THESIS – TI142307

DYNAMIC PRICING SCHEME FOR MANAGING PRODUCT SELLING ON FRUIT SUPPLY CHAIN MANAGEMENT

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SURABAYA
2017

DYNAMIC PRICING SCHEME FOR MANAGING PRODUCT SELLING ON FRUIT SUPPLY CHAIN MANAGEMENT

This thesis is composed with the expectation of getting approval from Industrial Engineering Department Graduate Program, supervisor, and examiners member of this research to fulfill the requirements for the Degree of Master in Engineering

At
Institut Teknologi Sepuluh Nopember

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Exam Date: July 19th, 2017
Graduation Period : September 2017

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Is a complete independent work of mine, completed without using any illegal information, nor the work of others that I recognize as my own work.

All cited and references are listed in the bibliography.

If it turns out that this statement is not true, I am willing to accept the consequences in accordance with the regulations.

Surabaya, July 2017
Sincerely,

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ACKNOWLEDGEMENTS

Bismillah, finally this thesis comes to its completion period. Alhamdulillah to Allah for his blessing, hence this thesis with the title **DYNAMIC PRICING SCHEME FOR MANAGING PRODUCT SELLING ON FRUIT SUPPLY CHAIN MANAGEMENT** can be completed.

This thesis is done as one of requirement in completing Master's Studies in Department of Industrial Engineering, Faculty of Industrial Engineering, Sepuluh Nopember Institute of Technology. This thesis can be completed with several favors and motivational spirit from various people. In this occasion, authors would like to present this acknowledgments and thankful give to

1. My parents, Dr. Sugeng Raharto and Prof. Yuli Hariyati, for your prayers, tears, various supports in thesis submission attempting period.
2. My sister and my brother in law, Ayu Hapsari Rahartian, S.Ak. and M. Rudy Efendi,S.T. for all support and motivation.
3. Mr. Erwin Widodo, S.T., M.Eng.,Dr.Eng. as author supervisor for his guidance, review, and guidance in order to make this thesis complete and well-delivered.
4. Prof. Ir. I Nyoman Pujawan, M.Eng.,Ph.D and Ms. Niniet Indah Arvitrida, S.T., M.T., Ph.D. as thesis examiners for their review and suggestion to make quality of this thesis better and improved.
5. Azalia Putri Cahyaning Rahmani, S.M. as external reviewer for reviewing content of this thesis is well-understood from different studies background perspectives.
6. Industrial Engineering Department Lecturers for their knowledge and framework sharing that complement several insight on this thesis completion.
7. Industrial Engineering Department Staff for preparing this thesis completion as required.

8. Friends from Master Degree of Industrial Engineering Class of 2015 for their support for this thesis completion and enrich authors knowledge.
9. All colleague and relations that cannot be mentioned one by one for their direct and indirect support for this thesis completion.

This thesis is imperfect work as well. Hence, further research to make this research area deeper is anticipated.

Surabaya, July 2017

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DYNAMIC PRICING SCHEME FOR MANAGING PRODUCT SELLING ON FRUIT SUPPLY CHAIN MANAGEMENT

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ABSTRACT

Recently fresh fruit sector is grown not only due to increasing of demand that spirited by healthy lifestyle but also requirement of quality food should be eaten daily. Its complexity make many research considered fruit in certain supply chain, called as Fruit Supply Chain (FSC). In FSC, customers tend to purchase products with a longer remaining lifetime and avoid the ones which give aging signal. Customer willingness to pay decreases once the product start to be deteriorated, which may cause slower demand for aging fruits. Consequently, retailers should enable discounted price for aging fruits products to retain or improve demand rate. Hence, a solution of this is creating price that dynamically following the condition of goods.

This research establishes pricing scheme, which is dynamic pricing to FSC. Main purpose of this research is explaining how to maximize supply chain profit by applying dynamic pricing. Remind that there is deterioration that does exist on FSC product and its customer preferences, dynamic pricing will be close to the real life particularly applied by FSC players.

A set of mathematical model is optimized on this research. It addresses dynamic pricing for FSC players to achieve better profitability. The result proves that dynamic pricing is urgent to be done. In order to avoid unsold product due to became deteriorated, FSC players can separate selling period into three periods, which are forward buying period, normal price period, and markdown price period. Moreover, there are several parameters involved on optimization has different impact on FSC profitability, where it should be thoroughly focused on by FSC players collaboratively.

Keywords: Fruit Supply Chain Management, Dynamic Pricing, Price-Dependent Demand

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CHAPTER I
INTRODUCTION

In chapter one, background of the research will be elaborated. Chapter one is consisted of research background, research question, objectives, benefits, limitations, and assumptions.

1.1 Research Background

According to Soto-silva et al. (2015), recently, fresh fruit sector is grown not only due to increasing of demand that spirited by healthy lifestyle but also requirement of quality food should be eaten daily. Based on FAO (2014), fresh fruit is defined as portion of a plant housing seeds commonly eaten as dessert. Based on that definition, fresh fruit is considered as fruit which can be consumed raw. Repeatedly, Soto-silva et al. (2015) argued that many regulation of food safety industrialization make fresh fruit should be produced by adopting good agricultural practices, automatization of sorting, selecting and packaging including sometimes some minor minimal processing tasks. Besides regulation, other factors such as globalization, competitor and customized products, make fresh fruits sector tends to be specialized and integrated vertically to become more competitive and dynamics. In this way, organizing fresh fruit under various related circumstances later called as Fruit Supply Chain (FSC).

Generally, FSC is more or less the same with other supply chains (SC). It considers various activities which are procurement, production, and distribution of fruits to the customer. Structure of FSC is not static but it can be diverse regarding the number of agents taking part in the different activities involved. It is ranging from farming processing, packaging, warehousing, transporting, distributing to marketing (Soto-silva et al. 2015). Based on several literature, FSC may be divided into several echelon. From Chen et al. (2016), that in China, fruit from suppliers or fruit producers are intermediary bridged by Facility Agriculture Enterprise (FAE) before later distributed to retailers. Based on this paper, it can be inferred that there is an existence of intermediate echelon between suppliers and retailers. Paper from

(Soto-silva et al. 2015) is on the same page with previous paper. In this paper, it is explained that fruit is sent by producers to large retailers before then distributed to smaller retailers, which are hotel, restaurant and catering companies (HoReCa), where it is also indicated that there is an existence of intermediary practices. Practices of FSC in Indonesia is indicating existence of intermediate echelon is mainly played by fruit broker which is also recognized as wholesaler, which gathers fruits from fruit producers or farmers, then resold it to retailers. Moreover, this proposed research accommodates referred research and structured Fruit Supply Chain with three echelons with flows of products and cash along supply chain.

