Role of Price Volatility and Cost of Cooperation in Agri-decision Making

Abstract

Agricultural cooperatives aim at providing stable prices to producers and assist farmers in capturing better market deals. Similarly, adoption of organic farming reorient the farmers towards a niche market with a better price premium and relatively lower price volatility. This paper attempts to examine farmers' decision of adoption of organic farming and cooperative participation under price volatility through an analytical game theoretic model. We analyse conditions under which farmers would prefer to opt for organic farming and participate in a cooperative. We examine the effect of price volatility and operational cost of cooperative, representing the maximum participation cost of farmer, on farmers' decision to participate in a cooperative and produce organic crop.

Key Words: Cooperative, Organic farming, Volatility, Operational cost, Decision, Game Theory

1 Introduction

With increased commodity price volatility, risk and uncertainty in farming have become an important concern for farmers, who are often characterized as price taking units with negligible influence on the final price of the commodity produced. Moreover, for small producers, with relatively low risk- bearing ability, uncertainty in revenue flow is pushing them to the margins of poverty. Production of organic commodity and transaction through cooperative can help in achieving economically sustainable lifestyle through a smooth and stable revenue flow for farmers as it commands high price premium and low price volatility.

Agricultural cooperatives have policies to keep prices relatively stable within a narrow spectrum. Within a cooperative, price volatility is shared among all the members of the cooperatives and each member receives an average price for the produce in a season, thereby reducing the price volatility over a longer duration. Cooperatives also ascertain relatively higher prices to farmers by shortening the supply chain.

Penetration to market for differentiated products can also result in relatively lower price volatility and apprehends price premium, and thus, can provide farmers an alternative to producing a conventional crop with high price volatility. Organic product commands a niche market for itself, and are reported to have less volatile prices (Kleemann and Effenberger [2010]; Franco [2009]; Su et al. [2013]). It has the potential to provide benefits to consumers by improving food quality and to producers by channelizing production towards areas of market demand (Lampkin [1994]). There has been a rapid increase in demand for high-quality organic produce.

However, in spite of the advantages of participation in cooperative and shifting to organic production techniques, farmers' reluctance to both is unambiguous. Barriers to adoption of organic farming is massively documented in literature (De Ponti et al. [2012]; Schneeberger et al. [2002]; Mzoughi [2011], Rigby and Cáceres [2001]). Nevertheless, failure of cooperatives due to lack of participation from members is additionally a major concern for many local and international institutions (Gardner and Lerman [2006]; Braverman et al. [1991]; Goldman et al. [2007]; Nilsson et al. [2012]). It is observed that farmers' willingness to join a cooperative is often associated with the price volatility of the commodity they produce (Table 1).

Table 1: Commodity-wise number of cooperatives and price volatility

Commodity	No. per thousand Agricultural HHs[a]		Percentage of HHs selling in cooperative[a]	CV of prices[b]
	No. of HHs selling to Cooperatives /govt. agency	All HHs		
Paddy	28	638	4.39	0.61
Maize	19	719	2.64	0.38
Wheat	25	368	6.79	0.39
Barley	0	140	0.00	0.37
Sugarcane	417	943	44.22	0.18
Potato	1	534	0.19	0.21
Onion	7	543	1.29	0.34
Groundnut	13	689	1.89	0.3
Rapeseed/Mustard	2	456	0.44	0.23
Coconut	15	491	3.05	0.17
Cotton	11	923	1.19	0.2
Pulses	2	397	0.50	0.28

Source: (a) NSS Report on Agriculture, 70th Round (b) Author's own calculation using annual producer price index data from FAOSTAT

As suggested by the correlation coefficient between the number of households selling to cooperatives and price volatility for a particular commodity (-0.23), the proportion of households selling to cooperative is higher for products with lower price volatility. The price volatility might also indirectly affect farmers' decision for the adoption of organic farming through their choice of cooperative participation.

There are limited studies that attempt to analyse the effect of price volatility on farmers choice at the production level. Our study seeks to address this issue. In this paper we examine farmers' decision on adoption of organic farming and cooperative participation under price volatility through an iterative analytical model. The objective is to find conditions under which farmers would prefer to opt for organic farming and participate in a cooperative.

The remainder of this paper is organised in four sections. Next section presents a brief review of the literature to place the significance of the study. The third and fourth section presents the model and analyse the results. The last section ends the paper with concluding remarks.

2 Literature Review

The objective of this section is to provide a brief account of the studies which have examined the agricultural supply chain in depth and discussed the need for a differentiated market, thereby placing the significance of the present study.

The concept of the supply chain has been applied to agricultural commodities very recently and has been studied extensively in the literature across different fields. One of the most imperative research in this area was initiated by Dolan et al. [1999] with reference to Horticulture Global Value Chain (GVC). This work extensively studied the market for fresh vegetables and identified the marketing channels. They found that the supply chain is largely dominated by large retailers, and they have adopted competitive strategies, attributing to quality and product differentiation. They analysed the role of large firms (mostly owned by exporters) in moving production away from small producers.

Talbot [2002] studied the supply chain of green coffee in Uganda, one among the major producers of coffee beans. This study showed that after liberalization supply chain of coffee has undergone considerable changes with numerous evidence of direct purchase by roasters from local exporters. However, in spite of such developments, the predominant purchasing route of green coffee remained via spot markets, thereby, highlighting the exploitative role of middlemen and curing houses in the process.

Fitter and Kaplinsky [2001] in their study analysed the input-output relation using the value chain approach and attempted at identifying power asymmetries along the chain. The study observed considerable power concentration with the importing countries. The study also highlighted the growing need for Fairtrade products that will enable the producers to get a fair price.

The impact of international prices on farmers' decision of investing on production and quality improvement has also been carried forward by a number of studies. For example, a study by USAID (2005) has showed that farmers' lack economic incentive to improve their product and service quality as it does not bring any higher prices from the local distribution channels. Analysing buyers bargaining power, Oxfam [2002] reports that low market prices creates a buyers' market where poor and powerless people from developing the world negotiate with the powerful buyers in more advanced countries in the open market.

An application of Global Value Chain analysis to coffee by Daviron and Ponte [2005] pointed out that in developing countries, producers of tropical commodities often do not have direct contact with the consumption places and hence are unable to obtain gains from the quality of the product they sell in the market although other actors involved in the value chain do reap the benefits of the improved quality and pass on the loss of the lower quality to producers. This results in disincentive for farmers to improve quality.

Fromm and Dubón [2006] and [Richards et al., 2011] point out that there are chances of gain from producing commodities for differentiated markets. The price paid in these markets is twice compared to conventional market price. In addition, they suggest that through internet auctions and direct buys, the role of intermediaries can be reduced, and this guarantees higher price to the producers. Studies have noticed increasing demand for organic and fair trade commodities (Park and Lohr [1996]).

