Coordination and Three-Stage Supply Chain Optimization of Agricultural Products in Bangladesh Under Uncertainties

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***Abstract*-This study, we present three-stage supply chain network (SCN) coordination and profit optimization of agricultural products considering uncertainties. Most of the agricultural products are in general cost expensive with high risk in probability due to its fluctuating prices. To develop a Mixed Integer Linear Programming (MILP) model and analyze the situation of insufficient production capacity for the producer as the reason for shortages. In this study to investigated Supply Chain Network (SCN) are three individual freelance supply organizations. SCN management has the difficulties for the disconnected and freelance economic people. Further, fast technological changes and high fight build SCN a lot of complicated. The problem of locating distribution centers (DCs) is one among the foremost necessary problems in design of SCN. The models are applied to a real case of optimization the profit before and after coordination and also to analyze the sensitivity under demand and cost uncertainty. The MILP models consider the facilities are coordinated by mutually sharing information with each other among producer, retailer and distributor. The formulated MILP model is solved by using A Mathematical Programming Language (AMPL) and results obtained by appropriate solver MINOS. Numerical example with the sensitivity of various parameters has been deployed to validate the models. Results show that after coordination, the individual profits could be increased without any extra investment, in the same time the end user cost price decrease.**

Keywords- Mixed integer linear programming, Coordination, Optimization, Agricultural products, Uncertainty

1. Introduction

Supply chain is one of the vital issues to overcome the new challenges of any kind of business especially in agricultural business. Now a days the world market is facing a ferocious competition and the highly expectation of the customers have enlarged the business enterprises. It is also facing the relationship with the customers and suppliers. Elegant management thinking pleaders the co-operation among business partners and the customers demand an extra trust to the productive competitive strategy. At this context that supply related chain network (SCN) has turned major of the senior management topics in the western countries from the nineteen century, especially within the productive and marketing industries. A huge some of recent interest in SCN has been properly developed in the agriculture products sector in every developing country. The counterparts in producing and marketing with executive of agricultural products of some developing countries have awarded the people in the world that helps them for the successful coordination and it is one of the key of the business process of SCN that can predict the competitive success. Besides this the business with agricultural products need more and more clear concept that they do not practice and instead of competition happens a lot of among the whole SCN. Supply Chain Management (SCM) is outlined because the coordination of the physical, logical and money flows management between the SCN, whose final goal is to deliver the proper product, within the correct amount, at the proper time, for the proper client, aspiring to with efficiency answer client demand described in [1]. Two-stage SCN considering uncertainty parameters the operational price, the client demand and therefore the capability of the facilities represents in [2]. Configuration choices square measure thought-about as initial stage variables and choices connected with transporting product from suppliers to customers square measure thought-about as second stage variables. A multi-stage stochastic SCN model problem with financial decisions and risk management and discuss the flows of product and different investments [3]. To develop a random mathematical formulation to deal with the problem of SCN style behind demand and provide unsure, that resembled through distribution functions [4]-[5]. In order to optimize cost minimization conferred a mixed-integer applied mathematics formulation for SCN under demand uncertainty [6]. To analyze a systematic literature review and reflection framework to inform the system is to innovation in aquaculture conceptualized and managed [7].

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In this study, producer-retailer-distributor multi-product, multi-distribution center and multi-customer location production problem is formulated as a MILP model, also formulate their coordination model which maximizes the total profit, and at the same time optimizes production land, profitable distribution center. We have incorporated the possibility of external procurement by the producer when it faces shortages and extended the model by considering the interested of the distributor also as long term partnership is described by the business entities in today's business environment. The distributors purchase the item from the producer and retailer, and then sell it in the market. To solve these formulated MILP model using A Mathematical Programming Language (AMPL) with appropriate solver MINOS. Finally, a numerical example along with the sensitivity of relevant parameters is considered to estimate the achievement of the models under cost and demand uncertainty.

The rest of this study is organized as follows: In section 2, talk over the review of literature, section 3 discusses data ingathering. In section 4, presents three mathematical formulation of MILP model which deals with the stage of research methodology. In section 5, discuss the solution procedure and numerical example. In section 6, discuss the results and sensitivity of the MILP model. Finally, in section 7, presents the conclusions and suggestions for the future work.

2. Review of Literature

The most remarkable competition among some business organizations are denoted by the post liberation period. Now we are living in a globalized world and this era is facing the ever rising expectation of the consumers. For that reason most of the business enterprises have been enforced to make a deep concentration to their SCN for the maintenance of the operation efficiently. Again the present evolution of the conception of SCN has been motivated with the ever rising technology advancement in E-Business, E-Logistics and E-Commerce. In this way SCN has become the most renowned research field with the capability of providing the industries with an effective tool to form a significant use over their competition. Moreover it is noticed that both the experts of research area and academicians have expressed much concentration towards SCN. So SCN works as system to utilize the different chances evolving for the globalization and also to keep in standing with the sharp competition.