Managing FSC is not as elementary as thought. Production fluctuation is one of challenge in fruit supply chain management. The fluctuation of agri-product, including fruits, its demand can be affected by several uncertain factors, such as weather, temperature, and customer preferences (Chen et al. 2016). The fast handling and seasonable attributes of fruits in relation to high volatility of supply and demand, make storage as critical activity to manage robust fruit supply chain management. Another challenge is about customer preferences. Fruit quality, like color, outlook appearance, and also best-before date label, become consideration aspects for customer to buy. This condition is cannot be avoided because fruit is considered as perishable goods, where deterioration does exist on perishable goods. Customers tend to purchase products with longer remaining lifetime and avoid the one which is giving aging signal. Meaning that customer willingness to pay is affected by physical condition of fruits. Customer willingness to pay decreases once the product life is approached which may cause slower demand for aging fruits. Consequently, retailers should enable discounted price for aging fruits products to retain or improve demand rate. Hence, essential consideration to preserve freshness and product quality require more limited delivery deadlines, more controlled storage conditions, and better quality of end products. Moreover, these make production, transport, and distribution planning in fruit supply chain need to be integrated in order to be optimized simultaneously. Statements explained before make FSC become more complex and harder to manage than other supply chain. (Soto-silva et al. 2015).

Challenges which mentioned in previous paragraph, forced several FSC players, which are fruit supplier, intermediary echelon (wholesaler), and also food retailer should be collaborated. Fauza & Lee (2015) commented that recently growth of research in the supply chain management had created a new way in managing inventories of a multi-echelon system. Meaning that, collaborative action should be carried by supplier, manufacturer, and also retailer, by determining the optimum order quantity to maximize supply chain revenue. Nevertheless, Wang et al. (2014) stated that integrated or coordinated pricing and lot sizing decision has been known to be crucial in supply chain management. Effective decision can potentially decrease conflicts among different tier of supply chain and improve its performance by reducing opportunity losses caused by separate decision. In another literature, (Yaghin et al. 2012) argued that both pricing and inventory decisions need to be made, where price decision is used to control demand side, while inventory replenishment is used to control supply side. For short life cycle products, dynamic pricing and ordering decisions are useful due to dynamic changing of market demands, in order to obtain maximum cumulative profit from the product during its lifecycle.

Based on discussion of way to overcome challenge in FSC from several referred papers, next step is finding another referred papers which elaborated joint inventory and pricing techniques for overcoming challenge in managing deteriorative items. First related paper is from Chen et al. (2016) that proposed joint inventory scheme, which consider the EOQ/EPQ of agri-fresh product (fruit) should be integrated and considering stochastic demand and also randomness of the market demand, deteriorative characteristic of perishable goods, and other realistic factors are included. The values of EOQ and EPQ are calculated by minimizing total cost. The total cost includes order cost, shortage cost, holding cost, and purchasing cost, where purchasing cost can be divided later into deterioration cost and sales cost. Another preliminary research done by Fauza & Lee (2015) considered revenue-based approach to determine supply chain profit for handling perishable products on two echelon fruit supply chain. This research proposed a better model, indicated by gathering better supply chain profit, which challenged model from its referred literature. Latest research done by Maiti & Giri (2016), proposed two period pricing scheme under optimization modelling on two echelon on short life cycle products supply chain. Different from two preliminary studies, this research compared supply chain profit under different sales period and pricing scheme on short life cycle products such as electronic devices. Generally, an analogy can be made by comparing electronical devices and fruits. Electronical devices price is changed based on technology advances. In example, launching of Samsung S6 in the early period, yields high revenue for Samsung. Then, when Samsung S7 launched by Samsung with updated technology which can be consider better than preliminary model, which is Samsung S6, it will make Samsung S6 enter a new period of sales with lower price than before. Moreover, people might say that preliminary model such as Samsung S4, S5, and S6 considered as an obsolete products due to existence of the latest product, Samsung S7. This condition is more or less the same with fruits. Fruits, which on its good condition, it will yield higher revenue for seller due to huge customer willingness to pay. Once the deteriorative period began, the price will be decreasing. Hence, this research can be applied on FSC, that later considered as referred literature for proposed research.

This proposed research are in between research of Fauza & Lee (2015) and Maiti & Giri (2016). Main purpose of this research is explaining how to maximize supply chain profit by applying dynamic pricing, which is close to Maiti & Giri (2016). While FSC scheme and consideration of deteriorative period, is more related to Fauza & Lee (2015). Two scenarios between using single period pricing and three period pricing between supplier and wholesaler will be modelled and simulated using certain parameters, to compare supply chain profit gathered by those two scenarios. Last but not least, sensitivity analysis will be done for complementary analysis for this proposed research. Detailed modeled will be explained thoroughly in chapter four. This proposed model will be beneficial for giving insight that collaborative action that led to better supply chain profit is urgently adopted for organizing fruit supply chain. Moreover, topic brought by this research, which is dynamic pricing, is close to real life activities. In example, bottling company applies dynamic pricing for their vending machine, when in sunny day selling period, price of one bottle of cold drink might be more expensive than in cloudy day. Changes of price is enabled by censors embedded in their vending machine.