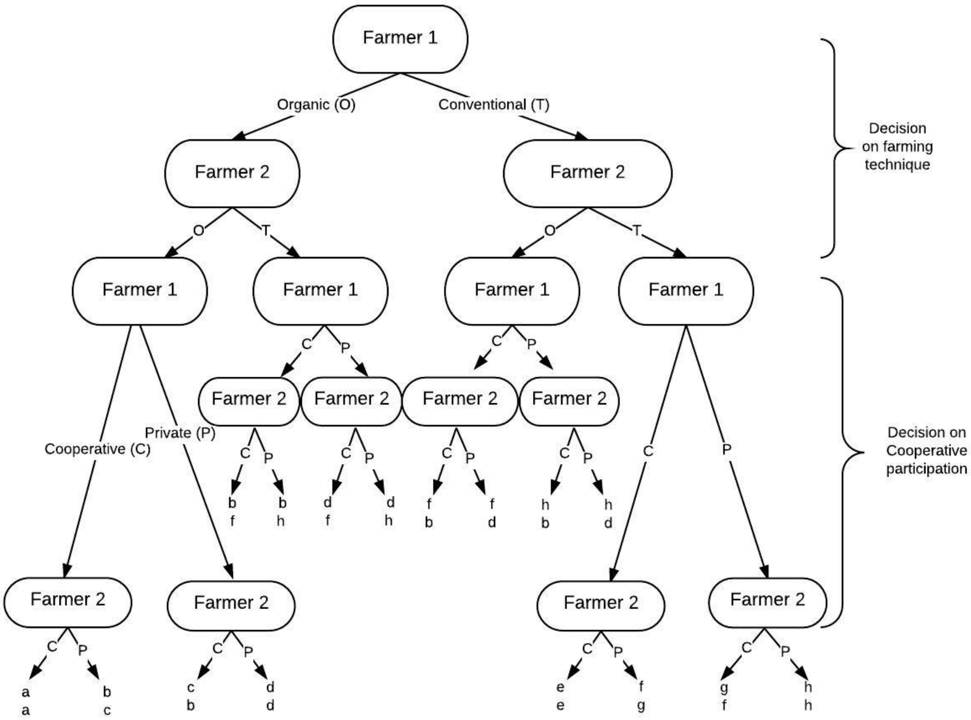
Role of Farmer associations and cooperatives have also been studied widely in literature, especially by Bacon [2005], Verhaegen and Van Huylenbroeck [2001], Raper et al. [2005] and Dempsey [2006]. Bacon [2005] have found that farmer associations and cooperatives play an essential role in supporting farmers to convert their production technique and adopting a quality standard. Cooperatives also play a major role in reducing the cost of information gathering [Verhaegen and Van Huylenbroeck, 2001]. While, Raper et al. [2005] states that cooperatives enable farmers in gaining access to specialized markets. According to Dempsey [2006], strong institutional development interventions provide the basis for success in cooperative coffee in Ethiopia. According to him, this has a positive impact on new coffee export value chain resulting in improved quality of produce and gained access for farmers in higher value coffee markets with a sustainable income. However, sometimes lack of coordination between local institutions and producer cooperatives proves to be a major hindrance in improving the status of smallholders in Fromm and Dubón [2006], especially after liberalization.

An examination of literature suggests that moving to organic production technique and shortening of supply chain via cooperative appears to improve farmers livelihood, however, farmers reluctance in accepting these changes are often observed. There are no studies that attempt to analyse farmers' decision in opting for organic farming and cooperative participation. Our study is an attempt to address this issue.

3 Model

We formulate a two-stage model to describe farmers' production decision and the decision to participate in cooperative, on the basis of the prices they expect to receive. Farmers can choose between private firm and cooperative owned processor to sell their produce. Free entry and exit from cooperative is possible. Cooperatives help in vertical integration of farmers to the supply chain evading the middlemen and helps them in receiving higher prices compared to the private firm.

Two farmers A and B produces crop using two different techniques: Conventional or Organic. They can sell their produce to two different options: Cooperative or Private Firm. Both farmers simultaneously decide on production technique first and later decides on selling option simultaneously. Graphical representation of the problem is given below (Figure 1):



In the Figure 1, 'O' represents a choice of producing organic crop and 'T' represents a choice of producing conventional crop. Similarly, 'C' represents choice of selling through cooperatives and 'P' represents choice of selling to private market.

Membership to cooperative is open, anyone can become a part of the cooperative. Farmers participating in cooperative receive the final payment at the end of cropping season for seasonal crops. Agricultural and plantation commodities are highly weather sensitive and is prone to high supply and price fluctuation. Revenue from these commodities widely depend on the time of delivery of the produce. Producers selling to private firm face this volatility in the price and fluctuating revenue. However, producers delivering to cooperative share this risk by receiving average price for the entire season as well as for different quality. In cooperatives, most of the cyclical fluctuations in price or changes in consumer demand is spread out across all producers by offsetting higher-than-average returns with lower-than-average returns and farmers tend to receive by an large a stable price over the year.

Farmers do not hold the commodity for long and sell it immediately after harvest to either of the two processing units: a cooperative or a private firm. Decision of selling is taken one period advance at the time of sowing the seeds. If the farmer wants to sell its produce to the cooperative in the next period, s(he) needs to join the cooperative in the current period. If s(he) does not, by default, s(he) will have to sell its produce to the private firm.

Let, q_c be the total quantity sold by each farmer in the cooperative and q_f be the total quantity sold by each farmer to private firm. Demand is assumed to be infinite.

Cost function of farmer is given by:

$$c(q_i) = \frac{1}{2}q_i^2 \tag{1}$$

where, q_i is the commodity produced by i^{th} individual.

The cost function of the cooperative is given by:

$$c(Q_c) = F \tag{2}$$

Where, Q_c is the total quantity sold through cooperative. Cost of processing of product (variable cost of the cooperative) is assumed to be zero and operational cost of cooperative (henceforth referred as operational cost) is a fixed cost given by F.

The objective of the farmer is to maximize expected utility of profits. Let the utility function of both the farmers follows constant absolute risk aversion (CARA) and is given as follows:

$$U = -e^{-\alpha\Pi} \tag{3}$$

Where, α is the coefficient of absolute risk aversion.

Farmer is risk averse as $U'(\Pi) > 0$ and $U''(\Pi) < 0$.

Farmer's profit function can be defined as:

$$\Pi = Pq - c(q) \tag{4}$$

Where, q is the total quantity sold by the farmer and $c(q)$ is the total cost incurred. P is the price of the commodity, assumed to be a random variable with f(P) as the density function. Assuming a small economy, farmers are price takers. The production decision is taken in advance such that future spot price of the commodity is not know. However, given that the current period price follows normal distribution with mean P_μ and variance σ^2, farmers assume that spot prices in the next period also follows normal distribution with mean P_μ and variance σ^2.[1]

Thus, the expected profit function[2] is given by:

$$E(U) = P_\mu q - \frac{1}{2}q^2 - \frac{\alpha}{2}\sigma^2 q^2 \tag{5}$$

By selling to private firm, farmers receive the spot price prevalent in the market at that point of time. However, by selling in cooperative, farmers receive the average price given by P_μ at the end of cropping season thereby getting protected from price fluctuations.

Let the average price for conventional crop be P_t and the variance in price be ${\sigma_t}^2$. Similarly, average price for organic crop be P_o and the variance in price be ${\sigma_o}^2$.

