join dairy contract farming which may contribute to household welfare, productivity and food safety adoption practices. We evaluate the effect of participation in contract farming on a number of welfare outcomes, such as household expenditure, adult equivalent expenditure, gross margin and net return per cow equivalent, gross margin and net return per liter of milk, lactation productivity and adoption index of food safety practice. Below, we explain these outcome measures in detail.

4.1 Household expenditure

Household income can be used as a measure of household welfare, but household expenditure is often preferred because it is less prone to seasonal fluctuations and measurement errors, hence, is considered more reliable (Deaton, 1997). We therefore consider household expenditure instead of income as a welfare indicator in this study. It is expected that contract farming participation of households result in increased yields or outputs, thus, more consumption of farm products or more income from sale of products for the consumption of other goods. Also, the resource allocation effects of contract farming may induce changes in expenditure. The expenditure comprises different sub-components including food consumption, housing, energy, transportation, communication, health and educational expenses, expenditures on other consumer durables and non-durables and transfer payments made by households. The different sub-components were aggregated to obtain total household annual expenditure. Later the household annual expenditure was converted to expenditure per adult equivalent terms which is the ratio of total household expenditure and household's total number of adult equivalents. A household's total number of adult equivalents was calculated by considering each individual under 15 as 0.5 adult, each individual between the ages of 15 and 65 as one adult, and each individual over 65 as 0.75 adults (Deaton, 1997).

4.2 Farm profit and productivity

Bellemare (2010) argues that farm profits are better measure of welfare. We also consider farm profit measured by gross margin and net return per cow equivalent and per liter of milk as welfare

indicators [2]. We expect that farm profit will be positively affected by contract farming participation. Table 3 presents detailed profit calculation, which clearly shows that gross margin and net return per cow per year is comparatively high for contract grower.

Table 3. Economics of dairy rearing for contract and non-contract farmers (Tk[3]/cow/year)

Cost and return item	Amount (Tk./cow/year)	
	Contact	Independent
Variable costs		
Labour cost	8986.95(13)	11243.99(18)
Fodder	17831.47(26)	18607.98(29)
Concentrate	30457.89(45)	24592.67(38)
Vitamin & other	4014.68(6)	4580.82(7)
Veterinary	2312.61(3)	2088.49(3)
Transport cost	741.55(1)	494.68(1)
Other costs	2334.82(3)	1174.98(2)
Total variable costs (TVC)	66679.96(98)	62783.61(98)
Fixed cost		
Housing*	593.57(1)	665.08(1)
Equipment**	617.47(1)	504.07(1)
Total fixed costs (TFC)	1211.04(2)	1169.15(2)
Total cost (TC) (TVC+TFC)	67890.99(100)	63952.76(100)
Gross revenue		
Return from milk (total milk production multiplied by per unit price)	70017.01(73)	56743.63(68)
Return from Cowdung	2141.24(2)	1392.44(2)
Inventory change***	24135.16(25)	25604.35(31)
Total gross revenue (GR)	96293.41(100)	83740.42(100)
Gross margin (GM=GR-TVC)	29613.45	20956.81
Net return (NR = GR - TC)	28402.42	19787.66

Note: Percentage share are in parenthesis *(Initial investment – salvage value)/ economic life; *(Purchase value – salvage value)/ economic life; ***Net change in inventory (NCI) is calculated as NCI = (closing stock + consume/ gifted + sold + died) - (opening stock+ bought). Source: Field survey, 2016

Alternatively, we also look at farm productivity as an outcome measure to see the impact of contract farming. Productivity measured at lactation level i.e. lactation yield[4]. Lactation yield is the total milk production per cow in a lactation period.

[2] Cow equivalent is calculated using the conversion factor as cow and adult=1, heifer=0.8, calf=0.4 (Kabir and Talukder, 1999).

[3] The exchange rate in 2016 was US$1= 79 Bangladeshi Taka at time of the survey.

[4] Lactation is number of days/months a cow gives milk in a calving period.

4.3 Food Safety Practice Adoption

Apart from the above welfare outcomes, we are also interested in the role of contract farming in adopting food safety practices, as the milk is highly prone to safety issues. To do so, by following Kumar *et. al.,* (2011 and 2017) we develop a food safety adoption index at the farm level to estimate farmers' compliance with food safety practices. The survey gathered information from farmers on 45 distinct good agricultural practices, including hygienic milking, hygienic milk storage, maintenance of hygienic premises and surrounding environment, and animal health. We requested an objective response from farmers on whether or not they follow each of the 45 mentioned practices; we summed up all affirmative answers given by a farm household to create an aggregate score of good practices, which works as a proxy for that household's compliance with food safety practices (FSPs). We then identified the maximum and minimum scores among surveyed households to develop a standardized index for compliance with FSPs, and calculated a food safety adoption index (FSAI) for each household as follows:

$$\text{FSAI}= \frac{S_A - S_L}{S_M - S_L}$$

Where S_A is the household's actual score, S_L and S_M is the minimum and maximum score among surveyed households respectively. We compared the average FSAI of contract and noncontract farmers in descriptive as well as in regression means to see the causal impact of contracting farming on food safety practices (FSPs) adoption rate.

5. Results and Discussion

This section begins with a descriptive statistics which describe the differences between contract and non-contract farmers using simple mean and t-tests of the control and outcome variables. Further, this section presents nonparametric evidence of the impact of contract farming on welfare by comparing Kernel density estimates for the welfare measures selected for analysis for both the participating households and non-participants in contract farming. These descriptive and nonparametric results fail to control for confounding factors and are only suggestive. Finally, we present the results of the econometric analysis of the determinants of participation in a contract farming schemes and the causal impact of participation on household welfare and food safety.

5.1 Descriptive statistics

Table 4 presents mean comparisons by participation status for the variables used for analysis as well as the result of a t-test of difference in means for each variable. One hundred and ninety five (49 percent) of the total sample households are participating in contract farming and 207 (51 percent) of the total sample households are not participating. The first part of the table 4 presents the outcome variables and the second part presents the control/independent variables used in the analysis. Table 4 also presents lagged income and price before joining contract, social network

questions used as a vector of IVs in this article. In terms of outcome variables, all the variables including total annual household expenditure, household expenditure per adult equivalent, gross margin, net return, lactation yield and food safety practice adoption are significantly different between contract and non-contract dairy farmers. It suggests that the average contract farming participant household welfare and food safety practice adoption is higher than non-participant.

In terms of control or independent variables, farm size of contract farmers is significantly higher than non-contract farmers. Contract farmers are also more likely to be more educated and have greater access to credit. Furthermore, herd size and likelihood of access to electricity are higher among dairy contract farmers. Interestingly, contract farmers are more likely to be located in areas farther away from the market but closer to the collection center. On average, contract farmers have attended larger percentage of community meeting than non-contract farmers. The vector of IVs (exclusion restriction variables) also significantly differs between contract and non-contract farming household. For example, the households who participate in contract farming, report a significantly higher price fluctuation in two years and one year before joining contract and low average price in the last three years before joining contract. Village participation rate in contract farming is also high and that they spent more time with cooperative and other institutions and less time with government institutions than the households who do not participate in contract farming (Table 4).

Table 4. Descriptive statistics of outcome and control variables

Variable	Type	Definition and measurement	All (N=402)		Contract (N=195)		Independent (N=207)		Diff. (Cont.-Indep.)†
			Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Outcome variables									
Total exp	Continuous	Total annual expenditure of the household (Tk.)	559068.90	461894.30	681615.50	550686.30	443626.50	319535.60	237989.00**
Expenditure per person	Continuous	Adult equivalent expenditure (Tk./ person)	199584.80	139382.70	237616.80	150354.80	163757.50	117766.60	73859.30***
GM per cow	Continuous	Gross margin per cow equivalent (Tk)	25155.92	16418.71	29613.45	17549.19	20956.81	14078.10	8656.64***
GM per liter	Continuous	Gross margin per liter of milk (Tk)	15.09	8.32	16.49	8.84	13.78	7.59	2.71***
NR per cow	Continuous	Net return per cow (Tk)	23966.46	16217.41	28402.41	17477.99	19787.66	13715.15	8614.75***
NR per liter	Continuous	Net return per liter of milk (Tk)	14.35	8.25	15.79	8.82	12.99	7.46	2.80***
Lactation yield	Continuous	Total milk produced by a cow within lactation period (liter)	2554.30	587.93	2681.70	620.56	2434.28	529.49	247.42***
FSAI GAP	Continuous	Good agricultural practice	0.41	0.18	0.43	0.18	0.39	0.17	0.04**
Independent variables									
Age	Continuous	Age of household head (year)	45.72	12.53	45.85	13.13	45.59	11.97	0.26
Age squared	Continuous	Age of household head (years) squared	2246.60	1217.03	2273.26	1285.71	2221.49	1151.16	51.77
Education	Continuous	Education of household head (years of schooling)	4.55	4.54	5.06	4.81	4.07	4.23	0.99**
Education squared	Continuous	Education of household head (years of schooling)squired	41.31	63.02	48.62	69.33	34.43	55.74	14.19**
Highest education	Continuous	Education of the highest educate person of the household (years of schooling)	9.90	4.31	9.95	4.12	9.85	4.50	0.10
Household size	Continuous	Household size (number)	5.58	2.94	5.55	2.93	5.61	2.96	-0.06
Dependency ratio	Continuous	Ratio of working age and depended person in the household (ratio)	0.64	0.56	0.65	0.53	0.63	0.59	0.02
Main occupation	Dummy		0.29	0.45	0.24	0.43	0.34	0.47	-0.10**
HH experience	Continuous	Experience in farming of the household head (year)	22.19	11.84	21.31	11.53	23.03	12.09	-1.72
Farm size	Continuous	Farm size (decimal)	171.68	299.89	209.99	403.76	135.58	137.29	74.41**
Cow equivalent	Continuous	Herd size: Cow equivalent animal (no.)	5.12	4.15	6.35	4.84	3.96	2.95	2.39***