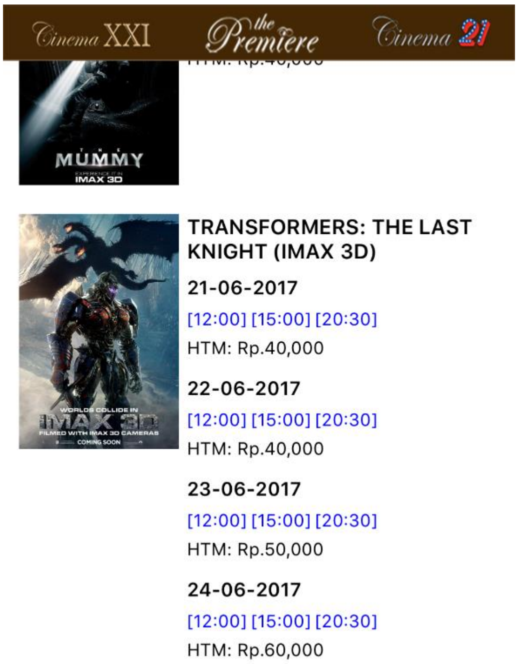


Figure 1.1 Cinemas Dynamic Pricing

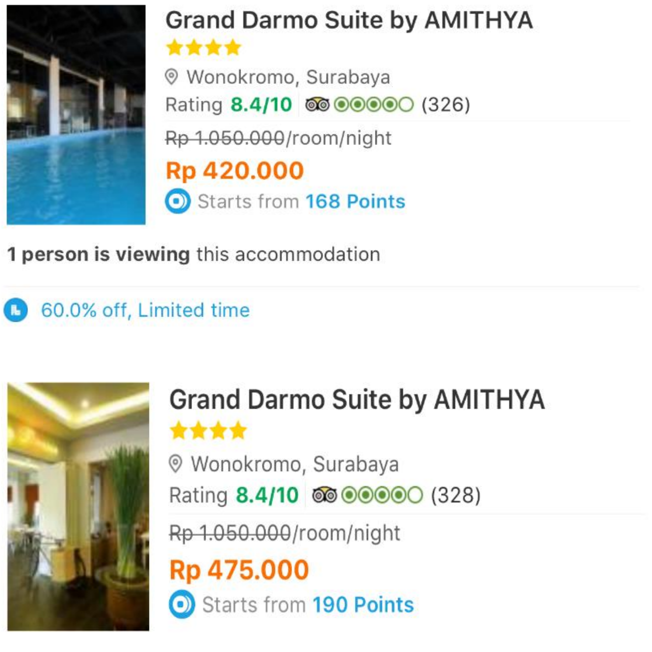


Figure 1.2 Hotel Dynamic Pricing

In Indonesia, several evidences prove that dynamic is well received in business areas. Based on Figure 1.1 presented above, known that there is a differences of ticket price. Ticket price on weekdays, which 21 – 22 june is considered as weekdays is been attached with lower price than 23-24 which considered as weekend that offer higher price to customers. Cinema Company tend to charge more on the weekend as markup price to yield more profit.

Another example from Figure 1.2, known that dynamic pricing is also applied on tourism sector. Grand Dharmo Hotel offer Rp 420,000 for standard room on weekdays. While on the weekend, Grand dharmo charge more money for the same type of room, which was Rp 475,000. This price is offered by hotel wholesaler, which is can be assumed there is preliminary agreement or might be forward buying of selected hotel. Hence, wholesaler could play the prices to customer, which dynamic pricing already well operated on this circumstances. Then there is question showed up, whether that scheme can also be applied to fruit entity scheme. This researched will answer that question comprehensively and observe throughout its supply chain as system and also on echelon level. Later, it will make this research interesting to be presented.

1.2 Research Question

Research question is desirable question that can be achieved by doing this research. There are three research question for this research, which are:

1. How to construct mathematical formulation and present dynamic pricing model for three echelons fruit supply chain?
2. How to select the most suitable dynamic pricing scenario and define threshold price for forward buying, normal, and markdown price on three echelon fruit supply chain?
3. How to identify the most sensitive parameter on three echelon fruit supply chain profitability with price-dynamics scheme?

1.3 Objectives

Objectives are things will be focused to achieve by conducting this research. There are three objectives from this research, which are:

Presenting different dynamic pricing scenario model of FSC with intermediary echelon.

Formulating mathematical model for each scenario for dynamic pricing, which are forward buying price, normal price, and also markdown price.

Applying optimization model under different pricing scenario with several considered parameter values for comparing which more profitability scenario on FSC scheme.

Presenting sensitivity analysis on several parameters included in mathematical model to present which parameter is most sensitives to three-echelon fruit supply chain profitability.

1.4 Benefits

Benefits are things will be achieved by conducting this research. There are several benefit from this research, which are benefit for researcher and benefit for company (object).

1.4.1 Benefit for Researcher

There are several benefits for researcher by conducting this research, which are:

1. Learn new knowledge in fruit supply chain management scheme.
2. Contribute engineering research in fruit supply chain management.
3. Initiate usage of price dynamic on multi echelon fruit supply chain model.

1.4.2 Benefit for Company (Object)

There are several benefits for company (object) by conducting this research, which are:

1. Understand effect of initiating dynamic pricing, which are forward buying, normal, and markdown price on fruit supply chain.
2. Assist fruit supply chain players to commit on collaborative action to achieve supply chain profit.

1.5 Limitations

Limitation is boundary of this research. There are several limitation on this research, which are:

1. Multi echelon in this research only considering one supplier, one manufacturer, and one retailer.
2. Commodity in this research is only one product (single product).

1.6 Assumption

Assumption is aspect that did not measure and affect to this research. There are several assumption used in this research model, which are:

1. Production rate in supplier or farmer are constant.
2. Demand rate in farmer, wholesaler, and retailer is linear.
3. Lead time is considered as zero.
4. Inventory is not considered on this scheme.
5. Demand is always positive (no backorder or shortages allowed).
6. Supplier act as Stackelberg leader where wholesaler and retailer acted as followers.
7. Dynamic Pricing scheme using one farmer, one wholesaler, and one retailer.

CHAPTER 2
LITERATURE REVIEW

In chapter two, literature review of the research will be elaborated. Chapter two is consisted of compilation of keywords that related with this research.

2.1 Supply Chain Management

Supply Chain Management (hereafter SCM) has different definition on different literature. Simchi-Levi (2008) define supply chain management as set of approaches utilized to definitely integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements.

In other reference from Chopra, Meindl (2007) stated that supply chain consisted of all parties involved, directly, or indirectly, in fulfilling a customer request, such as manufacturer, suppliers, transporter, warehouse, retailers, and even customer. It contained several function, which are new product development, marketing, operation, distribution, finance, and customer service. Objective of every supply chain should be to maximize overall value generated, where value is mostly correlated with supply chain profitability.