Thus, the objective function of farmer selling to private firm is given by:

$$\text{maximize} \quad E(U) = P_i q_{if} - \frac{1}{2}{q_{if}}^2 - \frac{\alpha}{2}{\sigma_i}^2{q_{if}}^2, \forall i = \{t, o\} \tag{6}$$

where, q_{if} is the amount of conventional/organic produce each farmer sells to private firm.

Each farmer in the cooperative decides on the output level that maximizes his/her expected profit given the contribution of other member. Farmers expect to get a average price $P_i\{\forall i = t, o\}$ by selling in cooperative and zero variance in price. However, members of the cooperative proportionately share the operational cost of cooperative denoted by F.

Therefore, the objective function of each farmer selling in cooperative is be given by:

[1] We assume farmer follow rational expectation.

[2] For derivation refer to Appendix 1

$$\underset{q_c}{\text{maximize}} \quad E(U) = P_i q_{ic} - \frac{1}{2} {q_{ic}}^2 - \frac{\alpha}{2} {\sigma_i}^2 {q_{ic}}^2 - \left[\frac{F}{q_{ic} + q_{ic'}}\right] q_{ic} \tag{7}$$

Where, q_{ic} is the amount one conventional/organic farmer is selling through cooperative and $q_{ic'}$ is the amount of produce other individual is contributing to the cooperative. The last term in the equation denotes the operational cost shared proportionally by each farmer. Since, both farmers are homogeneous, q_{ic} equals to $q_{ic'}$ and hence, each farmer pays $\frac{F}{2}$ as cost of participation if both of them participates. If only one farmer participates, $q_{ic'} = 0$ and he/she has to borne full operational F.

Three cases are considered, for organically produced crop and conventional crop respectively: 1) When both the farmers sell their produce to Cooperative. 2) When both the farmers sell their produce to Private Firm. 3) When one sells to Cooperative and another to Private Firm. We solve the game using backward induction.

4 Analysis

4.1 Equilibrium in conventional market

Suppose both the farmers produces conventional crop. How do they decide on whether to sell through cooperative or not?

Operation of cooperatives incur cost. Since, cooperatives are owned by farmers who are the members of the cooperative, they share the operational cost proportionately depending on the amount they sell through cooperative. Decision on whom to sell depends on the operational cost.

Proposition 1: *For a given value of F, α, σ_t, P_t, and ${P_t}^2 > 2F$, decision of participation in a conventional cooperative is given as follows:*

$$\textit{Participation decision} = \begin{cases} \textit{Both partcipating in cooperative} & \forall F \leq \frac{\alpha{\sigma_t}^2{P_t}^2}{2(1+\alpha{\sigma_t}^2)} \\ \textit{Both selling to Private Firm} & \forall F \geq \frac{\alpha{\sigma_t}^2{P_t}^2}{(1+\alpha{\sigma_t}^2)} \\ \textit{Either of the two} & \forall \frac{\alpha{\sigma_t}^2{P_t}^2}{(1+\alpha{\sigma_t}^2)} \leq F \leq \frac{\alpha{\sigma_t}^2{P_t}^2}{2(1+\alpha{\sigma_t}^2)} \end{cases}$$

Proof: See Appendix 2.

Operational cost F represents the maximum cost of participation in cooperative a farmer can incur. There exists a trade-off between the dis-utility from paying a higher participation cost and higher volatility in private firm. When operational cost is below $\frac{\alpha {\sigma_t}^2 {P_t}^2}{2(1+\alpha {\sigma_t}^2)}$, dis-utility from higher volatility dominates operational cost and farmers prefers to sell all the produce in cooperative. However, as operational cost increases, the trade-off between higher operational cost and higher volatility in private firm becomes stringent. When the disutility from higher operational cost overcomes disutility from higher volatility, farmers prefer to sell their produce to private firm.

Corollary 1: *Tendency of farmers to participate in cooperative is more for commodities that has lower operational cost, ceteris-paribus and vis-a-versa.*

Proof: See Appendix 2, Equation (19).

Suppose there are two commodities, one that require higher operational cost and thus higher participation fee and another with lower operational cost. Assuming other things being same, commodity with lower operational cost attracts more farmers to cooperative and has more number of cooperatives than commodity with high operational cost.

Corollary 2: *If the operational cost is high for any commodity, participation in cooperative requires price volatility for that commodity to be extremely high, ceteris paribus.*

Proof: See Appendix 2, Equation (20).

Unless the price volatility of the commodity is sufficiently high, it can not dominate the dis-utility of higher operational cost and thereby pushing farmers to private firm and facing the volatility. This means commodities with lower price volatility and a higher storage and processing charges tends to see less cooperatives and more sell in private market.

Corollary 3: *Higher the degree of risk aversion of farmer, higher is the chances of s(he) becoming a member of cooperative.*

Proof: See Appendix 2, Equation (20).

Farmers' attitude towards risk is an important determinant in farmers' decision of cooperative participation. If a farmer is more risk averse, s(he) has a higher tendency to join a cooperative and avoid price fluctuation as well as revenue fluctuation even for a little higher operational cost.

4.2 Equilibrium in organic market

Suppose both farmers produces organic crop. How is cooperative participation decision for organic crop different from conventional crop?

Similar to conventional crop scenario, for organic crop also cooperative participation decision depends on the operational cost, price and price volatility of organic produce and farmers degree of risk aversion. Average price for organic produce is higher that the average price of conventional produce, however, the price volatility in organic produce is lesser than the price volatility of conventional produce (Oberholtzer et al. [2005]; Buck et al. [1997]; Raynolds [2000]).

Proposition 2: *For a given value of F, α, σ_o, P_o, and ${P_o}^2 > 3F$, decision of participation in an organic cooperative is given by:*

$$\textit{Participation decision} = \begin{cases} \textit{Both partcipating in cooperative} & \forall F \leq \frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \\ \textit{Both selling to Private Firm} & \forall F \geq \frac{4\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \\ \textit{Either of the two} & \forall \frac{4\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \leq F \leq \frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \end{cases}$$

Proof: See Appendix 3.

The threshold for organic cooperative and private firm participation is much higher than the conventional crop implying organic farmers require much higher operational cost for selling to Private firm rather than conventional crop.

Volatility in conventional private market is far higher than volatility in organic private market. Thus, income stream from conventional crop is far more volatile than income from organic. Therefore, even a lower operational cost can offset the effect of higher volatility in conventional market. But, for organic crop a higher operational cost is required.

The results in Proposition 1 and Proposition 2 holds true even when both farmers follow different production technique. i.e. If $F \leq \frac{\alpha {\sigma_t}^2 {P_t}^2}{2(1+\alpha {\sigma_t}^2)}$, dominant strategy for conventional farmers is to participate in cooperative and else, to sell to private firm. Similarly, if $F \leq \frac{2\alpha {\sigma_o}^2 {P_o}^2}{3(1+\alpha {\sigma_o}^2)}$, dominant strategy for organic farmer is to participate in cooperative, else, to sell to private firm.

4.3 Decision on farming technique and selling choice

Selling decision is juxtaposed on the choice of farming technique to get a solution for the entire problem. Decision on farming technique depends on the price and volatility of organic and conventional produce and on the selling decision. What to produce and where to sell is conditional on the operational cost.