For all large scale business, managing a SCN may be a complicated method, but manage an agricultural products supply chain is even more difficult due to: restricted and short shelf lives, temperature and wetness necessities, and restrictions relating to time windows for product deliveries, high client expectations, and low profit margins. Production planning, products distribution, investments in technology, quality fresh food supply, environmental impacts like operational activities, transportation, contribute to cut back the postharvest wastage, business safety and considering various uncertainty presented in [8]-[12]. Customer perspective, information and environmental sustainability issues in the logistics service provider industry [13], optimization supply chain increasing competitiveness and decision making techniques to decrease costs and risk [14].

Due to high customer expectation, all kind of business effort have been solidified their SCN for feasible business operations. In the literature, Optimizing shipment, ordering and pricing policies in a two-stage SCN with price sensitive demand [15]. Sustainability in food retail industry through reverses logistics [16]. MILP problem to solve a capacitated vehicle routing drawback minimizing time and number of auto presented in [17]. They enforced the model to a true life drawback of a distribution company and solved it numerically. In addition, super network equilibrium model investigated [18]. They combined super network with SCN and transport a network. They thought-about not solely the behavior of freight carriers however additionally the transport network users, and determined the transport prices generated within the offer chain networks. They additionally investigated the interaction between transport networks and SCN.

3. Data Ingathering

Data ingathering may be a crucial step, since the standard of information collected influences the results of the study. If the results accuracy defines the problem under study, those results enable deeper information of the problem. Typically this stage consumes a long time, and contributes to correct information and to supply input to the mathematical model.

We tend to developed our MILP models by ingathering information for agricultural product optimization in at random elite samples of 235 market players who are directly or indirectly concerned in agricultural business from four districts in Bangladesh, additionally we gathered detailed information on agricultural activities, including availability if land, water, labor, fertilizer, capital, types of products; fixed and variable prices associated to installation of plants, warehouses, distribution centers and agricultural products hub facilities; transportation prices, process and transportation times associated to transportation modes. The mathematical model consists in an exceedingly ancient SCN, during which flows area unit initiated from suppliers and finish in customers. Thus, the SCN consists within the following entities: suppliers, productions facilities, DC's, WH's, agricultural products hubs and markets. Every entity is delineated by its geographical location and therefore the entities area unit connected through the construction flows between them.

4. Mathematical Model Formulation

This section describes the proposed mathematical formulation. Before mathematical formulation of MILP models, we have discussed indices, sets, parameters and decision variables that are relevant with our work in this study.

Sets:

L: Set of production locations indexed by l;
C: Set of customers indexed by j;
P: Set of products indexed by i;
D: Set of distribution center indexed by k.

Parameters for producer model:

u_{il} The price of i^{th} product at l^{th} location (\$/kg)

l_{il} Labor Requirement of i^{th} product at l^{th} location (ha)

v_{il} Labor cost of i^{th} product at l^{th} location (\$/unit)

w_{il} The amount of water need of i^{th} product at l^{th} location (ha)

g_{il} Water cost of i^{th} product at l^{th} location (\$/unit)

f_{il} Fertilizer Requirement of i^{th} product at l^{th} location (kg/ha)

c_{il} The price of unit raw materials for i^{th} product at l^{th} location (\$/unit)

r_{il} The amounts of raw materials need to produce i^{th} product at l^{th} location (\$/unit) .

t_{il} Unit transportation cost of raw materials for i^{th} product at l^{th} location (\$/unit)

p_{il} The production cost of i^{th} product to l^{th} location at (\$/unit).

h_{il} Unit holding cost of i^{th} product from l^{th} location for some given unit of time (\$/unit-time)

g^*_{il} Fertilizer cost of i^{th} product at l^{th} location (\$/unit).

p_i Uncertainty probability of i^{th} product

d_{ij} Unit demand of i^{th} product for j^{th} customer

$TCLA$, is the total cultivated land available

TWA, is the total amount of water available

Parameters for distributor model:

U^1_{li} Annual fixed cost for l^{th} DC operation of i^{th} product
U^2_l Annual fixed cost for l^{th}DC operation
U^3_{li} Unit producing cost of i^{th} product for l^{th} DC
U^4_{liJ} Unit shipment cost of i^{th} product for j^{th} customer through l^{th} DC
U^5_{li} Unit holding cost of i^{th} product for l^{th} DC
U^6_{liJ} Unit transportation cost of i^{th} product for j^{th} customer through l^{th} DC
D_{IJ} Unit demand of i^{th} product from j^{th}customer
Ca_{lI} Products capacity of i^{th} product for l^{th} DC

T_{lj} Unit transportation time from l^{th} DC to j^{th}customer

Parameters for retailer model:

f_{li} Retailer fixed cost of i^{th} product at l^{th} location (\$/kg)

p_{lij} Retailer production cost of i^{th} product at l^{th} location for j^{th} customer (\$/kg)

H_{lij} Retailer holding cost of i^{th} product at l^{th} location for j^{th} customer (\$/kg)

pc_{li} Retailer production capacity of i^{th} product at l^{th} location (kg)

tt_{lj} Retailer unit time transportation at l^{th} location for j^{th} customer (h)

rt_{lj} Retailer required delivery time transportation at l^{th} location for j^{th} customer (h)

rt^*_{lj} Retailer obligatory time transportation at l^{th} location for j^{th} customer (h)

p_{ij} Retailer penalty cost of i^{th} product for j^{th} customer (\$/kg)