Migration	Dummy	=1 if any member of the household migrated within last 5 years	0.09	0.29	0.07	0.26	0.11	0.31	-0.04
Credit	Continuous	Amount of credit taken in last year (Tk)	47263.68	81327.27	69174.36	100340.6	26623.19	50107.87	42551.17***
Organization member	Continuous	Number of household member as member of organization	0.40	0.58	0.58	0.63	0.23	0.47	0.35***
Extension visit	Continuous	Number of extension visit by different GOs and NGOs	7.57	11.11	10.07	13.36	5.22	7.80	4.85***
Electricity access	Dummy	=1 if the household has access to electricity	0.85	0.35	0.91	0.29	0.80	0.40	0.11***
Community meeting	Continuous	Proportion of the community meeting attended (%)	25.52	33.48	33.27	36.95	18.22	28.04	15.05***
Risk preference	Dummy	=1 if the household head like to take risk	0.36	0.48	0.33	0.47	0.38	0.49	-0.05
Distance market	Continuous	Distance of output market from home (Km)	1.88	1.45	2.41	1.59	1.37	1.10	1.04***
Distance collector	Continuous	Distance of collection centre from home (Km)	1.01	1.12	0.82	1.17	1.20	1.03	-0.38***
Village participation	Continuous	Village participation rate in contract farming (%)	55.46	31.82	73.08	27.12	38.86	26.61	34.22***
Price range 2yrs	Continuous	Difference between maximum and minimum price received within last two years before joining contract (Tk/liter)	7.78	6.20	9.91	7.17	5.77	4.24	4.14***
Price range 1yrs	Continuous	Difference between maximum and minimum price received within last one year before joining contract (Tk/liter)	7.25	5.90	9.56	6.78	5.06	3.82	4.50***
Average price	Continuous	Average price received in last three years before joining contract (Tk/liter)	36.30	5.32	35.47	6.79	37.08	3.24	-1.61***
Time spent cooperative	Continuous	Time spent per year with cooperative member (hour)	6.55	22.23	11.52	30.37	1.87	6.89	9.65***
Time spent GO	Continuous	Time spent per year with member of government institution (hour)	4.46	25.59	1.98	22.96	6.80	27.69	-4.82*
Time spent Other	Continuous	Time spent per year with member of other organization (hour)	41.86	164.48	85.65	228.40	0.61	3.09	85.04***

Note: †T-test *** Significant at 1%. ** Significant at 5%. * Significant at 10%.

5.2 Nonparametric evidence

Before going to the econometric results, it is helpful to take a first look at whether contract farming positively affects the welfare of the households non-parametrically. Figures 3 to 6 plot Kernel density estimates by participation status for household expenditure, household expenditure per adult equivalent, lactation yield and food safety practice adoption. Figures 3 to 6 suggest that participants and nonparticipants in contract farming differ along almost all indicators but among them total household expenditure (Figure 3) and household expenditure per adult equivalent (Figure 4) are both clearly higher for participants, and lactation yield (Figure 5) and food safety practice adoption rate (Figure 6) are modestly higher for participants. The density of expenditure and expenditure per adult equivalent of households who participate in contract farming clearly appear higher than the non-participants but lactation yield and food safety practice adoption rates do not clearly appear to vary systematically between participants and non-participants.

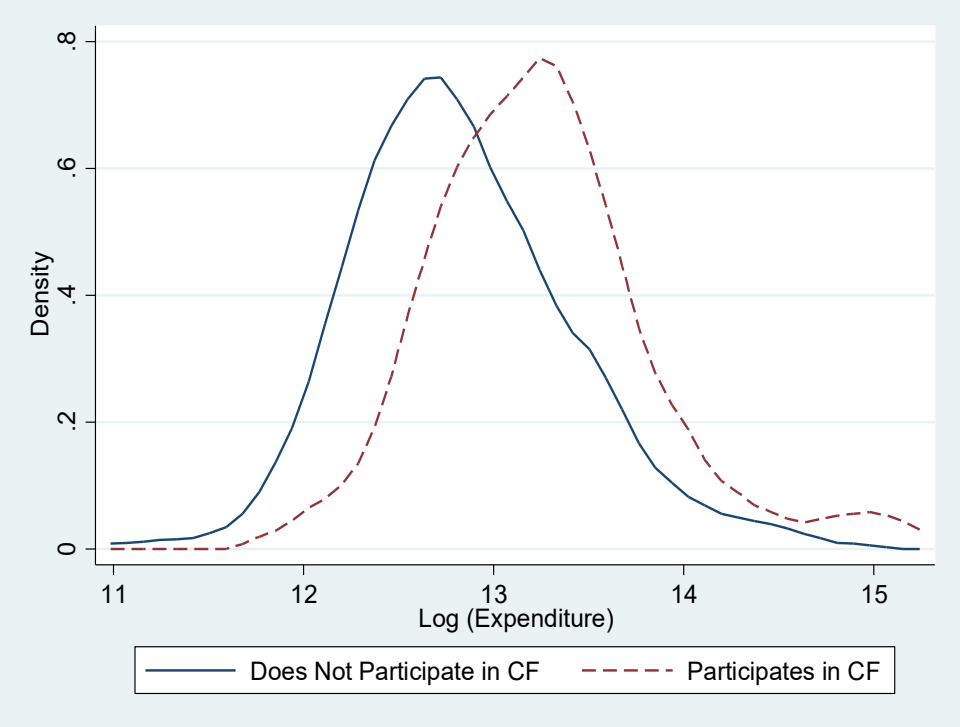

Figure 3. Kernel density estimation of household expenditure by dairy contract farming participation status with Epanechnikov Kernel and bandwidth set equal to 0.5.

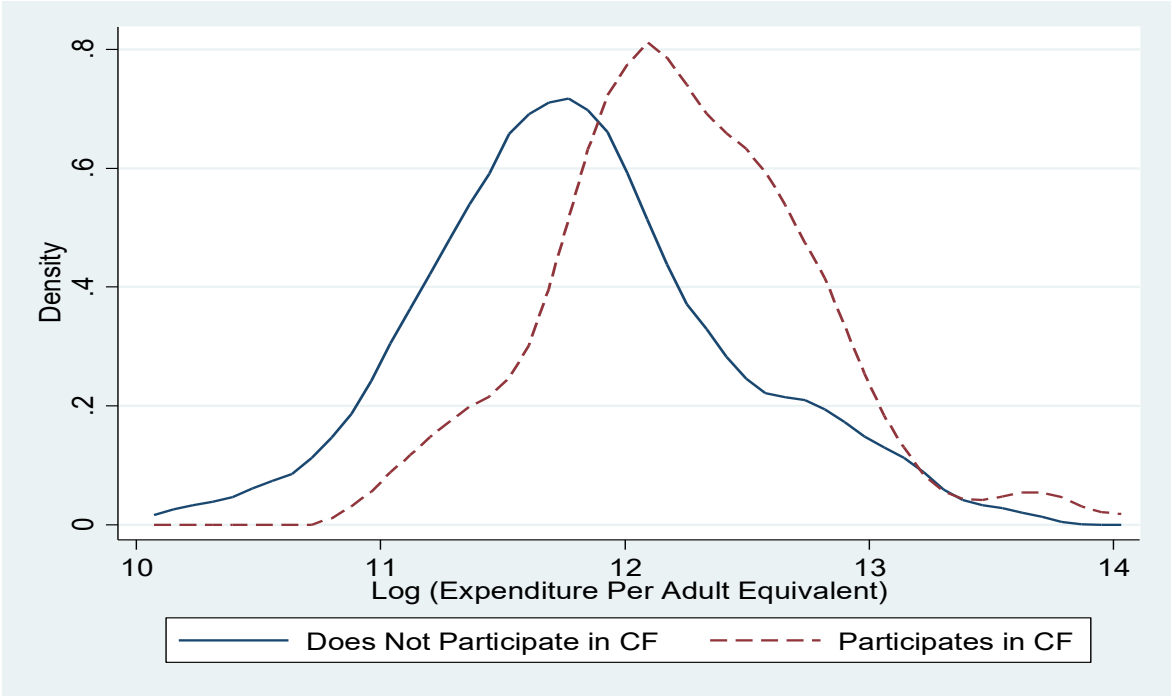

Figure 4. Kernel density estimation of household expenditure per adult equivalent by dairy contract farming participation status with Epanechnikov kernel and bandwidth set equal to 0.5.