Proposition 3: *For a given value of F, α, P_t, P_o, σ_t, σ_o and an upper limit on the ratio of price and price volatility of organic and conventional crop such that $\frac{P_o^2}{P_t^2} < \frac{3}{2}$ and $\frac{\sigma_t^2}{\sigma_o^2} < \frac{3}{2}$, decision on cooperative participation and production technique is given as follows:*

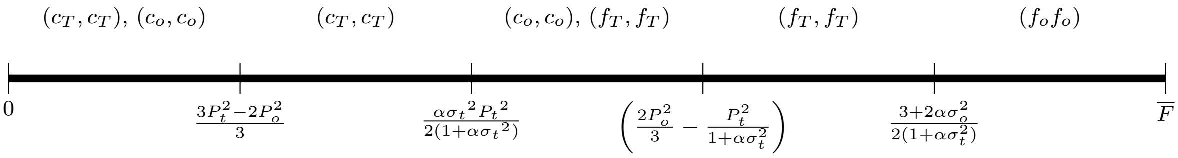
$$\text{Overall decision} = \begin{cases} \text{Produce O/T; Sell to C} & \forall F \leq \frac{3P_t^2 - 2P_o^2}{3} \\ \text{Produce T; Sell to C} & \forall \frac{3P_t^2 - 2P_o^2}{3} \leq F \leq \frac{\alpha {\sigma_t}^2 {P_t}^2}{2(1+\alpha {\sigma_t}^2)} \\ \text{Produce O/T; Sell to C/P} & \forall \frac{\alpha {\sigma_t}^2 {P_t}^2}{2(1+\alpha {\sigma_t}^2)} \leq F \leq \left(\frac{2P_o^2}{3} - \frac{P_t^2}{1+\alpha\sigma_t^2}\right) \\ \text{Produce T; Sell to P} & \forall \left(\frac{2P_o^2}{3} - \frac{P_t^2}{1+\alpha\sigma_t^2}\right) \leq F \leq \frac{3+2\alpha\sigma_o^2}{2(1+\alpha\sigma_t^2)} \\ \text{Produce O; Sell to P} & \forall F \geq \frac{3+2\alpha\sigma_o^2}{2(1+\alpha\sigma_t^2)} \end{cases}$$

Where, O represents Organic crop, T represents Conventional crop, C represents Cooperative and P represents Private firm.

Proof: See Appendix 4.

Figure 1 summarizes proposition 3:

Figure 1



Where, c_T and c_o respectively represents selling of conventionally and organically produced crop through cooperative and f_T and f_o represents selling of conventionally and organically produced crop to private firm respectively.

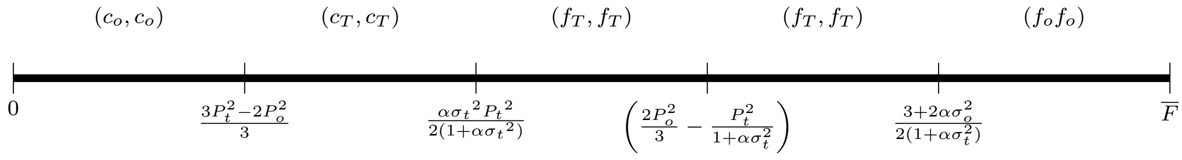
First segment signifies range of very low operational cost. Operational cost is so low that it is always beneficial for farmers to participate in cooperative no matter what they produce. However, producing organic crop is pareto optimal over traditional crop as organic commands price premium.

In the second segment, farmers prefer producing conventional crop rather than organic crop and sell in cooperative, even though organic receives higher premium. This is because the sum of cost of extra effort for organic production and the operational cost of cooperative is dominating the price premium that organic product commands and hence, it becomes profitable to produce conventional crop.

The third segment signifies a region where dis-utility from price volatility of conventional produce is dominated by the operational cost, however, for organic produce dis-utility of volatility continues to dominate operational cost. Hence, either both of them produces organic and sell to cooperative or produce conventional and sell to private. Nevertheless, here also the sum of cost of extra effort for organic production and the operational cost dominates the price premium of organic, hence farmer choose to produce conventional crop and sell to private firm. Same is true for the fourth section as well.

However, in the last segment, dis-utility from very high operational cost offsets the dis-utility from volatility for both organic and conventional produce. Additionally, lower volatility and higher price in organic market offsets the lower price and higher volatility in conventional market, and therefore, farmers produce organic and sell to private firm.

Figure 2



Corollary 5: A change in price volatility of conventional crop increases cooperative participation for both organic and conventional crop.

Increased volatility in the conventional market reduces participation in the conventional private market and increase participation in cooperative. With increasing volatility, the uncertainty in revenue flow increases and therefore to avoid fluctuation in revenue farmers either join conventional cooperative even for higher operational cost or start producing organic product and join cooperative when operational cost is very low.

The operational cost of cooperative plays a consequential role in choosing selling options as well as deciding on farming technique. Given that organic farming requires the extra cost of effort, only a very low operational cost can compensate for that and induce farmers in producing the organic crop and participate in cooperative. However, as operational cost increases, farmers incline to move towards conventional farming to evade the extra cost of effort. Nevertheless, high operational cost also persuades them to sell their produce to the private firm and accept volatility rather than much higher cooperative participation cost.

Conclusion

The paper highlights the role of tacit trade-off between price volatility and operation cost of cooperative (maximum participation cost of cooperative) in decision of cooperative participation as well as trade-off between operational cost and cost of effort in choosing between techniques of production. This paper has an important contribution to understanding why there are fewer cooperatives for volatile commodities and why organic farming is still in a dormant phase. For commodities with high price volatility, a risk-averse farmer always prefer to join a cooperative and avoid the risk of fluctuating revenue only when the maximum participation cost of cooperative is lower than the dis-utility from fluctuating revenue. Further, organic farming is most desirable when farmers can sell their produce through cooperatives.

However, selling through cooperative requires low participation cost. Hence, unless the operational cost of cooperative is low or a sufficient number of farmers willing to form cooperative, organic production is not a profitable option for farmers to adopt.

This paper also has important policy contributions. If the objective of the government is to encourage sustainable practices in farming and provide economically sustainable revenue to farmers through cooperative participation, first a foremost thing required is a reduction in operational cost of cooperative. Organic production with cooperative participation is viable only when the operational cost of cooperative is very low. Institutions can provide assistance in operations of the cooperatives, for example, by building infrastructure, thereby reducing operational cost.

Secondly, the price differential between organic and conventional crop also plays an important role in deciding between which technique to adopt. If the price differential is increased, we can have higher chanced of people participating in organic cooperative rather than moving to cooperative for the conventional crop. If the organic product does not command a sufficient price premium, farmers will be reluctant in adopting organic production technique, given the cost of extra effort organic production require.

References

Christopher Bacon. Confronting the Coffee Crisis: Can Fair Trade, Organic, and Specialty Coffees Reduce Small-Scale Farmer Vulnerability in Northern Nicaragua? *World Development*, 33(3):497–511, March 2005.