Tc_{ij} Retailer unit transportation cost at l^{th} location for j^{th} customer (\$/kg)

mc_l Retailer unit maintenance cost at l^{th} location (\$/kg)

d_{ij} Unit demand of i^{th} product from j^{th} customer (kg)

pp_{li} Retailer purchasing price of i^{th} product at l^{th} location (\$/kg)

Decision variables for producer:

x_{lij}, is the total amount of i^{th} product shipped from l^{th} location/distribution center for j^{th} customer (kg)

$$x_l = \begin{cases} 1, \textit{if location l is used,} \\ \textit{0, else} \end{cases}$$

$$w_{lj} = \begin{cases} 1, \textit{if customer j is used distribution center l,} \\ \textit{0, else} \end{cases}$$

Producer Model:

Objective function,

$$Maximize, Z = z_1 - z_2 \quad (1)$$

After knowing the distributor's order quantity, producer's income is obtained by the multiplication of the selling price and demand quantity. It is assumed that producer's selling price, s_{li} is fixed for each product i. Therefore producer's total income (z_1) is defined by,

$z_1 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} s_{li} x_{lij}$	(1.1)

Producer's investment:

The total investment of producer is required to satisfy order quantity of distributor as well as customer's demand for all products. In this model, fixed opening cost, labor cost, fertilizer cost, water cost, holding cost and transportation cost are considered as producer's costs. Therefore, mathematically producer's total investment (z_2) is defined as,

$z_2 = \sum_{l=1}^{L} \alpha_l x_l + \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}((t_{li} + c_{li}) r_{li} + (p_{il} + h_{il}) x_{lij} + v_{li} l_{li} + w_{li} g_{il} + f_{li} g^*_{li})$	(1.2)

Subject to constraints,

$\sum_{l=1}^{L}\sum_{i=1}^{m} x_{lij} \le TCLA$	(1.3)
$\sum_{l=1}^{L}\sum_{i=1}^{m} L_{li} x_{lij} \le TLA$	(1.4)
$\sum_{l=1}^{L}\sum_{i=1}^{m} W_{li} x_{lij} \le TWA$	(1.5)
$\sum_{l=1}^{L}\sum_{i=1}^{m} F_{li} x_{lij} \le TFA$	(1.6)
$\sum_{l=1}^{L} x_{lij} \le d_{ij} \ , \forall i,j$	(1.7)
x_{lij}, F_{li}, W_{li}, L_{li}, h_{li}, p_{li}, c_{li}, r_{li}, v_{li}, f_{li}, w_{li}, l_{li}, g_{li}, g^*_{li}, t_{li}, ud_{lij}, **TCLA, TLA, TWA, TFA are non-negative and** x_l **is binary.**	(1.8)

Distributor Model:

The objective function of the model is difference between total income and total cost:

$Maximize, z^* = z_5 - z_6$	(2)

Where z_3 is the total income and z_4 is the total cost.

$z_5 = \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} s^{**}_{li}$	(2.1)
$z_6 = \sum_{l=1}^{L}\sum_{i=1}^{m} y_l u^1_{li} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} u^2_{lji} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} u^3_{lji} + \sum_{l=1}^{L} x_l u^4_l + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} u^5_{lji}/2 + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} w_{lj} u^6_{lji}$	(2.2)

Subject to constraints:

$\sum_{l=1}^{L} x_{lij} \le d_{ij} \ , \forall i,j$	(2.3)
$\sum_{j=1}^{n} x_{lij} \le ca_{li}, \forall i,l$	(2.4)
$\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} \le \alpha\, y_l \ , \forall l$	(2.5)
$\sum_{l=1}^{L} w_{lj} = 1 \ , \forall j$	(2.6)
X_{lji}, s^{**}_{li}, U^1_l, U^2_{lji}, U^3_{lji}, U^4_l, U^5_{lji}, U^6_{lji}, d_{ij}, Ca_{li}, α **are non-negative and** y_l, w_{lj} **are binary** $\forall j,i,l$	(2.7)

Decision variables for retailer:

Q_{lij}, is the total amount of i^{th} product shipped from l^{th} location for j^{th} customer (kg)

Z_3, is the total income

Z_4, is the total cost

Z^*, is the maximum profit

S^*_{li} , is the retailer selling price of i^{th} product at l^{th} location (\$/kg)

$$z_l = \begin{cases} 1, \text{if location } l \text{ is used,} \\ 0, \text{else} \end{cases}$$

$$y_{lj} = \begin{cases} 1, \text{if customer } j \text{ is assaign to producer } l\,, \\ 0, \text{else} \end{cases}$$

Retailer Model:

Objective function,

$$Maximize, z^{*} = z_3 - z_4 \tag{3}$$

Where,

$$z_3 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} s_{li}^{*} x_{lij} \tag{3.1}$$

$$z_4 = \sum_{l=1}^{L} x_l y_{li} + \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} (Tc_{ij} x_{lij} + (p_{ilj} + h_{ilj} + mc_l) x_{lij} + d_{ij} p_{ij} (rt_{ij} - rt_{ij}^{*})) \tag{3.2}$$