Langley (2009) stated on his book that supply chain management represented the third phase of an evolution started in 1960s with the development of physical distribution concept that focused on outbound side of a firm's logistic system. Focus of physical distribution is on total system cost and analyzing tradeoff scenarios to arrive at the best or lowest system cost. Hence, separately supply chain management can be viewed as a pipeline or conduit for the efficient and effective flow of products/materials, services, information, and financials from supplier's supplier through various intermediate organizations/companies out to customer's customer. Moreover, supply chain also can be defined as system of connected networks between the original vendors and ultimate final customer. Another perspective of supply chain that is an extended enterprises that crosses the boundaries of individual firms to span related activities of all the companies involved in total supply chain, which should execute three type of flows, which are flow of goods/services, information flow, and financial flow.

Based on three literature explained above, there are several points that can be inferred from definition of supply chain management. First point is integration. Integration among echelon along supply chain is issues that focused by SCM. Second point is goods delivered. Goods, where it can be as products or services, become the entity that elaborated on SCM. Later, way to process and delivered goods along supply chain become an issue on SCM. Third is objective. Outcome of doing supply chain management is achieving goal set by echelons involved on supply chain, where it can be minimized cost or maximized supply chain profitability. In addition, Lee et.al (2016) stated that to successfully adopt SCM Philosophy, strategic and operational objectives should be set by echelons who involved and done supply chain practices. Strategic SCM is set of activities that concern about strategic activities, which are focused on long-term decision and effort to achieve SCM objective. In the other hand, operational objectives, which is referred to tactical activities, which breakdown strategic objectives into workable tasks done on daily, weekly, or monthly projects to ensure strategic objectives can be achieved. Nowadays, many technical aspects intersects with SCM philosophy. In example, intersection between sustainability and supply chain, resulted new SCM research area which is called by Sustainable Supply Chain Management (SSCM). Another example intersection between risks management and supply chain, gathered a new model of supply chain called Supply Chain Risks System (SCRS). In this proposed research agriculture technical aspect, for handling perishable fruit is intersected with supply chain created another research area on supply chain, which is called by Fruit Supply Chain (FSC) that will become research area on this research.

2.2 Fruit Supply Chain

Based on subchapter 2.1, it can be inferred that supply chain can intersect with another technical aspects. On this subchapter, fruit supply chain will be elaborated as research area on this proposed research, where fruit supply chain is coming from intersection between supply chain and fruit entities from agri-food products. Food and Agriculture Organization (2014) defined fresh fruit itself as portion of a plat housing seeds commonly eaten as dessert. Based on Akhtar et al. (2016), on its research stated that fruit is considered as part of agri-food products which is another example of the products are dairy, meat, fruit, and vegetables. In another literature from Akbari Kaasgari et al. (2017) stated that fruit and vegetables considered as perishable products, where its value decreased during time, deviated from its normal and expected performance.

In last 10 years, agri-food industry, especially fresh fruit sector have recognized and started embracing SCM as a key concept for its competitiveness. It strengthen by the fact that demand of healthy food, where fruits and vegetables included, is increasing (Soto-silva et al. 2015). The obstacle to fulfill the demand rate came from fast handling and seasonable attribute of fruits. Fruits and vegetables have a very short life and are the most perishable agricultural produce (Balaji & Arshinder 2016). Consequently, due to its short life, fruits will suffer quality degradation and deterioration rate that effect quality of fruits. Hence, effort to preserve freshness and product quality related with sweetness, crunchiness, and strength needed special consideration for preparing better delivery, storage controlling, and minimizing losses due to deterioration. Moreover, globalization, competitors, regulations, customized products, make fresh fruit sector tend to be specialized and integrated vertically in Fruit Supply Chain (FSC).

Structure of FSC is different from literature to another literature. From Akhtar et al. (2016) explained that FSC normally consists of farmers, processor/wholesalers, retailers and consumers. Nevertheless, bigger FSC can enable another echelon to be involved such as chemical dealers, input suppliers, and transport or logistics parties. Importer and exporter can also involve in international or global agri-food supply chains. In other literature written by Bao et al. (2012), there are 13 entities played on fruit supply chain in China. Then, the author categorized all entities into several groups, first is cropper planters, who has responsibility to produce fruits on FSC. Second group is broker, which consisted of individual brokers, partnership brokers, broker companies, and another similar companies, whose role is intermediaries or agents in FSC. Third is agricultural product wholesale market that consisted of retailer that sold fruit in FSC. In line with previous literature, Chen et al. (2016) also stated an existence intermediaries echelon on FSC in China, which named Facility Agricultural Enterprises (FAE). Hence, it can be inferred from reviewed literature, that FSC consisted of first echelon who responsibled for planting fruits, later called as farmer. Second echelon is intermediary echelon, who responsible for bridging between farmer into third echelon, which is echelon who responsible for selling fruits, and it is called seller. The configuration of FSC presented on Figure 2.1 below

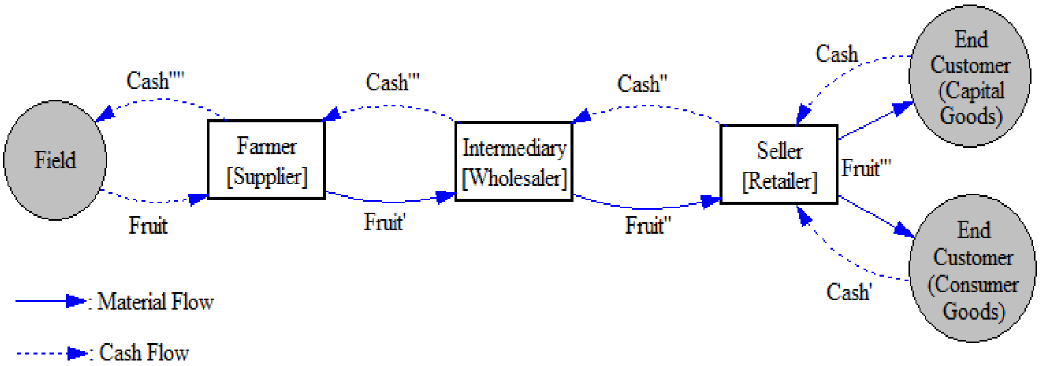


Figure 2.1 Fruit Supply Chain Scheme

Based on Figure 2.1 shown above, there are four echelons directly involved in Fruit Supply Chain. First is Farmer. Farmer acted as a supplier who had money invested to the plantation to produce fruit to be sold to manufacturer. Next is Intermediary Echelon that also act as wholesaler who bought fruit from supplier in bulk. Later, Intermediary Echelon unitized fruits then sold it to retailers. Third echelon is seller who acted as retailer as well. From unitized fruits, retailer do another unitizing for fruits into various packaging fruits which later to be sold to end customer. Customer itself, can be divided into two groups of customer based on the function. First is end customer with capital goods, that used fruits as entity to be sold later to another customer, and last but not least, end customer with consumer goods, who directly consumed the fruits into dispose.