A. Braverman, J. Guasch, M. Huppi, and L. Pohlmeier. Promoting Rural Cooperatives in Developing Countries: The Case of Sub-Saharan Africa. 1991.

Daniel Buck, Christina Getz, and Julie Guthman. From farm to table: The organic vegetable commodity chain of northern california. *Sociologia ruralis*, 37(1):3–20, 1997.

Benoit Daviron and Stefano Ponte. *The Coffe Paradox: Global markets, commodity trade, and the elusive promise of development.* 2005.

Tomek De Ponti, Bert Rijk, and Martin K. van Ittersum. The crop yield gap between organic and conventional agriculture. *Agricultural Systems*, 108:1–9, April 2012.

Jim Dempsey. A case study of institution building to link Ethiopian co-operative coffee producers to international markets. Technical report, ACDI/VOCA, Ethiopia, 2006.

Catherine Dolan, John Humphrey, and Carla Harris-Pascal. Horiculture commodity chains: The impact of the UK market on the Africanfresh vegetable industry. 1999.

R Fitter and R Kaplinsky. Can an agricultural'commodity'be de-commodified, and if so who is to gain? 2001.

Jacques Franco. An analysis of the California market for organically grown produce. *American Journal of Alternative Agriculture*, 4(01):22, October 2009.

Ingrid Fromm and Juan A. Dubón. Upgrading and Value Chain Analysis: The case of small-scale coffee farmers in Honduras. In *Conference on International Agricultural Research for Development*, Tropentrag, 2006. University of Bonn.

Bruce Gardner and Zvi Lerman. Agricultural Cooperative Enterprise in the Transition from Socialist Collective Farming. *Journal of Rural Cooperation*, 34(1):1–18, 2006.

Rebecca L. Goldman, Barton H. Thompson, and Gretchen C. Daily. Institutional incentives for managing the landscape: Inducing cooperation for the production of ecosystem services. *Ecological Economics*, 64(2):333–343, December 2007.

Linda Kleemann and Alexandra Effenberger. Price Transmission in the Pineapple Market: What Role for Organic Fruit? 2010.

N. H. Lampkin. Organic farming: Sustainable agriculture in practice. In N. H. Lampkin and Susanne Padel, editors, *The Economics of Organic Farming: An International Perspective*, pages 3–9. Centre for Agricultural Bioscience International (CABI), Wallingford, UK, 1994.

Naufel Mzoughi. Farmers Adoption of Integrated Crop Protection and Organic Farming: Do Moral and Social Concerns Matter? *Ecological Economics*, 70(8):1536–1545, 2011.

Jerker Nilsson, Gunnar L.H. Svendsen, and Gert Tinggaard Svendsen. Are Large and Complex Agricultural Cooperatives Losing Their Social Capital? *Agribusiness*, 28(2): 187–204, 2012.

Lydia Oberholtzer, Carolyn Dimitri, and Catherine Greene. *Price premiums hold on as US organic produce market expands*. US Department of Agriculture, Economic Research Service Washington (DC), 2005.

Oxfam. *Mugged: Poverty in your Coffee Cup*. Oxfam International and Make Fair Trade, London, 2002.

Timothy A Park and Luanne Lohr. Supply and demand factors for organic produce. *American Journal of Agricultural Economics*, 78(3):647–655, 1996.

Kellie Curry Raper, J. Roy Black, Michael Hogberg, and James H. Hilker. Assessing Bottlenecks in Vertically Organized Beef Systems. *Journal of Food Distribution Research*, 36(1):151–155, 2005.

Laura T Raynolds. Re-embedding global agriculture: The international organic and fair trade movements. *Agriculture and human values*, 17(3):297–309, 2000.

Timothy J Richards, Ram N Acharya, and Ignacio Molina. Retail and wholesale market power in organic apples. *Agribusiness*, 27(1):62–81, 2011.

D. Rigby and D. Cáceres. Organic farming and the sustainability of agricultural systems. *Agricultural Systems*, 68(1):21–40, April 2001.

Walter Schneeberger, Ika Darnhofer, and Michael Eder. Barriers to the Adoption of Organic Farming by Cash-Crop Producers in Austria. *American Journal of Alternative Agriculture*, 17(1):24–31, 2002.

Ye Su, Scott Brown, and Michael Cook. Stability in Organic Milk Farm Prices: A Comparative Study. In *Agricultural and Applied Economics Association's AAEA & CAES Joint Annual Meeting*, Washington, DC, 2013.

John M Talbot. Information, Finance and the New International Inequality: The Case of Coffee. *Journal of world-systems research*, 8(2):214–250, 2002.

Ingrid Verhaegen and Guido Van Huylenbroeck. Costs and benefits for farmers participating in innovative marketing channels for quality food products. *Journal of Rural Studies*, 17(4):443–456, October 2001.

Appendix 1

Since, price is distributed normally, profit also follows a normal distribution with mean Π_μ and variance Π_σ^2.

Then, the expected utility is given as:

$$E(U) = \int f(\Pi) d\Pi \tag{8}$$

Where, $f(\Pi) = \left[\frac{1}{(2\pi\Pi_\sigma^2)^{1/2}}\right] e^{-\left(\frac{(\Pi-\Pi_\mu)^2}{2\Pi_\sigma^2}\right)}$ is the probability density function.

Hence,

$$E(U) = \frac{1}{(2\pi\Pi_\sigma^2)^{1/2}} \int e^{-\left(\frac{(\Pi-\Pi_\mu)^2}{2\Pi_\sigma^2}\right)} (-e^{\alpha\Pi}) d\Pi$$

$$= -\frac{1}{(2\pi\Pi_\sigma^2)^{1/2}} \int e^{-\left(\frac{(-\Pi^2 - \Pi_\mu^2 + 2\Pi\Pi_\mu - 2\alpha\Pi\Pi\sigma^2)}{2\Pi_\sigma^2}\right)} d\Pi$$

$$= -\frac{1}{(2\pi\Pi_\sigma^2)^{1/2}} \int e^{-\left(\frac{-(\Pi + (\alpha\Pi_\sigma^2 - \Pi_\mu))^2 + \alpha^2\Pi_\sigma^4 - 2\alpha\Pi_\sigma^2\mu}{2\Pi_\sigma^2}\right)} d\Pi$$

$$= -e^{\frac{\alpha^2\Pi_\sigma^2}{2 - \alpha\Pi_\mu}} \int \frac{1}{(2\pi\Pi_\sigma^2)^{1/2}} e^{-\left(\frac{-(\Pi + (\alpha\Pi_\sigma^2 - \Pi_\mu))^2}{2\Pi_\sigma^2}\right)} d\Pi$$

$$= -e^{\frac{\alpha^2\Pi_\sigma^2}{2 - \alpha\Pi_\mu}} \quad (9)$$

Monotonic transformation of equation (9) can result in:

$$E(U) = \Pi_\mu - \frac{\alpha\Pi_\sigma^2}{2} \quad (10)$$

$$\Pi_\mu = E(P)q - \frac{1}{2}q^2$$

$$= P_\mu q - \frac{1}{2}q^2$$

$$\Pi_\sigma = E(\Pi^2) - [E(\Pi)]^2$$

$$= E(Pq - \frac{1}{2}q^2)^2 - \left(E(P)q - \frac{1}{2}q^2\right)^2$$

$$= [E(P^2) - (E(P))^2]q_f^2$$

$$= \sigma^2 q^2$$

$$E(U) = P_\mu q - \frac{1}{2}q^2 - \frac{\alpha}{2}\sigma^2 q^2 \quad (11)$$

Equation (11) represents the expected utility function of the farmer.