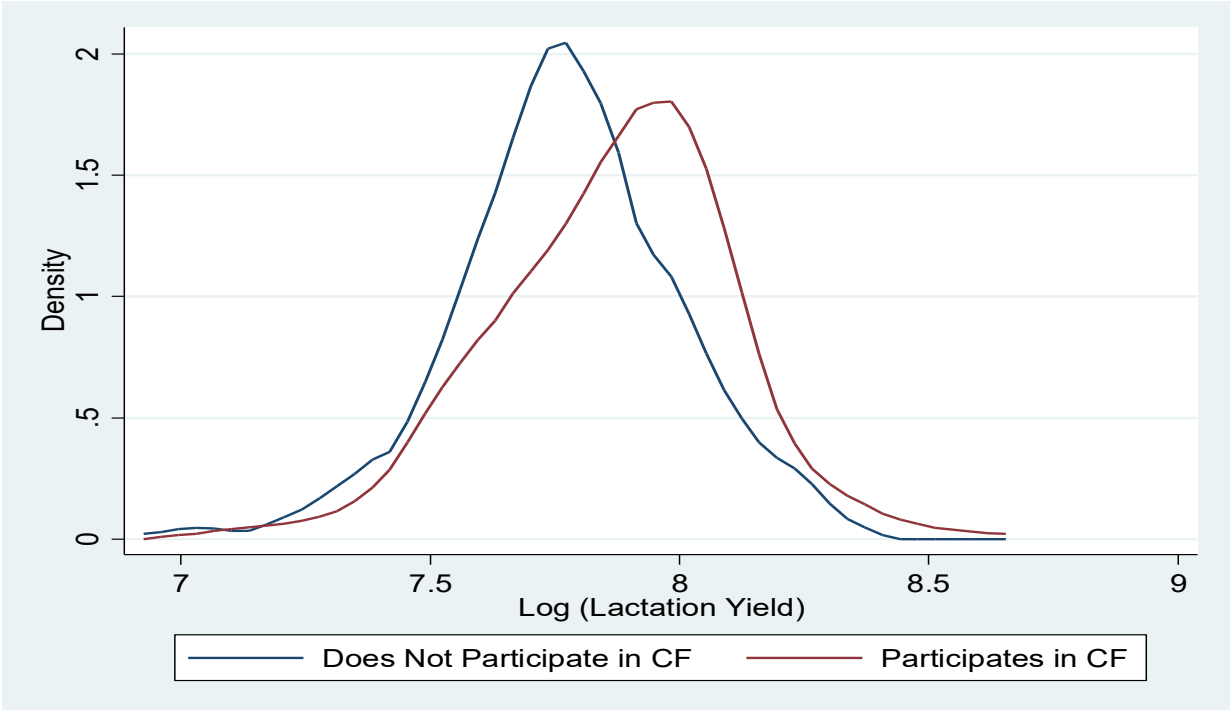

Figure 5. Kernel density estimation of lactation yield per cow by dairy contract farming participation status with Epanechnikov Kernel and bandwidth set equal to 0.5.

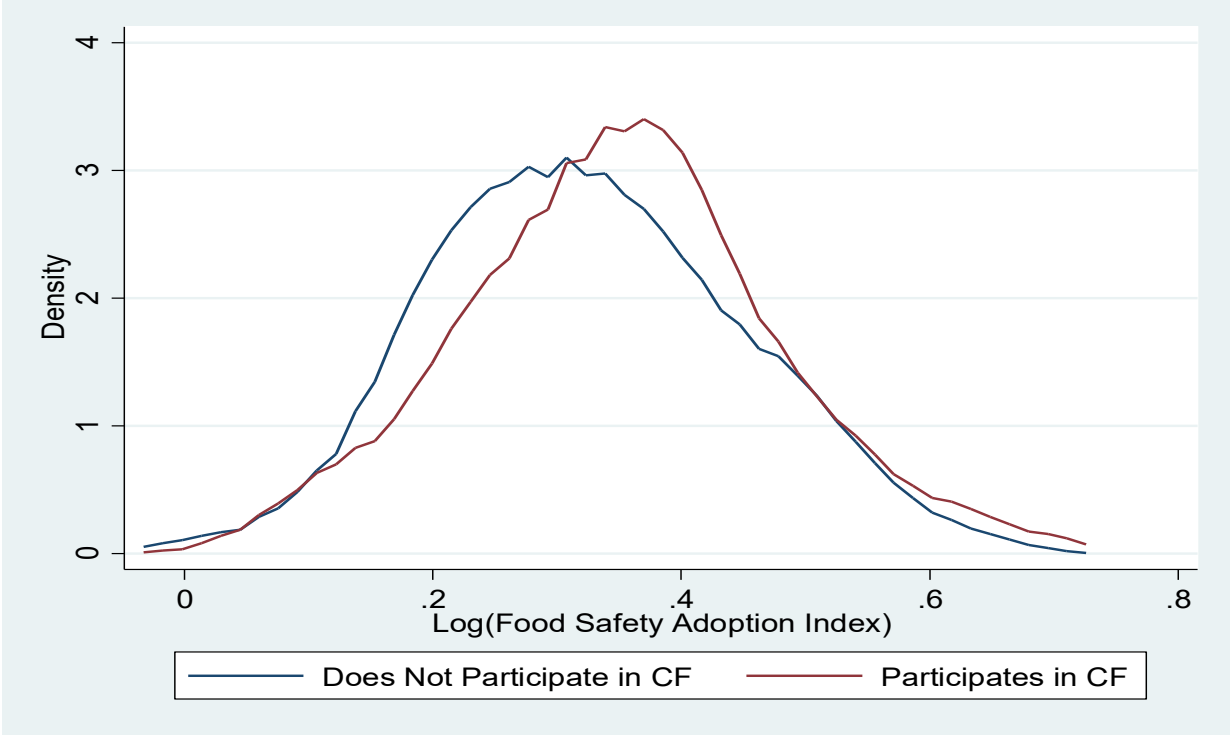

Figure 6. Kernel density estimation of FSAI by dairy contract farming participation status with Epanechnikov Kernel and bandwidth set equal to 0.5.

5.3 Who participates in contract?

We begin with an estimation of a probit model to predict participation in contract farming (Table 5). The dependent variable in the probit model is coded as 1 for contract farming participants and 0 for non-participants. The estimated model is statistically significant at 1% level. The probit model also correctly predicts 92.04% of the sample observations.

The variables in the vector of IVs are all significantly different from zero. For example village participation rate in contract farming (excluding the farmer in question) positively affects participation decision. Similarly, maximum and minimum milk price difference before (two and one years) joining contract also positively affects participation decision. This is expected with risk averse and the role of contract farming in risk sharing if price fluctuate then farmers may decide to participate in contract and reduce their price risk. On the other hand, average price (average of 3 years) received before joining contract negatively affect participation decision as expected because who received low average price in the last 3 years before contract, their likelihood of participation is high compare to who received higher average price. Social network variables such as time spent with cooperative and other type of institutions positively impact on participation decision. On the other hand who spend more time with government institutions are less likely to

participate in contract farming. Because of involvement with government institutions they may get lot of privilege from the government institutions (e.g. input subsidies, credit, information, etc), and may be their focuses on dairy farming is also less and consequently they invest less time.

The highest educated member households are less likely to participate in contract farming. Households with migrants are also less likely to participate in contract farming. The more experienced the household head in farming is also less likely to participate in dairy contract farming. Likewise, households whose family members are members of organizations are more likely to participate in contract farming than households. Further household distance from the output (milk) market positively impact participation, the remotely located households are more likely to participate in contract farming. Lastly, the herd size of a household is positively related with the likelihood of participation in contract farming (Table 5).

Table 5. Probit estimation results for first stage of the Treatment regressions: determinants of participation in dairy contract farming

Variable	Marginal effect	Std. Err.
Dependent variable: = 1 if participates in contract farming; = 0 otherwise		
Age	-0.014	0.010
Age squared	0.000	0.000
Education	0.000	0.007
Education squared	0.000	0.001
Highest education	-0.006*	0.003
Household size	-0.002	0.004
Dependency ratio	-0.031	0.022
Main occupation	0.020	0.031
HH experience	-0.002*	0.001
Farm size	0.000	0.000
Cow equivalent	0.007**	0.003
Migration	-0.124**	0.054
Credit	0.000**	0.000
Organization member	0.056***	0.020
Extension visit	0.005***	0.001
Electricity access	0.042	0.036
Community meeting	0.000	0.000
Risk preference	0.030	0.033
Distance market	0.017*	0.010
Distance collector	-0.015	0.012
Village participation	0.002***	0.000
Price range 2yrs	0.006**	0.003
Price range 1yrs	0.008***	0.003

Average price	-0.006***	0.002
Time spent cooperative	0.005***	0.002
Time spent GO	-0.011***	0.004
Time spent Other	0.007**	0.003
Constant	1.488	2.143
Union fixed effect	Yes	
Log pseudo likelihood	-73.8158	
Wald chi^2 (32)	212.26***	
Pseudo R^2	0.7349	
% predicted correctly	92.04	
Number of observation	402	

Notes: Standard errors are robust. * Significance at the 1% level. ** Significance at the 5% level. *** Significance at the 1% level.