Subject to constraints,

$\sum_{l=1}^{L}\sum_{i=1}^{m} x_{lij} \leq \sum_{i=1}^{m} d_{ij} \ , \forall j$	(3.3)
$\sum_{l=1}^{L}\sum_{j}^{n} x_{lij} \leq \sum_{j=1}^{n} d_{ij}, \forall i$	(3.4)
$\sum_{l=1}^{L} x_{lij} \leq d_{ij} \ , \forall i,j$	(3.5)
$\sum_{j=1}^{n} x_{lij} \leq ca_{li}, \forall i,l$	(3.6)
$\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} \leq \alpha \ x_l \ , \forall l$	(3.7)
$\sum_{l=1}^{L} y_{lj} = 1, \forall j$	(3.8)
$x_{lij}, Tc_{ij}, d_{ij}, h_{lij}, p_{lij}, mc_l, d_{ij}, p_{ij}, rt_{ij}, rt^{*}_{ij}$ **are non-negative and** x_l , y_{li} **are binary** $\forall\ l, i, j$.	(3.9)

Producer-Distributor-Retailer coordinated model

This study the sooner non-coordinated model during a supply chain coordination point of view where we consider all the participants take decisions jointly and the producers and retailers decides to travel for outsourcing to recover lost sales, if possible. Any shortage resulting in a lost sale is usually detrimental even for the coordinated system as an entire and thus a price is usually related to it. Though, it is a channel penalty cost, here it is assigned to the farmer and retailer for its linear additive property. If α_1 ($0<=\alpha_1<=1$) is that the fraction of the demand shortfall which will be recovered by outsourcing or external procurement, the modified profit equations of the farmer, retailer and therefore the distributor are respectively as follows:

$$z_1 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} [x_{lij} + \alpha_1 (d_{ij} - x_{lij})] c_{li} \tag{4.1}$$

$$z_3 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} [x_{lij} + \alpha_1 (d_{ij} - x_{lij})] (s_{li} - c_{li}) \tag{4.2}$$

$$z_5 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} [x_{lij} + \alpha_1 (d_{ij} - x_{lij})] (s_{li}^{*} - s_{li}) \tag{4.3}$$

Hence the coordination return is given by,

$$z_7 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} [\{x_{lij} + \alpha_1 (d_{ij} - x_{lij})\} c_{li} + \{x_{lij} + \alpha_1 (d_{ij} - x_{lij})\} (s_{li} - c_{li}) + \{x_{lij} + \alpha_1 (d_{ij} - x_{lij})\} (s_{li}^{*} - s_{li})] \tag{4.4}$$

Which simplified, we have

$$z_7 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} [(1-\alpha_1) x_{lij} + \alpha_1 d_{ij}] s_{li}^{*} \tag{4.4}$$

Therefore the coordination profit is given by

$$Maximize, Z = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} [(1-\alpha_1) x_{lij} + \alpha_1 d_{ij}] s_{li}^{*} - [\sum_{l=1}^{L}\sum_{j=1}^{n} \{\alpha_l w_{lj} + (c_{li} + t_{li}) r_{li}\} + \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} (p_{lij} + h_{lij} + mc_l) x_{lij} + \sum_{l=1}^{L}\sum_{i=1}^{m} l_{li} v_{li} + f_{li} g_{li}^{*} + w_{li}^{*} g_{li} + \sum_{l=1}^{L}\sum_{i=1}^{m} y_l u_{li}^{1} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} (u_{lij}^{2} + u_{lij}^{3}) x_{lij} + \sum_{l=1}^{L} x_l u_l^{4} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} \frac{u_{lij}^{5}}{2} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} w_{lj} u_{lij}^{6} \tag{4.5}$$

Remaining set of constraints are described in the above three non-coordinated models.

5. Solution Approach and Numerical Example

To find the solution of the formulated MILP model, we have solved the proposed model by using AMPL (AMPL

Student Version 20121021) with appropriate solver MINOS. This program has accomplished on a Core-I3 machine with a 3.60 GHz processor and 4.0 GB RAM.

To analyze the effectiveness of the present models, we consider a numerical example, which consisting 5 production locations, 5 products and 2 customers (5L-5P-2C). The deterministic demand of unit products of customers are (4600, 3150, 2550, 2870, 3500) and (5600, 2000, 2200, 4650, 2700), producer fixed costs of per unit products (in BDT) for each locations are (14400, 15400, 15300, 14500,15000), (13600, 14600, 14600, 14500, 15400), (13700, 15800, 14800, 14700, 14600), (13800, 15700, 15500, 14600, 14700), and (14500, 14600, 14600, 15500, 15400), also wholesaler fixed costs of per unit products (in BDT) for each locations are (14000, 15000, 14000, 13000,15000), (16000, 16000, 16000, 15000, 14000), (17000, 18000, 18000, 17000, 16000), (18000, 17000, 15000, 16000, 17000), and (15000, 16000, 16000, 15000, 14000) respectively. All types of information don't existent here because of its large volume. The purpose of this example is to provide a consistent logistics support to the wholesaler as well as to find the suitable feasible location for the warehouse among the given set of locations, which optimize the entire supply chain.