Appendix 2

Equilibrium in conventional market

Farmers expect to get an average price P_t by selling in cooperative and the variance in the price ${\sigma_t}^2$ is zero. Thus the objective function of each farmer selling through cooperative can be written as:

$$\underset{q_c}{\text{maximize}} \quad E(U) = P_t q_{tc} - \frac{1}{2}{q_{tc}}^2 - \frac{\alpha}{2}{\sigma_t}^2{q_{tc}}^2 - \left[\frac{F}{q_{tc} + q_{tc'}}\right] q_{tc} \tag{12}$$

Where, q_{tc} is the amount one farmer is selling through cooperative and $q_{tc'}$ is the amount of produce other individual is contributing to the cooperative. F denotes the operational cost. Since, both farmers are homogeneous, q_{tc} equal to $q_{tc'}$ and hence, each farmer pays $\frac{F}{2}$ for operating the cooperative.

Substituting ${\sigma_t}^2 = 0$ in equation (12)

$$E(U) = P_t q_{tc} - \frac{1}{2}{q_{tc}}^2 - \frac{F}{2} \tag{13}$$

The utility maximizing output level '$q_{tc}*$' for each farmer is P_t.
Substituting the value of $q_{tc}*$ in the expected utility function, expected utility of each farmer becomes equals to $\frac{1}{2}({P_t}^2 - F)$.

When both of them sell everything to private firm:

When both farmers sell everything to private firm, the expected utility of the farmer depends on both: the average as well as the variance of the price. Farmer's objective is to solve the following problem:

$$\text{maximize} \quad E(U) = P_t q_f - \frac{1}{2}{q_{tf}}^2 - \frac{\alpha}{2}{\sigma_t}^2{q_{tf}}^2 \tag{14}$$

where, q_{tf} is the amount of produce each farmer sells to private firm.
Expected utility maximizing output level for farmer selling to private firm is $\frac{P_t}{1+\alpha{\sigma_t}^2}$.
Expected utility of each farmer equals to $\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$.

When one farmer sells in cooperative and another to private firm:

When only one farmer sells in cooperative, s(he) has to pay the whole operational cost. Hence, following equation (13), Expected utility function of farmer selling in cooperative is:

$$\underset{q_c}{\text{maximize}} \quad E(U) = P_t q_{tc} - \frac{1}{2} {q_{tc}}^2 - F \tag{15}$$

Expected utility maximizing output level:

$$q_{tc}* = P_t \tag{16}$$

Expected utility from selling in cooperative:

$$E(U)^* = \frac{{P_t}^2}{2} - F \tag{17}$$

Expected utility function of farmer selling to private firm:

$$E(U) = P_t q_{tf} - \frac{1}{2} {q_{tf}}^2 - \frac{\alpha}{2} {\sigma_t}^2 {q_{tf}}^2 \tag{18}$$

Expected utility maximizing output level for the farmer is $\frac{P_t}{1+\alpha {\sigma_t}^2}$.
Expected utility of farmer selling to private firm equals to $\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$.
Representing all the payoffs in matrix form:

	Cooperative	Private
Cooperative	$\frac{1}{2}({P_t}^2 - F)$, $\frac{1}{2}({P_t}^2 - F)$	$\left(\frac{{P_t}^2}{2} - F\right)$, $\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$
Private	$\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$, $\left(\frac{{P_t}^2}{2} - F\right)$	$\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$, $\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$

Farmers participate in cooperative only when:

$$\frac{{P_t}^2}{2} - F \geq \frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right) \tag{19}$$

$${\sigma_t}^2 \geq \frac{2F}{({P_t}^2 - 2F)\alpha} = k(say) \tag{20}$$

Equation (19) can only satisfy when ${P_t}^2 > 2F$ as right hand side of the equation is positive. Equation (20) states that, for a given value of k, when the volatility in the commodity price is high, a risk averse farmer prefer selling to cooperative.

From equation (20), $\frac{\delta k}{F} > 0$. Which means, for commodities with lower operational cost, the above condition satisfies even for lower volatility. However, if the operational cost is high fulfilment of above requires volatility to be extremely high.

Nash Equilibrium:

	Conditions	Nash Equilibrium
Case 1	$\frac{\alpha {\sigma_t}^2 {P_t}^2}{2(1+\alpha {\sigma_t}^2)} \geq F$	(Cooperative, Cooperative)
Case 2	$\frac{\alpha {\sigma_t}^2 {P_t}^2}{2(1+\alpha {\sigma_t}^2)} \leq F \leq \frac{\alpha {\sigma_t}^2 {P_t}^2}{(1+\alpha {\sigma_t}^2)}$	(Cooperative, Cooperative);(Private, Private)
Case 3	$\frac{\alpha {\sigma_t}^2 {P_t}^2}{(1+\alpha {\sigma_t}^2)} \leq F$	(Private, Private)

Appendix 3

Equilibrium in Organic market

For organically produced commodity, the average price is assumed to be P_o and the variance in the price is ${\sigma_o}^2$. In addition to this, organic farming also incurs additional effort in controlling for pest and diseases. Cost of effort is represented by $c(\epsilon) = \frac{1}{4} q_i^2$.

When both of them decides to participate in cooperative:

Thus the objective function of each farmer can be written as:

$$\underset{q_c}{\text{maximize}} \quad E(U) = P_o q_{oc} - \frac{1}{2} {q_{oc}}^2 - \frac{1}{4} {q_{oc}}^2 - \frac{\alpha}{2} {\sigma_o}^2 {q_{oc}}^2 - \left[\frac{F}{q_{oc} + {q_c}'^{o}} \right] q_{oc} \tag{21}$$

Where, q_{oc} is the amount of organic produce one farmer is selling through cooperative and $q_{oc'}$ is the amount of organic produce other individual is contributing to the cooperative.

Substituting $\sigma_o{}^2 = 0$ in equation (21)

$$E(U) = P_o q_{oc} - \frac{1}{2} q_{oc}{}^2 - \frac{1}{4} q_{oc}{}^2 - \frac{F}{2} \tag{22}$$

The utility maximizing output level '$q_{oc}*$' for each farmer is $\frac{2}{3}P_o$.

Substituting the value of $q_{oc}*$ in the expected utility function, expected utility of each farmer equals to $\frac{1}{3}P_o{}^2 - \frac{F}{2}$.

When both of them sell everything to private firm:

When both farmers sell everything to the private firm, the expected utility of the farmer depends on both: the average as well as the variance of the price. Farmer's objective is to solve the following problem:

$$\text{maximize} \quad E(U) = P_o q_f - \frac{1}{2} q_{of}{}^2 - \frac{1}{4} q_{of}{}^2 - \frac{\alpha}{2} \sigma_o{}^2 q_{of}{}^2 \tag{23}$$

where, q_{of} is the amount of produce each farmer sells to the private firm.