5.4 Impacts of contract farming

The significance of the 7 exclusion variables in Table 5 also supports the feasibility of using treatment effect regression; two stage least squire regression and Heckman selection methods as robustness check. Table 6 presents estimation results for (i) the treatment regression of household expenditure in columns 1 and 2, is instrumented with the variables at the bottom of Table 5. In Table 7 to 13, we followed the same strategy for other welfare indicators, productivity and food safety practice adoption.

The estimated coefficients are highly comparable across different models and estimators, also indicate the expected signs. For example, herd size is significantly and positively associated with almost all welfare indicators except gross margin per liter of milk and food safety practice adoption. The results of the selection equations (section (i) of the table) are consistent across specifications in Tables 6–13 including the probit model for participation in contract farming in table 5. The problem of endogenous selection is captured by the adjusted ρ-statistic, which is the hyperbolic arctangent of the correlation (ρ) between the residuals in the selection and outcome equations. For most dependent variables including household expenditure, gross and net margins per cow and per liter of milk and food safety practice adoption the outcome and selection equations cannot be considered independent (at the 1% level in most cases). For household expenditure per adult equivalent and lactation yield, selection bias is not significant, and therefore the OLS results may likely consistent.

Table 6 shows that the participation in contract farming is positively associated with household expenditure, but there is a considerable difference in estimated coefficients between the treatment regression and the OLS regression. While the OLS regression indicates that participation in contract increase household's total expenditure by 18%, the treatment regression suggests that participation in contract farming increase a 42% of household's total expenditure. Looking at the

other welfare measures used for this research, the empirical results indicate that contracting entails a 35% and 34% increase in a gross and net margin per cow respectively (Table 10 and 11). The participation in contract farming has significant effects on productivity measured by lactation yield, gross and net margin per liter of milk and household expenditure per adult equivalent (Table 8, 9, 12 and 7). The results in Table 13 show that a one unit increase in the likelihood of participating in contract farming improves the mean food safety adoption rate by a 9%. Given the empirical strategy applied, these estimates control for other observed determinants of welfare and food safety and any unobserved (latent) endogenous selection bias. In other words, we can conclude that there is a positive treatment (contract farming) effect ceteris paribus. Though it is difficult to compare two results (Bellemare, 2012), our results are in line with similar literatures such as Rao and Qaim (2011), Miyata et al. (2009), and Warning and Key (2002), reported 48%, 39% and 32% increase in income due to participation in contract farming respectively.

Finally, to check the robustness of the estimated results, Table 14 compares results for alternative estimators (2sls and Hackman two-steps) using the same dependent variables and control variables (observed covariates). Although the main interest variable (contract farming participation dummy) coefficients are not directly comparable due to the different approaches used to deal with selection bias, a consistent story emerges that is independent of the specific estimator used. It is evident that participation in contract farming has a strong positive impact on welfare measured by household expenditure, household expenditure per adult equivalent, gross and net margin per cow and per liter of milk, lactation yield, and on food safety practice adoption.

Table 6. Treatment regression and OLS estimation results for household expenditure

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of household expenditure		Dependent variable: Log of household expenditure	
Age	-0.079	0.064	-0.046***	0.016	-0.051***	0.016
Age squared	0.001	0.001	0.000***	0.000	0.001***	0.000
Education	-0.022	0.059	0.011	0.015	0.012	0.016
Education squared	0.001	0.004	0.000	0.001	0.000	0.001
Highest education	-0.025	0.028	0.000	0.006	-0.001	0.006
Household size	-0.044	0.032	0.012	0.009	0.011	0.010
Dependency ratio	-0.192	0.176	-0.090**	0.038	-0.100***	0.038
Main occupation	0.030	0.247	-0.069	0.056	-0.067	0.056
HH experience	-0.016	0.009	-0.001	0.002	-0.002	0.002
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.095***	0.035	0.067***	0.008	0.070***	0.008
Migration	-1.191***	0.389	0.351***	0.097	0.335***	0.097
Credit	0.000***	0.000	0.000	0.000	0.000	0.000
Organization member	0.480***	0.163	0.050	0.047	0.083*	0.046
Extension visit	0.048***	0.012	-0.003	0.002	-0.001	0.002
Electricity access	0.293	0.280	0.166**	0.069	0.179***	0.069
Community meeting	0.006*	0.003	0.001	0.001	0.002**	0.001
Risk preference	0.006	0.284	-0.026	0.052	-0.044	0.051
Distance market	0.306***	0.084	0.029	0.023	0.048**	0.021
Distance collector	-0.191*	0.107	0.058**	0.024	0.035	0.023
Contract farming			0.420***	0.133	0.181***	0.065
Village participation	0.021***	0.003				
Price range 2yrs	0.071***	0.026				
Price range 1yrs	0.092***	0.025				
Average price	-0.038*	0.022				
Time spent cooperative	0.032**	0.016				
Time spent GO	-0.099**	0.044				
Time spent Other	0.054**	0.022				
Constant	-0.030	1.835	13.420***	0.388	13.545***	0.396
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	411.11***				14.78***	
Log pseudo likelihood	-290.2704				-	
ρ (rho)	-0.629**	0.197			-	
R^2	-				0.543	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% level. ** Significance at the 5% level. *** Significance at the 1% level.

Table 7. Treatment regression and OLS estimation results for household expenditure per adult equivalent

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of household expenditure per adult equivalent		Dependent variable: Log of household expenditure per adult equivalent	
Age	-0.089	0.067	-0.052***	0.015	-0.056***	0.016
Age squared	0.001	0.001	0.001***	0.000	0.001***	0.000
Education	-0.030	0.060	0.008	0.014	0.009	0.015
Education squared	0.002	0.004	0.000	0.001	0.000	0.001
Highest education	-0.034	0.028	-0.004	0.006	-0.005	0.006
Household size	-0.044	0.033	-0.099***	0.009	-0.100***	0.009
Dependency ratio	-0.251	0.189	-0.040	0.037	-0.048	0.037
Main occupation	0.025	0.255	-0.080	0.053	-0.078	0.054
HH experience	-0.016*	0.010	-0.002	0.002	-0.002	0.002
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.090**	0.037	0.069***	0.007	0.071***	0.007
Migration	-1.188***	0.401	0.312***	0.095	0.301***	0.096
Credit	0.000***	0.000	0.000	0.000	0.000	0.000
Organization member	0.521***	0.172	0.048	0.049	0.073	0.048
Extension visit	0.046***	0.013	-0.002	0.002	-0.001	0.002
Electricity access	0.320	0.292	0.151**	0.066	0.160**	0.067
Community meeting	0.006	0.003	0.002***	0.001	0.002***	0.001
Risk preference	0.020	0.298	-0.026	0.051	-0.041	0.050
Distance market	0.313***	0.094	0.033	0.022	0.048**	0.020
Distance collector	-0.175	0.107	0.052**	0.024	0.035	0.022
Contract farming			0.375**	0.147	0.194***	0.065
Village participation	0.022***	0.003				
Price range 2yrs	0.074***	0.028				
Price range 1yrs	0.093***	0.026				
Average price	-0.044*	0.023				
Time spent cooperative	0.037**	0.018				
Time spent GO	-0.096**	0.043				
Time spent Other	0.059**	0.025				
Constant	0.494	1.874	13.174***	0.375	13.270***	0.381
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	566.41***				20.73***	
Log pseudo likelihood	-289.32775				-	
ρ (rho)	-0.498	0.260			-	
R^2	-				0.56	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% level. ** Significance at the 5% level. *** Significance at the 1% level.

Table 8. Treatment regression and OLS estimation results for lactation yield

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of lactation yield per cow		Dependent variable: Log of lactation yield per cow	
Age	-0.113	0.072	0.005	0.006	0.005	0.006
Age squared	0.001	0.001	0.000	0.000	0.000	0.000
Education	-0.009	0.060	0.007	0.006	0.007	0.006
Education squared	0.001	0.004	0.000	0.000	0.000	0.000
Highest education	-0.033	0.032	0.000	0.003	0.000	0.003
Household size	-0.046	0.035	0.010**	0.004	0.010**	0.004
Dependency ratio	-0.328	0.206	-0.031	0.020	-0.032	0.020
Main occupation	0.026	0.269	-0.010	0.026	-0.010	0.027
HH experience	-0.018*	0.010	-0.001	0.001	-0.001	0.001
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.070**	0.033	-0.017***	0.003	-0.017***	0.003
Migration	-0.981**	0.431	-0.041	0.039	-0.042	0.040
Credit	0.000**	0.000	0.000	0.000	0.000	0.000
Organization member	0.629***	0.173	0.016	0.020	0.018	0.020
Extension visit	0.044***	0.012	0.000	0.001	0.000	0.001
Electricity access	0.380	0.323	0.007	0.033	0.008	0.035
Community meeting	0.004	0.003	0.001***	0.000	0.001***	0.000
Risk preference	0.139	0.289	0.035	0.026	0.034	0.027
Distance market	0.347***	0.089	0.006	0.009	0.007	0.009
Distance collector	-0.186*	0.106	-0.008	0.011	-0.010	0.011
Contract farming			0.138***	0.041	0.125***	0.031
Village participation	0.022***	0.003				
Price range 2yrs	0.083***	0.031				
Price range 1yrs	0.084***	0.027				
Average price	-0.054**	0.025				
Time spent cooperative	0.045***	0.017				
Time spent GO	-0.098***	0.035				
Time spent Other	0.071***	0.028				
Constant	1.281	1.958	7.598***	0.148	7.605***	0.151
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	193.65***				7.330***	
Log pseudo likelihood	.09513908				-	
ρ (rho)	-0.079	0.152			-	
R^2	-				0.283	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% level. ** Significance at the 5% level. *** Significance at the 1% level.