2.3 Dynamic Pricing

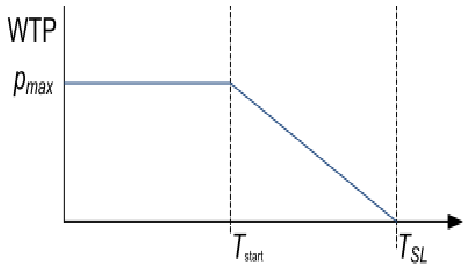
Based on subchapter 2.2, one underlined message can be inferred that handling fruit in supply chain become harder since short life, degradation, and deteriorate rate properties of fruits. Because of its properties, Wang & Li (2012) stated that quality of fruit can be considered as dynamic state due to its quality decreased continuously until the point that fruit become unfit for sale. Hence, fruits should be sold before spoil to ensure its safety and quality while maximizing profit. It is strengthened by statement from Cai et al. (2013) that in fruit supply chain, customers are sensitive to both retail price and level of freshness of the product.

Overcoming challenge mention in previous paragraph, many research insisted inventory control as solution. Inventory control for perishable products has been given much attention on inventory literature because of its existence in many studies (Wang & Li 2012). In another literature, (Yaghin et al. 2012) argued that for short life cycle products, dynamic pricing and ordering decisions are useful due to dynamic changing of market demands, in order to obtained maximum cumulative profit from the product during its lifecycle. Dynamic pricing is commonly found on topic of revenue management and demand management. Simchi-Levi (2008) stated differential pricing on revenue management in smart pricing chapter on his book. On this book, differential pricing is differed into several types, there are group pricing, channel pricing, regional pricing, time-based differentiation, product versioning, and coupons and rebates. Dynamic pricing is closed to idea of time-based differentiation, which company can charge at different cost on different periods. Consequently, he stated that dynamic pricing is suitable to be applied under condition of demand variability and seasonality in demand pattern. Aligned with previous explanation, Chopra stated that revenue management adjusted pricing and available supply of assets to maximize profits within several condition, which are products are highly perishable and has seasonal demands. Both explanation from Simchi-Levi and Chopra strengthened proposed idea that dynamic pricing also can be applied on fruit entities, which had properties of perishable and seasonal.

Demand variability is often explained under issue of demand management. Demand management is useful for distributing demand pattern. Pujawan on his online lecture session, gave an example that Indonesian communication privateowned company, applying different telephone call rate and offered various promotional like internet quota in the morning to afternoon, where the demand is lower in that period compare to afternoon to midnight. This term had an objective to move demand into earlier stage, which is often called as forward buying. Maiti & Giri (2016) gave another example that airline or lodging companies charge more on peak season than low season due to high demand. Repeatedly, in their research, dynamic pricing is applied for short-life cycle products, which is electronical devices. Mention in introduction section, electronical devices, such as cell phone, its life cycle become shorter when latest type of cell phone entered the market. Customer tend to purchase newer type of cell phone previous type of cell phone still on market, as long as the tradeoff cost is matched. This condition, is similar to fruit circumstances on its market. Wang & Li (2012) stated that when the prices are the same, customer preferred to buy newly replenish goods instead of expiring ones, hence retailers should do markdown pricing for expiry product to remain selling it. But none of research try to persuade pricing technique for fruit supply chain. Therefore, this proposed research tried to fill the gap of existence of research on dynamic pricing technique for fruit supply chain.

2.4 Mathematical Model

Mathematical model are widely used in many research. Each research presented different approach on its mathematical model. Research done by Fauza & Lee (2015), presented non-linear programming for overcoming challenge on deteriorative products supply chain. Objective of this research is finding better model to achieve supply chain profit compare to model from preliminary research that referred by the author. Approach of this paper is how to demonstrate joint inventory, both production and replenishment policy, which should be done for handling products with outdated periods. One of exciting point from this research, besides presenting on joint inventory approach, it also has insight on pricing, which is assumed declined gradually refers to time increment.



$$p(t)=\begin{cases} p_{\max} & 0 \le t < T_{start} \\ \dfrac{p_{\max}}{T_{SL}-T_{start}}\left(T_{SL}-t\right) & T_{start} \le t < T_{SL} \\ 0 & t \ge T_{SL} \end{cases} \quad (2)$$

Figure 2.2 Pricing Scheme Geometrical and Mathematical Scheme (Fauza & Lee 2015)

Based on Figure 2.2, it showed that price will be gradually declined after *Tstart* which refers to time when products enter its outdated period followed by decreasing of customer willingness to pay. Therefore, it is clearly elaborated by mathematical formulation that price is sensitive of outdated period. Price of product will be on normal price before *Tstart*, once product entering outdated period, price will start declining until zero value when products remain unsold over products shelf life.

Another research done by Chen et al. (2016), presented mathematical model more thoroughly. Pressure point of this research is on inventory scheme, respect to replenishment mechanism considering type of demand. Interesting insight from this research is the author demonstrated replenishment policies refers to different demand, which are deterministic and stochastic demand on FSC in China. In China FSC, there is an existence of intermediary echelon, has role as bridge between fruits supplier and reseller called Facility Agriculture Enterprises (FAE). Hence, FAE has responsibility to optimize and control products from supplier can fulfill retailer needs to fulfill demand. The objective of this research is proposing replenishment model with appliance of EOQ and EPQ mathematical models for deteriorative products with constant deteriorate rate assumption. Solution technique applied on this research is system dynamics, which showed by Figure 2.3, where it is possible to be implemented for propose research, however a different approach is needed.