Expected utility maximizing output level for farmer selling to private firm is $\frac{2P_o}{3+2\alpha\sigma_o{}^2}$.

Expected utility of each farmer equals to $\left(\frac{P_o{}^2}{3+2\alpha\sigma_o{}^2}\right)$.

When one farmer sells in cooperative and another to private firm:

When only one farmer sells in cooperative, s(he) has to pay the whole operational cost. Hence, following equation (22), Expected utility function of farmer selling in cooperative becomes:

$$\underset{q_c}{\text{maximize}} \quad E(U) = P_o q_{oc} - \frac{1}{2} q_{oc}{}^2 - \frac{1}{4} q_{oc}{}^2 - F \tag{24}$$

Expected utility maximizing output level:

$$q_{oc}* = \frac{2}{3}P_o \tag{25}$$

Expected utility from selling in cooperative:

$$E(U)^* = \frac{1}{3}{P_o}^2 - F \tag{26}$$

Expected utility function of farmer selling to private firm:

$$E(U) = P_o q_{of} - \frac{1}{2}{q_{of}}^2 - \frac{1}{4}{q_{oc}}^2 - \frac{\alpha}{2}{\sigma_o}^2 {q_{of}}^2 \tag{27}$$

Expected utility maximizing output level for the farmer is $\frac{2P_o}{3+2\alpha{\sigma_o}^2}$.
Expected utility of each farmer equals to $\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$.

Representing all the payoffs in matrix form:

	Cooperative	Private
Cooperative	$\frac{1}{3}{P_o}^2 - \frac{F}{2}$, $\frac{1}{3}{P_o}^2 - \frac{F}{2}$	$\frac{1}{3}{P_o}^2 - F$, $\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$
Private	$\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$, $\frac{1}{3}{P_o}^2 - F$	$\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$, $\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$

For both the farmers to participate in cooperative,

$$\left(\frac{1}{3}{P_o}^2 - F\right) \geq \left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right) \tag{28}$$

Equation (28) can only satisfy when ${P_o}^2 > 3F$.

Nash Equilibrium:

	Conditions	Nash Equilibrium
Case 1	$\frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \geq F$	(Cooperative, Cooperative)
Case 2	$\frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \geq F \geq \frac{4\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)}$	(Cooperative, Cooperative);(Private, Private)
Case 3	$\frac{4\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \leq F$	(Private market, Private market)

Appendix 4

Decision on Farming Technique and Selling Choice

Let $T_1^t = \frac{\alpha{\sigma_t}^2{P_t}^2}{2(1+\alpha{\sigma_t}^2)}$ and $T_2^t = 2T_1^t$.

$T_1^o = \frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)}$ and $T_2^o = 2T_1^o$

Four possible situations arises:

(1) $T_1^t < T_1^o$ and $T_2^t < T_1^o$

(2) $T_1^t < T_1^o$ and $T_2^t > T_1^o$

(3) $T_1^t > T_1^o$ and $T_1^t > T_2^o$

(4) $T_1^t > T_1^o$ and $T_1^t < T_2^o$

However, it is assumed that there exists an upper bound to the percentage difference in the price of organic vs conventional crop such that it is less than or equal to 2/3, i.e 67 percent and the ratio of $\frac{P_o^2}{P_t^2} < \frac{3}{2}$.[3]. With this assumption, only one case remains: $T_1^t < T_2^t < T_1^o < T_2^o$.[4]. Five different ranges for "F" is possible. By using the Nash equilibria from stage 2 subgames, different Nash equilibria for all the ranges for "F" as follows:

(a) $F \leq T_1^t$, i.e.Very low operational cost. Nash equilibrium in both the subgames solved earlier is (Cooperation, Cooperation).

(b) F lies between $T_1^t \& T_2^t$ i.e.low operational cost. Nash equilibrium for subgame 1 (for conventional crop) is both (Cooperation, Cooperation) and (Private, Private) whereas for subgame 2(for organic crop) is (Cooperation, Cooperation)

(c) F lies between $T_2^t \& T_1^o$ i.e. moderate operational cost. Nash equilibrium for subgame 1 (for conventional crop) is (Private, Private), whereas for subgame 2(for organic crop) is (Cooperation, Cooperation).

(d) F lies between $T_1^o \& T_2^o$ i.e. high operational cost. Nash equilibrium for subgame 1 (for conventional crop) is (Private, Private), whereas for subgame 2(for organic crop) is (Cooperation, Cooperation) and (Private, Private).

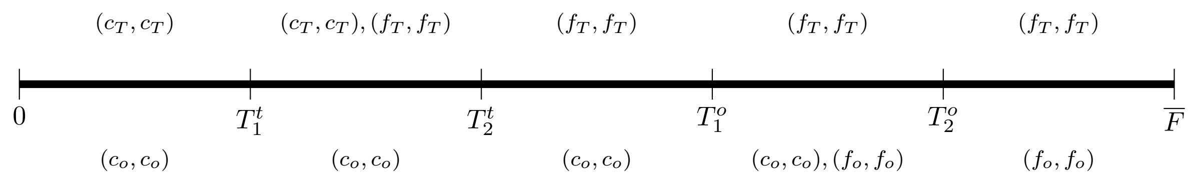
[3]Since same commodity with different quality attributes is considered, this is a reasonable assumption to make.

[4]For derivation refer to Appendix 5

(e) $F \geq T_2^o$ i.e. very high operational cost. Nash equilibrium in both the subgames is (Private, Private).

Let c_T and c_o represents sell of traditionally and organically produced crop through cooperative respectively and f_T and f_o represents selling of traditionally and organically produced crop to private firm respectively. The equilibria for different ranges can be represented graphically as follows:

Figure 3



Since,

$$\frac{P_o^2}{P_t^2} < \frac{3}{2} \tag{29}$$

.

$$\Rightarrow 2P_o^2 - 3P_t^2 < 0 \tag{30}$$

Case1: $F \leq T_1^t$ (Both goes to Cooperative)

	Organic(O)	Conventional (T)
Organic(O)	$\frac{1}{3}{P_o}^2 - \frac{F}{2}, \frac{1}{3}{P_o}^2 - \frac{F}{2}$	$\frac{1}{3}{P_o}^2 - F, \frac{1}{2}{P_t}^2 - F$
Conventional (T)	$\frac{1}{2}{P_t}^2 - F, \frac{1}{3}{P_o}^2 - F$	$\frac{1}{2}{P_t}^2 - \frac{F}{2}, \frac{1}{2}{P_t}^2 - \frac{F}{2}$

If $2{P_o}^2 - 3{P_t}^2 > 3F$, N.E. is both of them producing organic crop and selling in cooperative. However, with $2{P_o}^2 - 3{P_t}^2 < 0$ (refer to equation 30), this condition can never satisfy.

If $-3F < 2{P_o}^2 - 3{P_t}^2 < 3F$, N.E. is either both of them producing conventional crop or both producing organic and both selling through cooperative.

If $2{P_o}^2 - 3{P_t}^2 < -3F$, N.E. is both of them producing conventional crop and selling in cooperative.