Table 9. Treatment regression and OLS estimation results for gross margin per liter milk

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of gross margin per liter milk		Dependent variable: Log of gross margin per liter milk	
Age	-0.090	0.073	-0.004	0.013	-0.005	0.013
Age squared	0.001	0.001	0.000	0.000	0.000	0.000
Education	-0.013	0.062	0.005	0.008	0.005	0.008
Education squared	0.001	0.004	0.000	0.001	0.000	0.001
Highest education	-0.032	0.032	-0.004	0.004	-0.004	0.004
Household size	-0.048	0.037	-0.010*	0.006	-0.011*	0.006
Dependency ratio	-0.247	0.213	0.015	0.026	0.012	0.026
Main occupation	-0.004	0.256	0.006	0.035	0.006	0.037
HH experience	-0.019*	0.010	0.002	0.001	0.002	0.001
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.069**	0.032	0.006	0.004	0.007	0.005
Migration	-0.959**	0.475	0.030	0.047	0.025	0.049
Credit	0.000**	0.000	0.000*	0.000	0.000	0.000
Organization member	0.606***	0.176	0.001	0.024	0.010	0.024
Extension visit	0.043***	0.011	0.000	0.001	0.000	0.001
Electricity access	0.364	0.330	-0.029	0.037	-0.026	0.037
Community meeting	0.004	0.003	-0.001**	0.000	-0.001*	0.000
Risk preference	0.136	0.292	-0.017	0.029	-0.021	0.030
Distance market	0.372***	0.086	-0.002	0.014	0.003	0.014
Distance collector	-0.177*	0.100	0.000	0.013	-0.006	0.013
Contract farming			0.197***	0.048	0.131***	0.040
Village participation	0.022***	0.003				
Price range 2yrs	0.091***	0.027				
Price range 1yrs	0.075***	0.027				
Average price	-0.046**	0.023				
Time spent cooperative	0.046***	0.016				
Time spent GO	-0.093***	0.032				
Time spent Other	0.070***	0.026				
Constant	0.512	1.942	3.437***	0.293	3.471***	0.307
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	92.6***				2.980***	
Log pseudo likelihood	-132.66912				-	
ρ (rho)	-0.282***	0.073			-	
R^2	-				0.134	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% levels. ** Significance at the 5% levels. *** Significance at the 1% levels.

Table 10. Treatment regression and OLS estimation results for gross margin per cow

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of gross margin per cow		Dependent variable: Log of gross margin per cow	
Age	-0.079	0.070	0.002	0.015	-9.1E-05	0.016
Age squared	0.001	0.001	0.000	0.000	-3.8E-05	0.000
Education	-0.031	0.062	0.003	0.010	0.003711	0.010
Education squared	0.002	0.004	0.000	0.001	0.000309	0.001
Highest education	-0.030	0.032	-0.002	0.005	-0.00243	0.005
Household size	-0.058	0.037	-0.014**	0.007	-0.01413**	0.007
Dependency ratio	-0.221	0.208	0.021	0.031	0.016464	0.031
Main occupation	-0.031	0.257	-0.017	0.042	-0.01585	0.043
HH experience	-0.017	0.010	0.001	0.002	0.000822	0.002
Farm size	0.000	0.000	0.000	0.000	4.07E-05	0.000
Cow equivalent	0.077**	0.031	-0.014***	0.004	-0.01182***	0.004
Migration	-1.001**	0.489	0.019	0.055	0.0121	0.058
Credit	0.000**	0.000	0.000	0.000	6.80E-08	0.000
Organization member	0.558***	0.173	0.023	0.029	0.038554	0.029
Extension visit	0.045***	0.011	0.000	0.001	0.001276	0.001
Electricity access	0.271	0.321	-0.009	0.046	-0.00317	0.047
Community meeting	0.004	0.003	-0.001	0.000	-0.00038	0.001
Risk preference	0.133	0.289	-0.039	0.037	-0.04692	0.038
Distance market	0.373***	0.085	0.015	0.016	0.023504	0.016
Distance collector	-0.163	0.104	0.017	0.016	0.006316	0.016
Contract farming			0.352***	0.055	0.234472***	0.049
Village participation	0.023***	0.003				
Price range 2yrs	0.091***	0.026				
Price range 1yrs	0.079***	0.026				
Average price	-0.040*	0.022				
Time spent cooperative	0.047***	0.014				
Time spent GO	-0.096**	0.038				
Time spent Other	0.071***	0.026				
Constant	-0.003	1.914	10.612***	0.356	10.672***	0.375
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	156.62***				5.040***	
Log pseudo likelihood	-206.1215				-	
ρ (rho)	-0.414***	0.073			-	
R^2	-				0.178	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% level. ** Significance at the 5% level. *** Significance at the 1% level.

Table 11. Treatment regression and OLS estimation results for net return per cow

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of net return per cow		Dependent variable: Log of net return per cow	
Age	-0.090	0.071	0.003	0.016	0.001	0.017
Age squared	0.001	0.001	0.000	0.000	0.000	0.000
Education	-0.026	0.061	0.003	0.010	0.003	0.010
Education squared	0.001	0.004	0.000	0.001	0.000	0.001
Highest education	-0.030	0.033	-0.002	0.005	-0.002	0.005
Household size	-0.054	0.036	-0.015**	0.007	-0.015**	0.007
Dependency ratio	-0.238	0.209	0.033	0.033	0.028	0.033
Main occupation	-0.012	0.261	-0.014	0.047	-0.013	0.048
HH experience	-0.017*	0.010	0.001	0.002	0.001	0.002
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.077**	0.032	-0.011***	0.004	-0.010**	0.004
Migration	-1.029**	0.467	0.029	0.056	0.022	0.059
Credit	0.000**	0.000	0.000	0.000	0.000	0.000
Organization member	0.580***	0.174	0.018	0.030	0.032	0.031
Extension visit	0.045***	0.012	0.000	0.001	0.001	0.001
Electricity access	0.291	0.324	-0.009	0.049	-0.004	0.049
Community meeting	0.004	0.003	-0.001	0.001	0.000	0.001
Risk preference	0.129	0.293	-0.044	0.039	-0.050	0.040
Distance market	0.362***	0.086	0.018	0.017	0.026	0.018
Distance collector	-0.166	0.104	0.018	0.017	0.008	0.017
Contract farming			0.342***	0.062	0.243***	0.053
Village participation	0.023***	0.003				
Price range 2yrs	0.089***	0.027				
Price range 1yrs	0.080***	0.027				
Average price	-0.043*	0.023				
Time spent cooperative	0.047***	0.015				
Time spent GO	-0.093***	0.035				
Time spent Other	0.071***	0.027				
Constant	0.340	1.927	10.535***	0.378	10.586***	0.394
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	135.85***				4.370***	
Log pseudo likelihood	-246.38042				-	
ρ (rho)	-0.322***	0.053			-	
R^2	-				0.147	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% levels. ** Significance at the 5% levels. *** Significance at the 1% levels.

Table 12. Treatment regression and OLS estimation results for net return per liter milk

Variable	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of net return per liter of milk		Dependent variable: Log of net return per liter of milk	
Age	-0.095	0.073	-0.003	0.013	-0.005	0.014
Age squared	0.001	0.001	0.000	0.000	0.000	0.000
Education	-0.013	0.062	0.004	0.008	0.005	0.008
Education squared	0.001	0.004	0.000	0.001	0.000	0.001
Highest education	-0.031	0.032	-0.004	0.004	-0.004	0.004
Household size	-0.047	0.037	-0.012*	0.006	-0.012*	0.006
Dependency ratio	-0.253	0.212	0.024	0.027	0.022	0.027
Main occupation	-0.001	0.259	0.005	0.037	0.006	0.039
HH experience	-0.019*	0.010	0.002	0.002	0.002	0.002
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.070**	0.032	0.007*	0.004	0.008*	0.005
Migration	-0.978**	0.463	0.038	0.048	0.034	0.050
Credit	0.000**	0.000	0.000*	0.000	0.000	0.000
Organization member	0.610***	0.175	-0.006	0.025	0.003	0.026
Extension visit	0.043***	0.011	0.000	0.001	0.000	0.001
Electricity access	0.361	0.330	-0.027	0.038	-0.024	0.039
Community meeting	0.004	0.003	-0.001*	0.000	-0.001	0.000
Risk preference	0.125	0.293	-0.021	0.031	-0.025	0.032
Distance market	0.364***	0.087	0.000	0.014	0.004	0.015
Distance collector	-0.176*	0.101	0.001	0.013	-0.005	0.013
Contract farming			0.199***	0.051	0.138***	0.042
Village participation	0.022***	0.003				
Price range 2yrs	0.090***	0.028				
Price range 1yrs	0.076***	0.027				
Average price	-0.047**	0.023				
Time spent cooperative	0.046***	0.016				
Time spent GO	-0.093***	0.032				
Time spent Other	0.069***	0.026				
Constant	0.635	1.938	3.375***	0.305	3.406***	0.318
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	79.28***				2.570***	
Log pseudo likelihood	-157.560				-	
ρ (rho)	-0.244***	0.068			-	
R^2	-				0.119	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% levels. ** Significance at the 5% levels. *** Significance at the 1% levels.