6. Result Analysis and Discussion

In this section, fundamental findings regarding the numerical example of the proposed models as described in Table 1. Which provide the comparative analysis of the decision variables before and after coordination for complete or partially recovered the deficit products by external sources? The percentage of the change of profit for various cases is obtained by the following formula:

$$PI(\%) = \frac{(Total\ return - Total\ investment)}{Total\ investment} \times 100$$

The individual profit of producer, retailer and distributor is calculated using the above formula.

6.1 Before coordination:

The individual profit (percentage on investment) of the producer, retailer and distributor are given as,

Producer profit= 29.91%, Retailer profit= 12.28%, Distributor profit=19.59% and Net profit= 61.78%.

6.2 After coordination:

When the value of α_1 is assumed and the problem is solved using the solution procedure, whose results are tabulated in Table 1.

Table 1: Coordinated policy with various outsourcing

S. No.	α_1	Producer profit%	Retailer profit%	Distributor profit%	Net profit%
1	0.01	**32.96**	23.42	**30.06**	**86.44**
2	0.03	30.91	25.99	34.43	91.33
3	0.05	29.70	27.42	36.95	94.07
4	0.07	28.92	28.45	38.60	95.97
5	0.09	28.35	29.20	39.75	97.30
6	0.10	28.14	29.50	40.21	97.85
7	0.30	26.40	31.95	43.79	102.14
8	0.50	29.98	32.68	44.74	103.39
9	0.70	29.73	32.97	45.18	103.88
10	1.00	**25.55**	33.21	**45.52**	**104.28**

The result shows that maximum profit is obtained for the coordinate policy when α_1=1 that is for complete outsourcing, even though the producer profit decrease. Therefore it has become possible to outsource the entire shortage beneficially. It is also observed that as the value of α_1 is increased the coordinated benefit is also increased.

The profit components of the different market players of the supply chain network are shown in Table 2.

Table 2: Net profit components of the different market players

Market players	Net profit% after coordination	Net profit% before coordination	Improvement with respect to non-coordinate policy(percentage)
Distributor	45.52	19.59	25.93
Retailer	33.21	12.28	20.93
Producer	**25.55**	**29.91**	-4.36
Coordinated benefit	**104.28**	**61.78**	42.50

The apparent loss of the producer may be completely compensated by the retailer and distributor larger gain and still the system has a coordination profit 42.50% with fully recovered of deficit products, which may be further shared to raise the individual profit higher than that of their earlier non-coordinated approach. Therefore, after coordination for complete outsourcing, the coordinated benefit is increased by 42.50%.

The profit components of the different market players of the supply chain network are shown in Table 3.

Table 3: Net profit components of the different market players

Market players	Net coordination profit% with complete outsourcing	Net coordination profit% without outsourcing	Improvement with respect to non-coordinate policy(percentage)
Distributor	45.52	26.41	19.11
Retailer	33.21	21.52	11.69
Producer	**25.55**	**34.66**	-9.11
Coordinated benefit	**104.28**	**82.59**	21.69

The apparent loss of the producer may be completely compensated by the retailer and distributor larger profit and still the system has a coordination profit with complete outsourcing is 21.69% according to without outsourcing, which may be further shared to raise the individual profit higher than that of their earlier without outsourcing coordinated approach.

Figure 1, shows that the profit before and after coordination for various market players in the relevant field. At first time, the producer profit increase in coordination method without outsourcing, but decrease with complete outsourcing. In the same time the total profit increase after coordination for both cases without and with outsourcing may be completely compensated by the retailer and distributor larger profit.