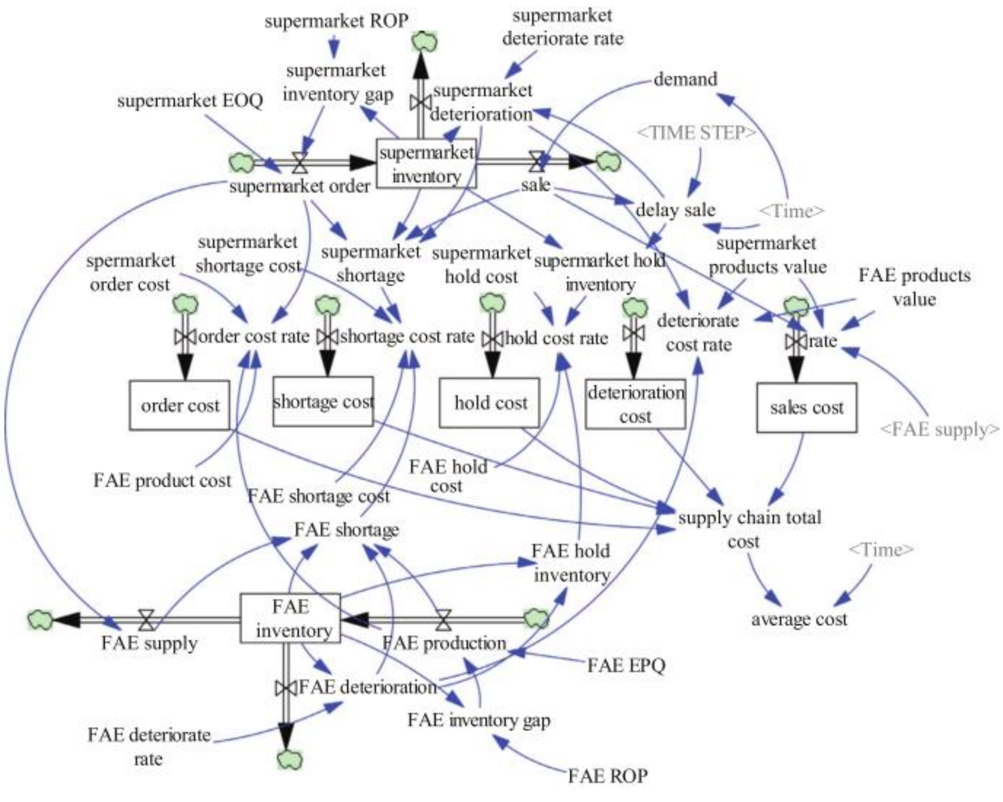


Figure 2.3 Stock and Flow Diagram of China Fruit Supply Chain (Chen et al. 2016)

Late published research done by Maiti & Giri (2016) expound a different perspective on contribute to supply chain research. While many research focused on inventory aspect for deteriorative products, like two previous research explained before, this research notice pricing technique being one of solution technique besides inventory optimization for fruit supply chain. Mention in earlier chapter, urgency of collaborative action along supply chain for handling deteriorative items such as fruits in order to yield supply chain profit, the author of this research demonstrate achieving better supply chain profit by enabling period-based pricing in products with obsolete period.

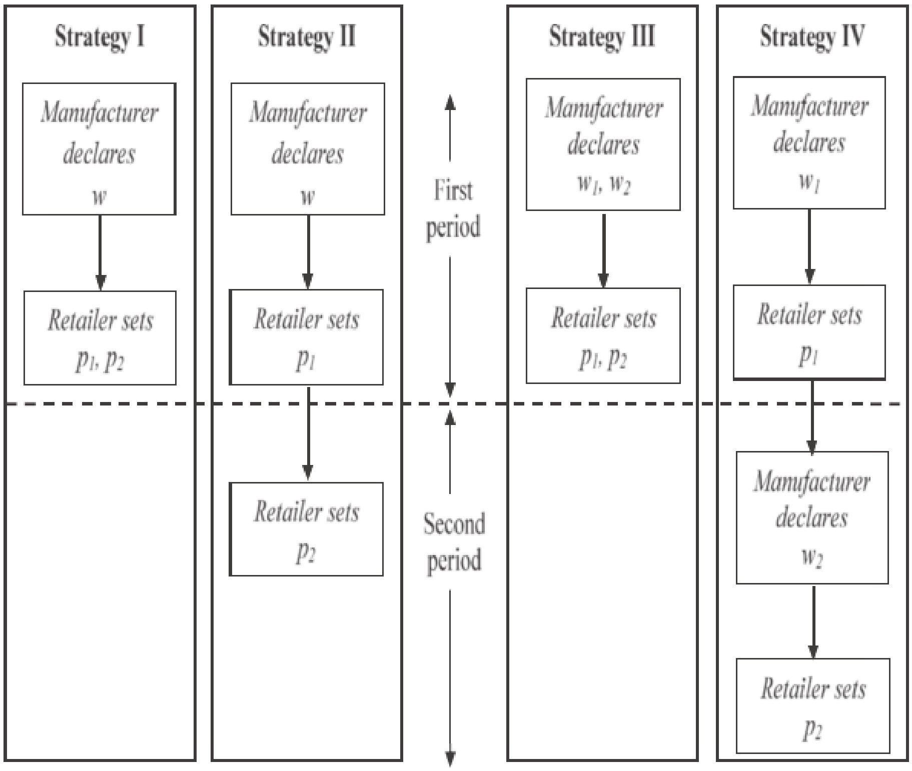


Figure 2.4 Pricing Strategies Scheme (Maiti & Giri 2016)

Shown by Figure 2.4 above, pricing strategy is enabled between two echelons, which are manufacturer and retailer. There are various pricing strategy, which price can be directly optimized in one period or price can be optimized on two different period. In strategy one and three, price is optimized on first period, where in strategy one, manufacturer declare its price, then retailer set its first and second price simultaneously. While in strategy three, manufacturer and retailer declare price separately between first price and second price, but it held on the first period.