Table 13. Treatment regression and OLS estimation results for food safety practice adoption

	1		2		3	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
	Treatment regression				OLS	
Variable	Dependent variable: = 1 if participates in contract farming; = 0 otherwise		Dependent variable: Log of net return per liter of milk		Dependent variable: Log of net return per liter of milk	
Age	-0.111*	0.067	0.021***	0.005	0.020***	0.005
Age squared	0.001	0.001	0.000***	0.000	0.000***	0.000
Education	-0.002	0.055	0.002	0.003	0.003	0.003
Education squared	0.000	0.004	0.000	0.000	0.000	0.000
Highest education	-0.045	0.028	0.000	0.002	-0.001	0.002
Household size	-0.031	0.028	0.003	0.002	0.003	0.002
Dependency ratio	-0.206	0.193	-0.009	0.010	-0.012	0.011
Main occupation	0.068	0.258	0.006	0.014	0.007	0.014
HH experience	-0.008	0.010	0.000	0.001	0.000	0.001
Farm size	0.000	0.000	0.000	0.000	0.000	0.000
Cow equivalent	0.059**	0.028	-0.002	0.002	-0.002	0.002
Migration	-1.204***	0.434	-0.016	0.021	-0.020	0.022
Credit	0.000***	0.000	0.000	0.000	0.000	0.000
Organization member	0.601***	0.156	-0.007	0.012	0.001	0.012
Extension visit	0.035***	0.010	0.000	0.001	0.000	0.001
Electricity access	0.252	0.288	0.004	0.017	0.007	0.018
Community meeting	0.002	0.003	0.000	0.000	0.000	0.000
Risk preference	-0.090	0.274	-0.028*	0.016	-0.032**	0.016
Distance market	0.379***	0.089	-0.002	0.005	0.002	0.005
Distance collector	-0.172*	0.104	0.003	0.006	-0.003	0.006
Contract farming			0.085***	0.026	0.025	0.016
Village participation rate	0.024***	0.003				
Price range 2yrs	0.089***	0.025				
Price range 1yrs	0.067**	0.027				
Average price	-0.057**	0.023				
Time spent with cooperative	0.038**	0.015				
Time spent with GO	-0.100***	0.038				
Time spent with Other	0.070***	0.023				
Constant	1.350	1.804	-0.124	0.121	-0.093	0.126
Number of observation	402					
Union fixed effect	Yes				Yes	
F-statistic/χ^2	135.14***				4.610***	
Log pseudo likelihood	250.15026				-	
ρ (rho)	-0.620***	0.124			-	
R^2	-				0.239	

Note: Variables and models are as described in the body of the paper. Robust standard errors are given; * Significance at the 10% levels. ** Significance at the 5% levels. *** Significance at the 1% levels.

Table 14. Two stage least squire and Heckman two-step estimator of results for various welfare and food safety practice adoption

Variable	Model 1: 2SLS (Two-stage IV)		Model 2: Heckman two-step estimator (LIML)	
	Coef.	Std. Err.	Coef.	Std. Err.
	Dependent variable: Log of total household expenditure			
Contract farming	0.258**	0.111	0.193***	0.065
	Dependent variable: Log of household expenditure per adult equivalent			
Contract farming	0.245**	0.110	0.207***	0.065
	Dependent variable: Log of lactation yield per cow			
Contract farming	0.147***	0.046	0.128**	0.033
	Dependent variable: Log of gross margin per cow			
Contract farming	0.359***	0.086	0.199***	0.048
	Dependent variable: Log of gross margin per liter of milk			
Contract farming	0.214***	0.070	0.111***	0.041
	Dependent variable: Log of net return per cow			
Contract farming	0.370***	0.099	0.207***	0.052
	Dependent variable: Log of net return per liter milk			
Contract farming	0.219***	0.076	0.117***	0.043
	Dependent variable: Log food safety practice adoption index			
Contract farming	0.106***	0.022	0.010	0.016
Number of Observation	402		402	

Note: selection equations not reported; LIML refers to limited information maximum likelihood, also known as the Heckman two-step estimator; Controls included but not reported are Age, Age squared, Education ,Education squared, Highest education, Household size, Dependency ratio, Main occupation, HH Experience, Farm size, Cow equivalent, Migration, Credit, Organization member, Extension visit, Electricity access, Community meeting, Risk preference, Distance market, Distance collector, union fixed effect in outcome equation and in selection equation additional included variables are Village participation rate, Price range 2yrs, Price range 1yrs, Average Price, Time spent with cooperative, Time spent with GO, Time spent with other.

6. Conclusions

In view of changing food system and the emergence of vertical coordination along the agri-food chains in developing countries, this research focuses on the role of contract farming as an institution to enhance dairy farmers' welfare and adoption of food safety practice in Bangladesh. Using data collected in Bangladesh in 2016, this article explores the determinants and impact of dairy contract farming on welfare and on the adoption of FSMs at the farm level in Bangladesh across two regions and two forms of contractual arrangements. As participation in contract farming is not random, the lagged response of several income and price variables and number of social network variables were used to construct a vector of IVs used for participation in contract farming.

The empirical results from the probit analysis suggest that in terms of land size, there does not seem to be a systematic bias against the small farmers in participation. Other attributes such as farming experience, herd size, family member migration status, credit organizational membership, extension, distance to output and collection center are important determinants of participation in contract farming. Furthermore, the results suggest that village participation rate in contract farming, maximum and minimum price difference before joining contract, average price received before joining contract and time spent with government, cooperative and other institutions significantly affect participation decision in contract farming.

Controlling for a range of factors including farmer, household, farm endowments and non-random selection into the contract farming using treatment regression, we found that participation in contract farming has statistically significant and robust positive impact on farmers' welfare. Specifically, the empirical results show that participation in dairy contract farming is associated with an increase in household's total expenditure of around 42 percent on average and household's expenditure per adult equivalent of around 37percent on average. Conditional on participation, contract farmers earn significantly higher gross and net profits. This higher profit mainly comes from higher output prices and a significantly positive increase in yield per lactation period due to participation in contract farming. Further, dairy contract farming has a statistically significant and positive impact on adoption of FSPs at the farm level. In particular, participation in contract farming improves the mean FSPs adoption rate by about 9 percent on average at the farm level. All of the results are robust to alternative specifications.

Findings from this study suggest that CF can increase farmer's income substantially and bring improvement in compliance with FSMs. That these take place in the context of developing dairy sector is quite informative from a policy perspective. In Contract farming, the choice of farmers by the integrators, the value distribution, and the location effect interact in complex ways, and it is hard to guess the net effects. Just as transaction costs and possible monopsony power of the buyers hamper contracting with small producers, there are several benefits of linking up with small farmers including diversification of risks and lower propensity for side selling. The case of contract farming in dairy shows that notwithstanding the higher costs under contract in the net, the positives happen to outweigh the negative, countervailing forces for the farmers. Contract farming in a small farmer context can as well improve the outcomes for farmers significantly.

References

Abebaw, D., & Haile, M. G. (2013). The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. *Food Policy*, *38*(1), 82–91.

Abebe, G. K., Bijman, J., Kemp, R., Omta, O., & Tsegaye, A. (2013). Contract farming configuration: Smallholders' preferences for contract design attributes. *Food Policy*, *40*, 14-24.

Asaduzzaman, M. (2000). Livestock sector, economic development and poverty alleviation in Bangladesh. *Changing rural economy of Bangladesh. Bangladesh Economic Association, Dhaka, Bangladesh*, 42-53.

Banglapedia (2015). Milk Vita. http://en.banglapedia.org/index.php?title=Milk_Vita (accessed on 011.05.2017).

Barrett, C. B. (2008). Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food policy*, *33*(4), 299-317.

BBS, 2006. Yearbook of Agriculture statistics. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, peoples republic of Bangladesh. Dhaka, Bangladesh.

BBS, 2011. Yearbook of Agriculture statistics. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, peoples republic of Bangladesh. Dhaka, Bangladesh.

BBS, 2014. Yearbook of Agriculture statistics. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, peoples republic of Bangladesh. Dhaka, Bangladesh.

BBS. 2007. Household Income and Expenditure Survey (HIES), 2005. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning.

Begum, I. A., Alam, M. J., Buysse, J., Frija, A., & Van Huylenbroeck, G. (2012). Contract farmer and poultry farm efficiency in Bangladesh: a data envelopment analysis. *Applied Economics*, *44*(28), 3737-3747.

Bellemare, M. F. (2010). Agricultural extension and imperfect supervision in contract farming: evidence from Madagascar. *Agricultural Economics*, *41*(6), 507-517.