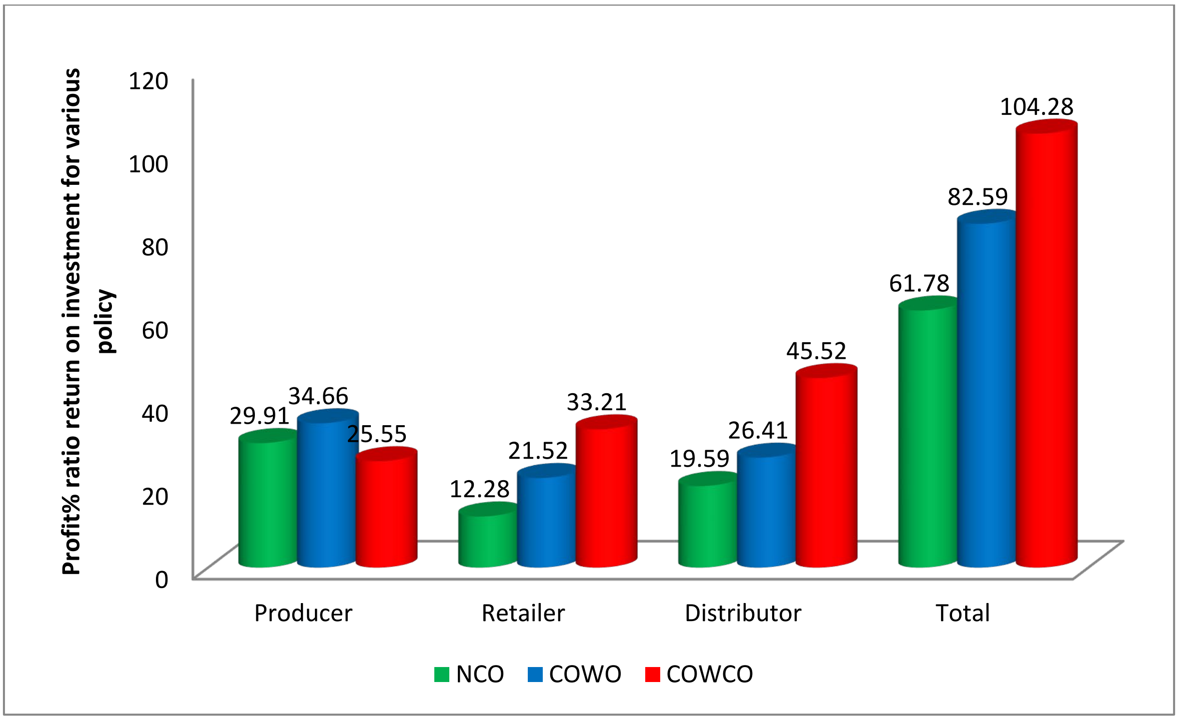

Figure 1. Profit of various market players before and after coordination

Therefore, coordination policy is the best policy for stable situation of agricultural sector in Bangladesh.

Sensitivity analysis was performed on the supply chain coordination and non-coordination model with demand and various cost uncertainty that uses the joint pricing policy. Decision variables were kept constant at the optimal level. Profit sensitivity to the demand and various cost uncertainty, when probability of demand was increased then retailer profit increased rapidly whereas producer and distributor profit increase slowly (Figure 2 and 3) before coordination (BC) and after coordination (AC). On the other hand, when various cost uncertainty increases then producer profit rapidly decrease, whereas retailer and distributor profit decrease slowly (Figure 4 and 5) both BC and AC. Also the relation of supply and demand effectively influence on profit. When demand decrease but supply increase then profit decrease (Figure 6).