Nevertheless, on strategy two and four price is optimized twice, where on first period, manufacturer declare its price, then retailer set its first period price, later on second period, retailer re-optimize the price refers on market situation on that period. Last but not least, both manufacturer and retailer determine their first price on first period then optimize their second price on second period. Game theory is applied as mathematical model to support strategy scenarios on its research, where price on manufacturer level, retailer level, and supply chain profit are the entities that optimized on its research.

$$p_1^c = \frac{\alpha(2\beta+3\gamma)+(\beta+\gamma)(2p_0\gamma+c(2\beta+\gamma))}{(2\beta+\gamma)(2\beta+3\gamma)},$$
$$p_2^c = \frac{p_0\gamma^2+c(2\beta+\gamma)(\beta+2\gamma)+\alpha(2\beta+3\gamma)}{(2\beta+\gamma)(2\beta+3\gamma)},$$
$$\Pi^c = \frac{2\beta(\alpha-c\beta)^2+(\alpha-c\beta)(3\alpha-5c\beta+2p_0\beta)\gamma+(c-p_0)(-3\alpha+4c\beta-p_0\beta)\gamma^2+(c-p_0)^2\gamma^3}{(2\beta+\gamma)(2\beta+3\gamma)}.$$

Figure 2.5 Example of Game Theory Formulation (Maiti & Giri 2016)

The proposed research will accommodate mathematical formulation concept on multi-echelon fruit supply chain under decentralized scheme, where intermediary echelon act as stackelberg leader for retailer. From mathematical model used on previous explained papers, mainly two echelon analyzed on its research which are supplier and retailer, while on this proposed research, three echelon will be configured due to existence of intermediary echelon on fruit supply chain structure, therefore there will be supplier, wholesaler, and retailer involved. Moreover, proposed research will elaborate period-pricing effort for selling fruits along supply chain, where research done by Maiti & Giri (2016) applying two-period pricing, this proposed research try to present three-period pricing, where forward buying, normal price, and markdown pricing scheme are applied. Hence, mathematical model for proposed research will be optimized using Matlab with modification of FMINCON function to solve the problem.

2.5 Research Position

This research topic is inspired by recent issues which are dynamic pricing applied in various area also the progression of supply chain research which concern about perishable goods. Then, papers from various journal are collected, and about 11 papers are sufficiently close to be reviewed and related to the topic. Collected papers are presented in table below.

Table 2.1 List of Reviewed Papers

NUMBER	REVIEWED PAPERS
[1]	Maiti, T. & Giri, B.C., 2016. Two-period pricing and decision strategies in a two-echelon supply chain under price-dependent demand. , 0, pp.1–20.
[2]	Fauza, G. & Lee, S., 2015. A Vendor-Buyer Inventory Model for Food Products Based On Shelf-Life Pricing. , 8(2), pp.67–73.
[3]	Chen, W., Li, J. & Jin, X., 2016. The replenishment policy of agri-products with stochastic demand in integrated agricultural supply chains. *Expert Systems with Applications*, 48, pp.55–66.
[4]	Soto-silva, W.E. et al., 2015. Operational research models applied to the fresh fruit supply chain. *European Journal of Operational Research*, 0, pp.1–11.
[5]	Cai, X. et al., 2013. Fresh-product supply chain management with logistics outsourcing. *Omega (United Kingdom)*, 41(4), pp.752–765. Available at: http://dx.doi.org/10.1016/j.omega.2012.09.004.
[6]	Chen, T., 2015. Computers & Industrial Engineering Effects of the pricing and cooperative advertising policies in a two-echelon dual-channel supply chain. *COMPUTERS & INDUSTRIAL ENGINEERING*, 87, pp.250–259. Available

NUMBER	REVIEWED PAPERS
	at: http://dx.doi.org/10.1016/j.cie.2015.05.013.
[7]	Roy, A., Sankar, S. & Chaudhuri, K., 2016. Computers & Industrial Engineering Joint decision on EOQ and pricing strategy of a dual channel of mixed retail and e-tail comprising of single manufacturer and retailer under stochastic demand. *Computers & Industrial Engineering*. Available at: http://dx.doi.org/10.1016/j.cie.2016.05.002.
[8]	Cárdenas-barrón, L.E., González-velarde, J.L. & Treviño-garza, G., 2015. Computers & Operations Research A new approach to solve the multi-product multi-period inventory lot sizing with supplier selection problem. *Computers and Operation Research*, 64, pp.225–232. Available at: http://dx.doi.org/10.1016/j.cor.2015.06.008.
[9]	Topan, E., Bayındır, Z.P. & Tan, T., 2016. PT US CR. *European Journal of Operational Research*. Available at: http://dx.doi.org/10.1016/j.ejor.2016.06.012.
[10]	Astuti, R. et al., 2013. Risks and Risks Mitigations in the Supply Chain of Mangosteen: A Case Study. , 6(1), pp.11–25.
[11]	Udenio, M., Fransoo, J.C. & Peels, R., 2015. Destocking, the bullwhip effect, and the credit crisis: Empirical modeling of supply chain dynamics. *International Journal of Production Economics*, 160, pp.34–46. Available at: http://dx.doi.org/10.1016/j.ijpe.2014.09.008.

Review process of each papers is examining paper with several criteria. Several criteria for examining are methodology used by paper, research area of each paper, main contribution, drawback, and also relevance score of reviewed papers. Reviewed papers are presented on table below

Table 2.2 List of Reviewed Papers

#	METHO-DOLOGY	RESEARCH AREA	MAIN CONTRIBUTION	RESEARCH DRAWBACK	RELE-VANCE SCORE
[1]	Game Theory Approach	Short Life Cycle Product Supply Chain	Present reference price on difference selling period	Extend Period on pricing dynamics	8
[2]	Non-Linear Programmin g	Perishable Food Supply Chain	Present improved model to yield better supply chain profit	Dynamic Pricing insight on perishable goods	7
[3]	Dynamic Modelling	Fruit Supply Chain	Provide stochastic demand on joint inventory	Optimal proportion of market backorder	7
[4]	Literature Review	Agri-Fresh Supply Chain	Show Various OR techniques applied in Agri-Fresh Supply Chain	Extend OR Perspectives	6
[5]	Game Theory	Fresh-Product Supply Chain	Presenting Scenarios for optimizing outsourcing logistics service	Only focus on centralized supply chain	5
[6]	Game Theory	Dual Channel Supply Chain	Presenting effect of cooperative advertising in supply chain profit	Focus on financial statement due to effect of advertising	5
[7]	Game Theory	Dual Channel Supply Chain	Presenting Joint inventory on dual channel under stochastic demand	Short of financial analysis	5
[8]	Game Theory	Short Life Cycle Product Supply Chain	Impact of inventory policies on financial condition	Short of analysis on different prices scheme	5