Bellemare, M. F. (2012). As You Sow, So Shall You Reap: The Welfare Impacts of Contract Farming. *World Development*, *40*(7), 1418–1434.

Bellemare, M. F., & Novak, L. (2017). Contract farming and food security. *American Journal of Agricultural Economics*, *99*(2), 357-378.

Berdegué, J. A., Balsevich, F., Flores, L., & Reardon, T. (2005). Central American supermarkets' private standards of quality and safety in procurement of fresh fruits and vegetables. *Food Policy*, *30*(3), 254-269.

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

Bernard, T., Taffesse, A. S., & Gabre-Madhin, E. (2008). Impact of cooperatives on smallholders' commercialization behavior: evidence from Ethiopia. *Agricultural Economics*, *39*(2), 147-161.

Besanko, D., Dranove, D., Shanley, M., & Schaefer, S. (2009). *Economics of strategy*. John Wiley & Sons.

BD Affairs (2019). BD Affairs: The largest information directory of Bangladesh. http://bdaffairs.com/government-of-bangladesh/ (accessed on 19.04.2019).

Bijman, J. (2002). *Essays on agricultural co-operatives; governance structure in fruit and vegetable chains* (No. ERIM PhD Series; EPS-2002-015-ORG).

Birthal, P. S., Joshi, P. K., & Gulati, A. (2005). *Vertical coordination in high-value commodities* (No. 85). International Food Policy Research Institute (IFPRI).

Blandon, J., Henson, S., & Cranfield, J. (2009). Small-scale farmer participation in new agri-food supply chains: Case of the supermarket supply chain for fruit and vegetables in Honduras. *Journal of International Development*, *21*(7), 971-984.

Blundell, R., & Costa Dias, M. (2000). Evaluation methods for non-experimental data. *Fiscal studies*, *21*(4), 427-468.

Boger, S. (2001). Quality and contractual choice: a transaction cost approach to the Polish hog market. *European Review of Agricultural Economics*, *28*(3), 241-262.

Bolwig, S., Gibbon, P., & Jones, S. (2009). The economics of smallholder organic contract farming in tropical Africa. *World Development*, *37*(6), 1094-1104.

Clapp, J. M., & Giaccotto, C. (1994). The influence of economic variables on local house price dynamics. *Journal of Urban Economics*, *36*(2), 161-183.

Cornelis(Kees), L. J., & Van, D. M. (2006). Exclusion From Coordinated Supply Chain. *Agro-Food Chains and Networks for Development*, 209–217.

Curtis, M. (2011). *Milking the Poor: How EU Subsidies Hurt Diary Producers in Bangladesh*. ActionAid Denmark.

Deaton, A. (1997). *The analysis of household surveys: a microeconometric approach to development policy*. World Bank Publications.

Dev, S. M., & Rao, N. C. (2005). Food processing and contract farming in Andhra Pradesh: A small farmer perspective. *Economic and Political weekly*, 2705-2713.

Dries, L., Germenji, E., Noev, N., & Swinnen, J. F. (2009). Farmers, vertical coordination, and the restructuring of dairy supply chains in Central and Eastern Europe. *World development*, *37*(11), 1742-1758.

Dugdill, B.T., Bennett, A., Saha , G.C., and Das, S. C. (1995). MILK VITA in Bangladesh: A case study. http://www.fao.org/ag/againfo/themes/documents/lps/dairy/dap/milkvita/milkvitaindex.htm#toc

Eckel, C. C., & Grossman, P. J. (1996). The relative price of fairness: Gender differences in a punishment game. *Journal of Economic Behavior & Organization*, *30*(2), 143-158.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic development and cultural change*, *33*(2), 255-298.

Fischer, E., & Qaim, M. (2012). Linking Smallholders to Markets: Determinants and Impacts of Farmer Collective Action in Kenya. *World Development*, *40*(6), 1255–1268.

Fold, N., & Pritchard, B. (Eds.). (2005). *Cross-continental Agro-food Chains: Structures, Actors and Dynamics in the Global Food System*. Routledge.

Francesconi, G. N., & Heerink, N. (2011). Ethiopian agricultural cooperatives in an era of global commodity exchange: does organisational form matter?. *Journal of African Economies*, *20*(1), 153-177.

Fukunaga, K., & Huffman, W. E. (2009). The role of risk and transaction costs in contract design: Evidence from farmland lease contracts in U.S. agriculture. *American Journal of Agricultural Economics*, *91*(1), 237–249.

Glover D, Kusterer K. (1990). *Small Farmers, Big Business: Contract Farming and Rural Development*. Hampshire, UK: Palgrave Macmillan

Glover, D. (1990). Contract farming and outgrower schemes in East and Southern Africa. Journal of Agricultural Economics, 41(3), 303-315.

Glover, D. J. (1984). Contract farming and smallholder outgrower schemes in less-developed countries. *World Development*, *12*(11–12), 1143–1157.

Greene, W. H. (2008). Econometric Analysis, 6th Edition, Upper Saddle Rive, NJ: Prentice-Hall.

Grosh, B. (1994). Contract farming in Africa: an application of the new institutional economics. *Journal of African Economies*, *3*(2), 231-261.

Gulati, A., Minot, N., Delgado, C., & Bora, S. (2007). Growth in high-value agriculture in Asia and the emergence of vertical links with farmers. *Global supply chains: standards and the poor: how the globalization of food systems and standards affects rural development and poverty*, 98-108.

Hafez, M. R. (2004), 'Small-scale dairying in Bangladesh', *Report of the Twenty-Eighth Session of the Animal Production and Health Commission for Asia and the Pacific, 27 September–1 October, Chiangmai, Thailand.*

Handschuch, C., Wollni, M., & Villalobos, P. (2013). Adoption of food safety and quality standards among Chilean raspberry producers - Do smallholders benefit? *Food Policy*, *40*, 64–73.

Heckman, J. J., LaLonde, R. J., & Smith, J. A. (1999). The economics and econometrics of active labor market programs. *Handbook of labor economics*, *3*, 1865-2097.

Hellin, J., & Higman, S. (2003). *Feeding the market: South American farmers, trade and globalization*. ITDG Publishing.

Hemme, T., & Uddin, M. M. (2010). Dairy Policy impacts on Bangladesh and EU 15 dairy farmers' livelihoods: Dairy Case study. International Farm Comparison Network (IFCN) Dairy Research Center, Kiel, Germany.

Hemme, T., Garcia, O., & Khan, A. R. (2004). A review of milk production in Bangladesh with particular emphasis on small-scale producers. *Rome, Italy: FAO*. Accessed on April 7, 2017. http://ageconsearch.umn.edu/bitstream/23774/1/wp030007.pdf

Hennessy, D. A., & Lawrence, J. D. (1999). Contractual relations, control, and quality in the hog sector. *Review of Agricultural Economics*, *21*(1), 52-67.

Henson, S., Reardon, T., (2005). Private agri-food standards: implications for food policy and the agri-food system. *Food Policy 30*(3), 241–253.

Holm. U, and Tinnberg, M. (2015). SMALL-HOLDER F ARMERS AND BUSINESS. PRAN Dairy Hubs (Tetra Pak). http://www.agrifood.net/documents/livestock/169-case-study-tetra-laval-dairy-hub-project/file (accessed on 05.01.2017).

Islam, A. H. M. S., Barman, B. K., & Murshed-e-Jahan, K. (2015). Adoption and impact of integrated rice–fish farming system in Bangladesh. *Aquaculture*, *447*, 76-85.

Ito, J., Bao, Z., & Su, Q. (2012). Distributional effects of agricultural cooperatives in China: Exclusion of smallholders and potential gains on participation. *Food Policy*, *37*(6), 700–709.

Jabbar M. A. (2009). Policy Barriers for Dairy Value Chain Development in Bangladesh with a Focus on the North West Region. CARE Bangladesh project "Strengthening Dairy Value Chain in Bangladesh" mimo, 75pp. http://www.carebangladesh.org/publication/Publication_3801771.pdf

Jabbar, M. A., Islam, S. M. E., Delgado, C., Ehui, S., Akanda, M. A. I., Khan, M. I., & Kamruzzaman, M. M. (2005). *Policy and Scale factors influencing efficiency in dairy and poultry producers in Bangladesh*. Joint working paper by ILRI/SLP/BSMRAU.

Jia, X., & Huang, J. (2011). Contractual arrangements between farmer cooperatives and buyers in China. *Food Policy*, *36*(5), 656-666.

Kabir, M. H., & Talukder, R. K. (1999). Economics of small scale dairy farming in Bangladesh under the Government support Programme. *Asian Australasian Journal of Animal Sciences*, *12*(3), 429-34.

Karim, Z. (1997). Agriculture for 21st century in Bangladesh. *A final draft policy report on National Livestock Development Policy, Ministry of Fisheries and Livestock, Dhaka, Bangladesh*.

Key, N., & McBride, W. D. (2008). Do production contracts raise farm productivity? an instrumental variables approach. *Agricultural and Resource Economics Review*, *37*(2), 176–187.

Key, N., & Runsten, D. (1999). Contract farming, smallholders, and rural development in Latin America: the organization of agroprocessing firms and the scale of outgrower production. *World development*, *27*(2), 381-401.