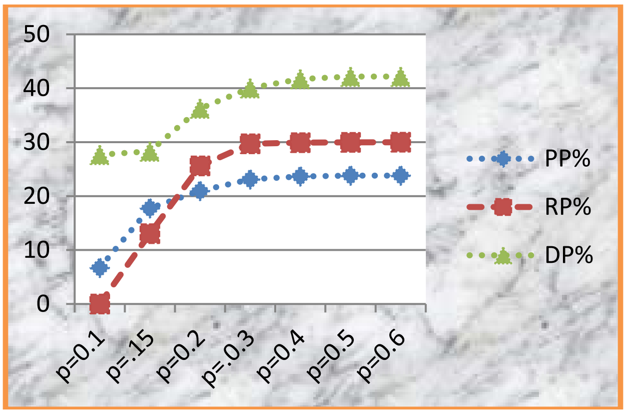

Figure 2. Profit sensitivity BC under demand uncertainty

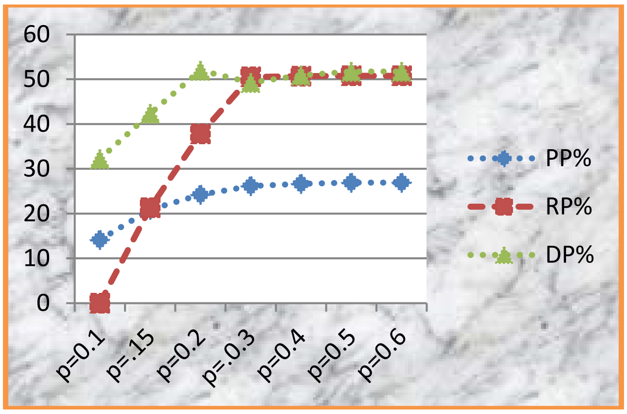

Figure 3. Profit sensitivity AC under demand uncertainty

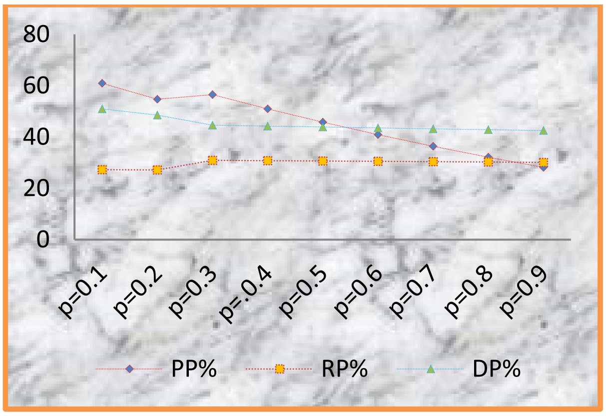

Figure 4. Profit sensitivity BC under cost uncertainty

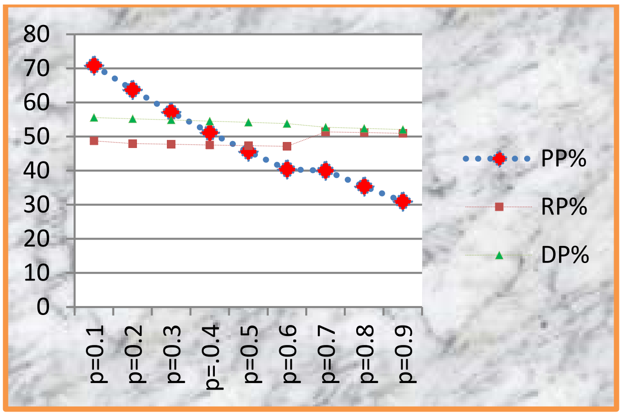

Figure 5. Profit sensitivity AC under cost uncertainty

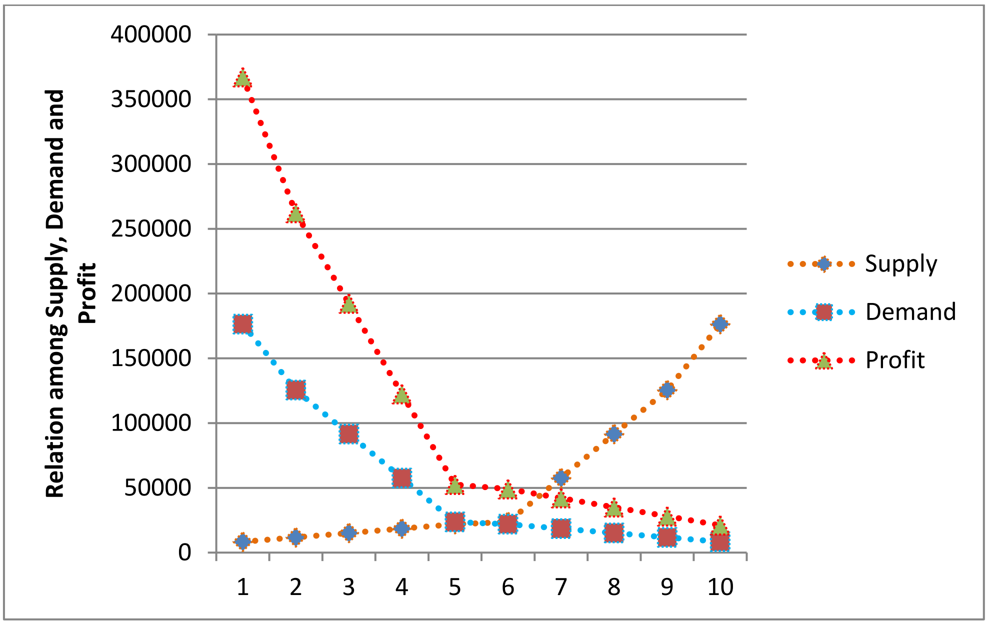

Figure 6. Profit sensitivity between supply and demands

The following figure 7-9, shows that the individual profit of producer, retailer and distributor BC and AC for demand uncertainty. When demand is increased then profit increase both BC and AC for all market players. In this case, the retailer profit increased or decreased more than the producer and distributor profit.

Profit sensitivity before and after coordination for producer, retailer and distributor under demand uncertainty described the following figures:

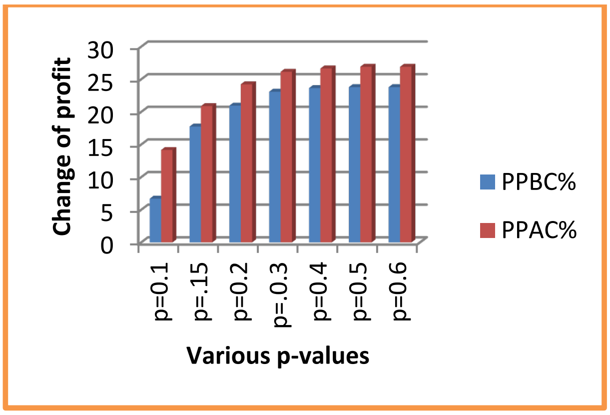

Figure 7. Producer profit sensitivity BC and AC coordination

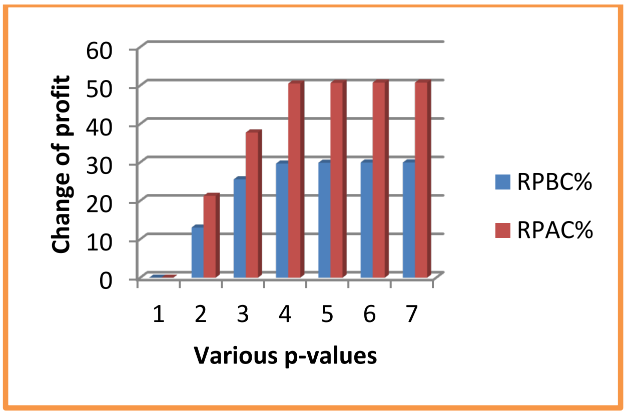

Figure 8. Retailer profit sensitivity BC and AC coordination

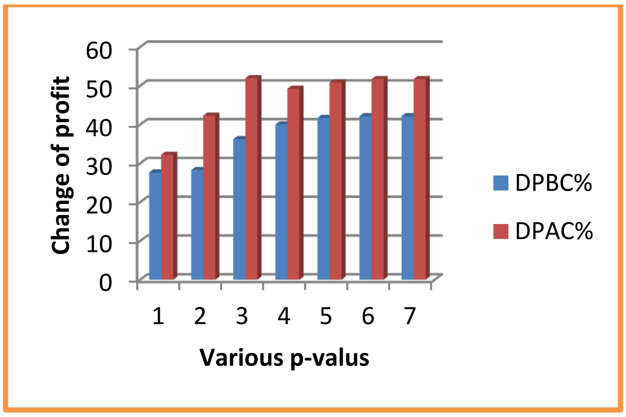

Figure 9. Distributor profit sensitivity BC and AC coordination

The following figure 10-12, shows that the individual profit of producer, retailer and distributor BC and AC for various cost uncertainty. When cost increased then profit decreased both BC and AC for all market players. In this case, cost uncertainty slightly effect on the retailer and distributor profit increased or decreased. In the same case, producer profit rapidly decreased.

Profit sensitivity before and after coordination for producer, retailer and distributor under various cost uncertainty described the following figures:

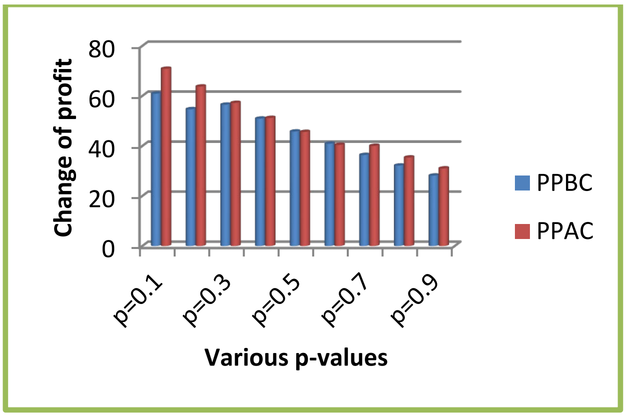

Figure 10. Producer profit sensitivity BC and AC coordination

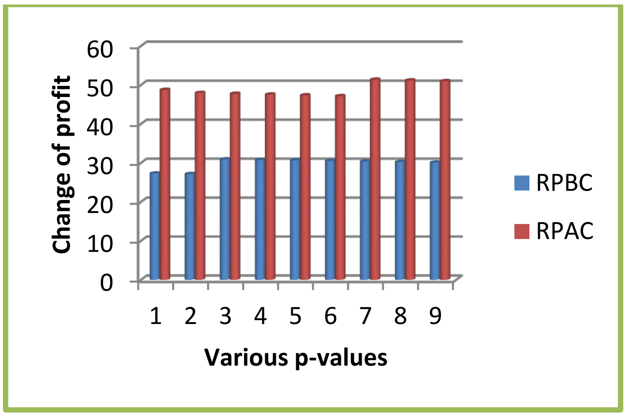

Figure **11.** Retailer profit sensitivity BC and AC coordination

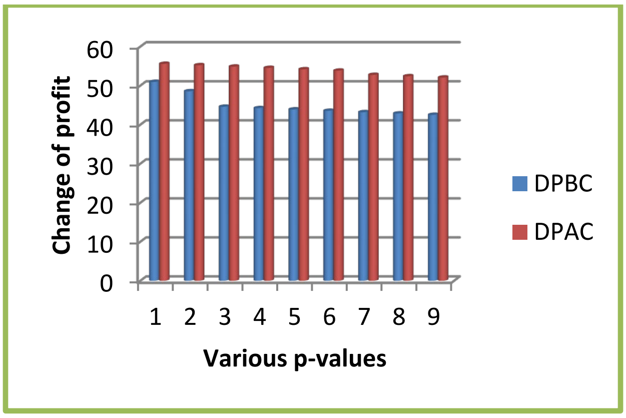

Figure 12. Distributor profit sensitivity BC and AC coordination

7. Conclusion

In this study, Four MILP based models are developed for the coordinated supply chain network and solved these models by using AMPL with appropriate solver MINOS. This paper, we assumed the insufficient production capacity of the producer as the reason for shortages; it has been shown that total coordinated profit may be improved by outsourcing. The formulated models simultaneously maximize the profit under cost and demand uncertainty. Some of the significance findings can be summarized as follows:

The illustrated numerical example shows that maximum profit is obtained for the coordinate policy when α_1=1 that is for complete outsourcing. The apparent loss of the producer may be completely compensated by the retailer and distributor larger gain and still the system has a coordination profit 42.50% with complete outsourcing, which may be further shared to raise the individual profit higher than that of their earlier non-coordinated approach. Therefore, after coordination for complete outsourcing, the coordinated benefit is increased by 42.50%. It is also observed that as the value of α_1 is increased the coordinated benefit is also increased. Therefore, after coordination for complete outsourcing, the coordinated benefit is increased by 21.69% according to without outsourcing, which may be further shared to raise the individual profit higher than that of their earlier without outsourcing coordinated approach. On the other hand, for stable situation the relation of supply and demand is very important. The demand and cost uncertainty is significant impact on profit for all market players BC and AC. In this case, cost uncertainty is the significant factor for producer more than the retailer and distributor. The work may also be expanded along a more progressive environment considering Mixed Integer Linear Fractional Programming problem.

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