Case 2: $T_1^t < F < T_2^t$ (Conventional Farmer sells to cooperative or private firm and Organic Farmer to Cooperative)

If conventional farmer sells in cooperative, equilibrium is same as in case 1. However, if he sells to private firm, game matrix looks like as below:

	Organic(O)	Co
Organic(O)	$\frac{1}{3}{P_o}^2 - \frac{F}{2}$, $\frac{1}{3}{P_o}^2 - \frac{F}{2}$	$\frac{1}{3}{P_o}^2$
Conventional (T)	$\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$, $\frac{1}{3}{P_o}^2 - F$	$\frac{1}{2}\left(\frac{P}{1+}\right.$

If $\frac{P_o^2}{3} - \frac{P_t^2}{2(1+\alpha\sigma_t^2)} > F$, N.E. is both producing organic crop and selling in cooperative. Since, $\frac{P_o^2}{3} - \frac{P_t^2}{2(1+\alpha\sigma_t^2)} < T_1^t$ (using equation 30), this condition can never satisfy.

If $\frac{P_o^2}{3} - \frac{P_t^2}{2(1+\alpha\sigma_t^2)} < F < \frac{2P_o^2}{3} - \frac{P_t^2}{(1+\alpha\sigma_t^2)}$, N.E. is either both of them produces organic and sell to cooperative or both produces conventional crop and sell it to Private firm.

If $\frac{2P_o^2}{3} - \frac{P_t^2}{(1+\alpha\sigma_t^2)} < F$, N.E. is both of them producing conventional crop and selling to Private firm.

Case 3: $T_2^t < F < T_1^o$ (Conventional Farmer sells to private firm and Organic Farmer to Cooperative)

Equilibrium is same as case 2.

Case 4: $T_1^o < F < T_2^o$ (Conventional Farmer sells to private firm and Organic Farmer to either Cooperative or Private firm)

If organic farmer sells in cooperative, Nash equilibrium is same as Case 3.

However, if he sells to Private firm, game matrix is as follows:

	Organic(O)	Conventional (T)
Organic(O)	$\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$, $\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$	$\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$, $\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$
Conventional (T)	$\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$, $\left(\frac{{P_o}^2}{3+2\alpha{\sigma_o}^2}\right)$	$\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$, $\frac{1}{2}\left(\frac{{P_t}^2}{1+\alpha{\sigma_t}^2}\right)$

If $\frac{P_o^2}{P_t^2} > \frac{3+2\alpha\sigma_o^2}{2(1+\alpha\sigma_t^2)}$, N.E. is both of them producing organic crop and selling to Private firm.

If $\frac{P_o^2}{P_t^2} < \frac{3+2\alpha\sigma_o^2}{2(1+\alpha\sigma_t^2)}$, N.E. is both of them producing conventional crop and selling to Private firm.

Since, F is less than $\frac{P_o^2}{P_t^2}$, a sufficient condition for above inequalities to hold can be:

If $F > \frac{3+2\alpha\sigma_o^2}{2(1+\alpha\sigma_t^2)}$, N.E. is both of them producing organic crop and selling to Private firm.

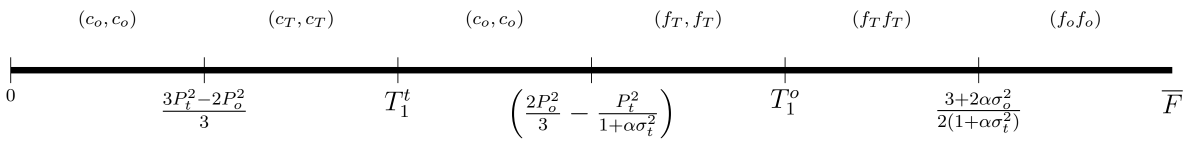
If $F < \frac{3+2\alpha\sigma_o^2}{2(1+\alpha\sigma_t^2)}$, N.E. is both of them producing conventional crop and selling to Private firm.

Case 5: $F \geq T_2^o$ (Both goes to Private firm)

Equilibrium is same as case 5.

Figure 3 summarizes the results for the entire game:

Figure 4



Appendix 5

It is evident from the values of T_1^t, T_2^t,T_1^o,T_2^o that $T_1^t < T_2^t$ and $T_1^o < T_2^o$

What is the relation between T_2^t and T_1^o.

$T_2^t = \frac{\alpha{\sigma_t}^2{P_t}^2}{(1+\alpha{\sigma_t}^2)}$.

$T_1^o = \frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)}$

If $T_1^o > T_2^t$

$$\Rightarrow \frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} > \frac{\alpha{\sigma_t}^2{P_t}^2}{(1+\alpha{\sigma_t}^2)}$$

$$\Rightarrow \frac{2\alpha{\sigma_o}^2{P_o}^2}{3(1+\alpha{\sigma_o}^2)} \times \frac{(1+\alpha{\sigma_t}^2)}{\alpha{\sigma_t}^2{P_t}^2} > 1$$

$$\Rightarrow 2{P_o}^2{\sigma_o}^2 + 2\alpha{P_o}^2\sigma^{o2}{\sigma_t}^2 - 3{P_t}^2{\sigma_t}^2 - 3\alpha{P_t}^2{\sigma_o}^2{\sigma_t}^2 > 0$$

$$\Rightarrow \alpha{\sigma_o}^2{\sigma_t}^2(2{P_o}^2 - 3{P_t}^2 > 2{P_o}^2{\sigma_o}^2 - 3{P_t}^2{\sigma_t}^2$$

$$\Rightarrow \alpha(2{P_o}^2 - 3{P_t}^2) > \left(\frac{2{P_o}^2}{{\sigma_t}^2} - \frac{3{P_t}^2}{{\sigma_o}^2}\right)$$

$$\Rightarrow 2{P_o}^2\left(\alpha - \frac{1}{{\sigma_t}^2}\right) > 3{P_t}^2\left(\alpha - \frac{1}{{\sigma_o}^2}\right)$$

$$\Rightarrow \frac{{P_o}^2}{{P_t}^2} > \frac{3(1-\alpha{\sigma_o}^2)}{2(1-\alpha{\sigma_t}^2)}$$

since, ${P_o}^2 > {P_t}^2$, L.H.S of the above equation is always greater that 1. For the above equation to hold true, we must have R.H.S to be less then 1.

$$\Rightarrow \frac{3(1-\alpha{\sigma_o}^2)}{2(1-\alpha{\sigma_t}^2)} < 1$$

$$\Rightarrow 3{\sigma_o}^2 - 2{\sigma_t}^2 > \frac{1}{\alpha}$$

since, α lies between o and 1, the R.H.S is always positive and greater than 1. A sufficient condition for satisfying the above equation is when,

$$\Rightarrow 3{\sigma_o}^2 - 2{\sigma_t}^2 < 0$$

$$\Rightarrow \frac{{\sigma_o}^2}{{\sigma_t}^2} < \frac{2}{3}$$

Thus, if $\frac{{\sigma_o}^2}{{\sigma_t}^2} < \frac{2}{3} \Rightarrow T_1^o > T_2^t$