Kumar, A., Thapa, G., Roy, D., & Joshi, P. K. (2017). Adoption of food safety measures on milk production in Nepal: Impact on smallholders' farm-gate prices and profitability. Food Policy, 70, 13-26.

Kumar, A., Wright, I. A., & Singh, D. K. (2011). Adoption of Food Safety Practices in Milk Production: Implications for Dairy Farmers in India. *Journal of International Food & Agribusiness Marketing*, *23*(4), 330–344.

Little, P. D., and M. J. Watts, (1994), Living Under Contract: Contract Farming and Agrarian Transformation in Sub-Saharan Africa, Madison: University of Wisconsin Press.

Maertens, M., & Swinnen, J. F. (2009). Trade, standards, and poverty: Evidence from Senegal. *World development*, *37*(1), 161-178.

Mahmoud, C. S., Hossain, I., & Shively, G. (2005). Vegetable Market Integration In Bangladesh. *The Bangladesh Development Studies*, *31*(3/4), 137–156. https://doi.org/10.2307/40795717

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

Masakure, O., & Henson, S. (2005). Why do small-scale producers choose to produce under contract? Lessons from nontraditional vegetable exports from Zimbabwe. *World Development*, *33*(10), 1721-1733.

McCulloch, N., & Ota, M. (2002). Export horticulture and poverty in Kenya. IDS Working Paper 174. Brighton, Sussex: IDS.

Mian, M. R. U., Fatema, J., & Rahman, M. H. (2007). Impact of Dairy Farming on Livelihood of Participating Women under Grameen Bank in a Selected Area of Rangpur District in Bangaldesh. Indian Journal of Agricultural Economics, 62(2), 259.

Minten, B., Randrianarison, L., & Swinnen, J. F. (2009). Global retail chains and poor farmers: Evidence from Madagascar. *World Development*, *37*(11), 1728-1741.

Mishra, A. K., Kumar, A., Joshi, P. K., & D'souza, A. (2016). Impact of contracts in high yielding varieties seed production on profits and yield: The case of Nepal. *Food Policy*, *62*, 110–121.

Miyata, S., Minot, N., & Hu, D. (2009). Impact of contract farming on income: linking small farmers, packers, and supermarkets in China. *World development*, *37*(11), 1781-1790.

Morrison, P. S., Murray, W. E., & Ngidang, D. (2006). Promoting indigenous entrepreneurship through small-scale contract farming: The poultry sector in Sarawak, Malaysia. *Singapore Journal of Tropical Geography*, *27*(2), 191–206.

Narayanan, S. (2013). Smallholder attrition in contract farming schemes in India: extent, causes, and concerns. *Food Chain*, *3*(3), 155–170.

Narayanan, S. (2014). Profits from participation in high value agriculture: Evidence of heterogeneous benefits in contract farming schemes in Southern India. *Food Policy*, *44*, 142–157.

Omore, A. O., Arimi, S. M., Kangethe, E., McDermott, J. J., Staal, S. J., Ouma, E. A., ... & Koech, R. (2002). Assessing and managing milk-borne health risks for the benefit of consumers in Kenya.

Oya, C. (2012). Contract Farming in Sub-Saharan Africa A Survey of Approaches, Debates and Issues - OYA - 2011 - Journal of Agrarian Change - Wiley Online Library, *12*(1), 1–33.

Pingali, P. (2004). Westernisation of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy. *Food Policy*, *32*(4), 281–298.

Porter, G., & Phillips-Howard, K. (1997). Comparing contracts: An evaluation of contract farming schemes in Africa. *World Development*, *25*(2), 227–238.

Poulton, C., Dorward, A., & Kydd, J. (2010). The future of small farms: New directions for services, institutions, and intermediation. *World Development*, *38*(10), 1413-1428.

Puhani, P. (2000). The Heckman correction for sample selection and its critique. *Journal of economic surveys*, *14*(1), 53-68.

Raha S K 2009 Status of Dairy Production and Marketing in Bangladesh – Milk marketing system. Handbook of Dairy Nutrition-Bangladesh. Edited by Peter H. Robinson and U. Krishnamoorthy. Published by American Soybean Association (ASA), International Marketing, New Delhi, India.

Rahman, M.M, and Ahsan. K (2013). Dairy development in India: A report on the study visit. http://www.aardo.org/aardohomepage/pdf/bangladesh.pdf (accessed on 09.02.2017).

Ramaswami, B., Birthal, P. S., & Joshi, P. K. (2006). Efficiency and distribution in contract farming: The case of Indian poultry growers. *MTID Discussion Papers*, *91*.

Rao, E. J., & Qaim, M. (2011). Supermarkets, farm household income, and poverty: insights from Kenya. *World Development*, *39*(5), 784-796.

Rao, E. J., Brümmer, B., & Qaim, M. (2012). Farmer participation in supermarket channels, production technology, and efficiency: the case of vegetables in Kenya. *American Journal of Agricultural Economics*, aas024.

Raynolds, L. T. (2002). Wages for wives: Renegotiating gender and production relations in contract farming in the Dominican Republic. *World Development*, *30*(5), 783-798.

Reardon, T., & Berdegue, J. A. (2002). The rapid rise of supermarkets in Latin America: challenges and opportunities for development. *Development policy review*, *20*(4), 371-388.

Reardon, T., & Timmer, C. P. (2007). Transformation of markets for agricultural output in developing countries since 1950: How has thinking changed?. *Handbook of agricultural economics*, *3*, 2807-2855.

Reardon, T., Timmer, C. P., Barrett, C. B., & Berdegué, J. (2003). The rise of supermarkets in Africa, Asia, and Latin America. *American journal of agricultural economics*, *85*(5), 1140-1146.

Roy, D., & Thorat, A. (2008). Success in High Value Horticultural Export Markets for the Small Farmers: The Case of Mahagrapes in India. *World Development*, *36*(10), 1874–1890.

Saadullah, M. (2002). Smallholder dairy production and marketing in Bangladesh. *Smallholder dairy production and marketing-Opportunities and constraints. Nairobi, Kenya: NDDB (National Dairy Development Board) and ILRI (International Livestock Research Institute)*, 7-21.

Schipmann, C., & Qaim, M. (2010). Spillovers from modern supply chains to traditional markets: product innovation and adoption by smallholders. *Agricultural Economics*, *41*(3-4), 361-371.

Shamsuddin, A. (2011). *SAARC Dairy Outlook SAARC Agriculture Centre*.

Shiferaw, B., Obare, G., & Muricho, G. (2008). Rural market imperfections and the role of institutions in collective action to improve markets for the poor. *Natural Resources Forum*, *32*(1), 25–38.

Simmons, P., Winters, P., & Patrick, I. (2005). An analysis of contract farming in East Java, Bali, and Lombok, Indonesia. *Agricultural Economics*, *33*(s3), 513-525.

Singh, S. (2002). Contracting out solutions: Political economy of contract farming in the Indian Punjab. *World Development*, *30*(9), 1621-1638.

Stefanides, Z., & Tauer, L. W. (1999). The empirical impact of bovine somatotropin on a group of New York dairy farms. *American Journal of Agricultural Economics*, *81*(1), 95-102.

Sykuta, M. E., & Cook, M. L. (2001). A New Institutional Economics Approach to Contracts and Cooperatives. *Amer. J. Agr. Econ*, *83*(5), 1273–1279.

Uddin, M. M., Sultana, M. N., Ndambi, O. A., Alqaisi, O., Hemme, T., & Peters, K. J. (2011). Milk production trends and dairy development in Bangladesh. *Outlook on Agriculture*, *40*(3), 263–271.

Warning, M., & Key, N. (2002). The social performance and distributional consequences of contract farming: An equilibrium analysis of the Arachide de Bouche program in Senegal. *World Development*, *30*(2), 255-263.

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

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

World Bank (2007). *India: Land policies for growth and poverty reduction*. New Delhi: World Bank Agriculture and Rural Development Sector Unit South Asia Region and Oxford University Press.

World Bank. (2008). *World development report 2008: Agriculture for development*. World Bank.

Wu, B. S. (2003). Regulating Agricultural Contracts : What are the Tradeoffs ? *Agricultural Economics*, 19–22.

Zaedi, M., Demura, K., Yamamoto, Y., Sawauchi, D., Masuda, K., & Nakatani, T. (2009). Dairy industry in Bangladesh and structures of Milk Vita. *The Review of Agricultural Economics, Hokkaido University*, *64*, 169-180.

Zhang, X., & Hu, D. (2011). Farmer-buyer relationships in China: the effects of contracts, trust and market environment. *China Agricultural Economic Review*, *3*(1), 42-53.

ALL IFPRI DISCUSSION PAPERS

All discussion papers are available **here**

They can be downloaded free of charge

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
www.ifpri.org

IFPRI HEADQUARTERS
1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org

SOUTH ASIA REGIONAL OFFICE
Block C, NASC Complex, DPS Marg
Opposite Todapur, Pusa
New Delhi 110012 India
Phone: +91-11-66166565
Fax: +91-11-66781699
Email: ifpri-newdelhi@cgiar.org
https://southasia.ifpri.info