#	METHO-DOLOGY	RESEARCH AREA	MAIN CONTRIBUTION	RESEARCH DRAWBACK	RELE-VANCE SCORE
[9]	Heuristics	Fast-Moving Products Supply Chain	Modelling inventory optimization for multi-item	Short of financial analysis	5
[10]	Fuzzy AHP, ISM	Fruit Supply Chain	Risk Mitigation on Fruit Supply Chain	Sensitivity Analysis of Model	5
[11]	Dynamics Modelling	Food Supply Chain	Explain a large part of demand dynamics credit to crisis	Simulated data combination across supply chain	5

= Benchmark Paper

Based on table 2.2, game theory are mostly applied when handling multi-echelon supply chain. Moreover, year published of most of papers applying game theory as solution technique, indicates that game theory is one of recent issue on multi-echelon supply chain. Therefore, most of papers are concerned about joint inventory, while dynamic pricing still lack of paper which concerned about.

Last but not least, fruit supply chain still rarely to be focused on research area of supply chain. Although, short life cycle product and also deteriorative items are begun to be concerned on several papers. Hence, the proposed research that concern about dynamic pricing on fruit supply chain with game theory approach is interesting and valuable to be executed.

Next, based on table 2.2 as well, there are highlighted papers which chosen to be benchmark paper and referred for the proposed research. Table below will present position of proposed research compare to highlighted papers.

Table 2.2.3 Research Position Tabulation Mapping

#	AUTHOR	YEAR	TYPE OF MULTI-ECHELON SUPPY CHAIN		METHOD		POLICY		
			Two Echelon	Three Echelon	Non-Linear Approach	Game Theory	Shelf-life based Pricing	Two Period Pricing	Third Period Pricing
1	Maiti, T. & Giri, B.C., 2016. Two-period pricing and decision strategies in a two-echelon supply chain under price-dependent demand. , 0, pp.1–20.	2016	√			√		√	
2	Fauza, G. & Lee, S., 2015. A Vendor-Buyer Inventory Model for Food Products Based On Shelf-Life Pricing. , 8(2), pp.67–73.	2015	√		√		√		
3	***Proposed Research***	2017		√		√			√

As shown above, proposed research is clearly to see differ from another two referred papers. First difference is proposed research will do study on three echelon in fruit supply chain, where intermediary echelon does exist, whereas referred paper are limited to two echelon. Second difference is the proposed research try elaborate third period pricing circumstances, where forward buying, normal pricing and markdown pricing are applied. In the other hand, first paper only present two-period pricing. While type of demand with two referred papers is the same, which is using deterministic demand. Last but not least, method used in this proposed research is the same with first paper, which is using game theory approach as solution technique to answer its research questions.

CHAPTER 3
RESEARCH METHODOLOGY

In chapter three, research steps will be elaborated. Chapter three consists of subchapters which are related to research design.

3.1 Designing Scenarios and The Mathematical Model

First step of research flow is designing scenario and mathematical model. After papers reviewing process that has been done and elaborated in previous chapter, and also research question has been established in the first chapter of this research, scenario must be built to encounter listed research question. Scenario of this research is the extended version from referred paper from (Maiti & Giri 2016), where this research will accommodate three periods pricing compare to two periods pricing from referred paper. Moreover, this research try to create two scenarios to compare fruit supply chain profitability whether using dynamic pricing and non-dynamic pricing.

Mathematical model will construct based on several literature review, which is deploying game theoretic mathematical formulation. This mathematical formulation later to be optimized using script on Matlab. There are several outcomes on formulation, which are dynamic price on each echelon (supplier, intermediary echelon, retailers) and supply chain profit. Mathematical formulation modification is applied on this research based on formulation in referred paper, which it is applying two periods and two echelons, while in this research will formulate fruit supply chain consists of three echelon on its chain, and also three prices applied on each echelon.

3.2 Data Collection Process

Second step is collecting data. Finding an outcomes of this research needed certain parameters value to be calculated by mathematical formulation. Data can be found by directly using primary research or indirectly using secondary data based on referred paper. This research will use secondary data to gather certain parameter values which are product cost (c), base demand (α), latest price correction (β), and also price changes review (γ). Value of these parameters will be taken from referred paper, that is (Maiti & Giri 2016) with modification.

3.3 Model Testing

Third step is model testing. The model testing begins by creating script by deploying mathematical formulation on Matlab. There are several steps on creating script, which are constructing nonlinear constraint group, linear constraint group, and objective function group. On each constraint group, dummy number is computed to check the normality of response. Then, dummy number is also used to check the normality of whole script and its ability to represent the problem formulated. If model testing process does not succeed, mathematical model should be redesigned. Geometrically this process will be well understand by using flowchart graph later.

3.4 Optimization Process

Model that already passed from model testing step, later be employed for optimization process. In optimization process, each scenario will be computed by using mathematical model and certain parameter values. There are two outcomes of this optimization process, which are prices for each selling period on each echelon, and fruit supply chain profit. By the outcomes, comparison and justification can be made between two scenarios, using dynamic pricing and non-dynamic pricing.

3.5 Sensitivity Analysis Process

Following step is enabling sensitivity analysis. In this process, each threshold parameter values used on computation process, will be altered greater and lower to simulate each scenario further. Objective of this process is showing which parameter is more sensitive compare to other that affect each echelon profit. Furthermore, it also try to show which combination of parameter value that could yield better profitability for each echelon and whole supply chain. Result of sensitivity analysis will be presented graphically on line chart.

3.6 Discussion of Findings

Discussion of findings will be elaborated thoroughly about the outcome of computation and also sensitivity analysis process. On this step, there will be further discussion about result from the optimization process and message delivered from the optimization result. Moreover, result of various charts from sensitivity analysis will be elaborated in order to get the implication of parameters to fruit supply chain. Last but not least, listed research question that trigger this research will be clearly answered.

3.7 Conclusion and Future Research Direction

Last step is conclusion and future research direction. In this step, the research will be summarized holistically from introduction to its outcome. Moreover, implication of result to users according to application of dynamic pricing on fruit supply chain will be clearly stated. Last but not least, several drawback from this research will be elaborated in order to enable further research in following periods. The flow of research design is drawn on flowchart below.

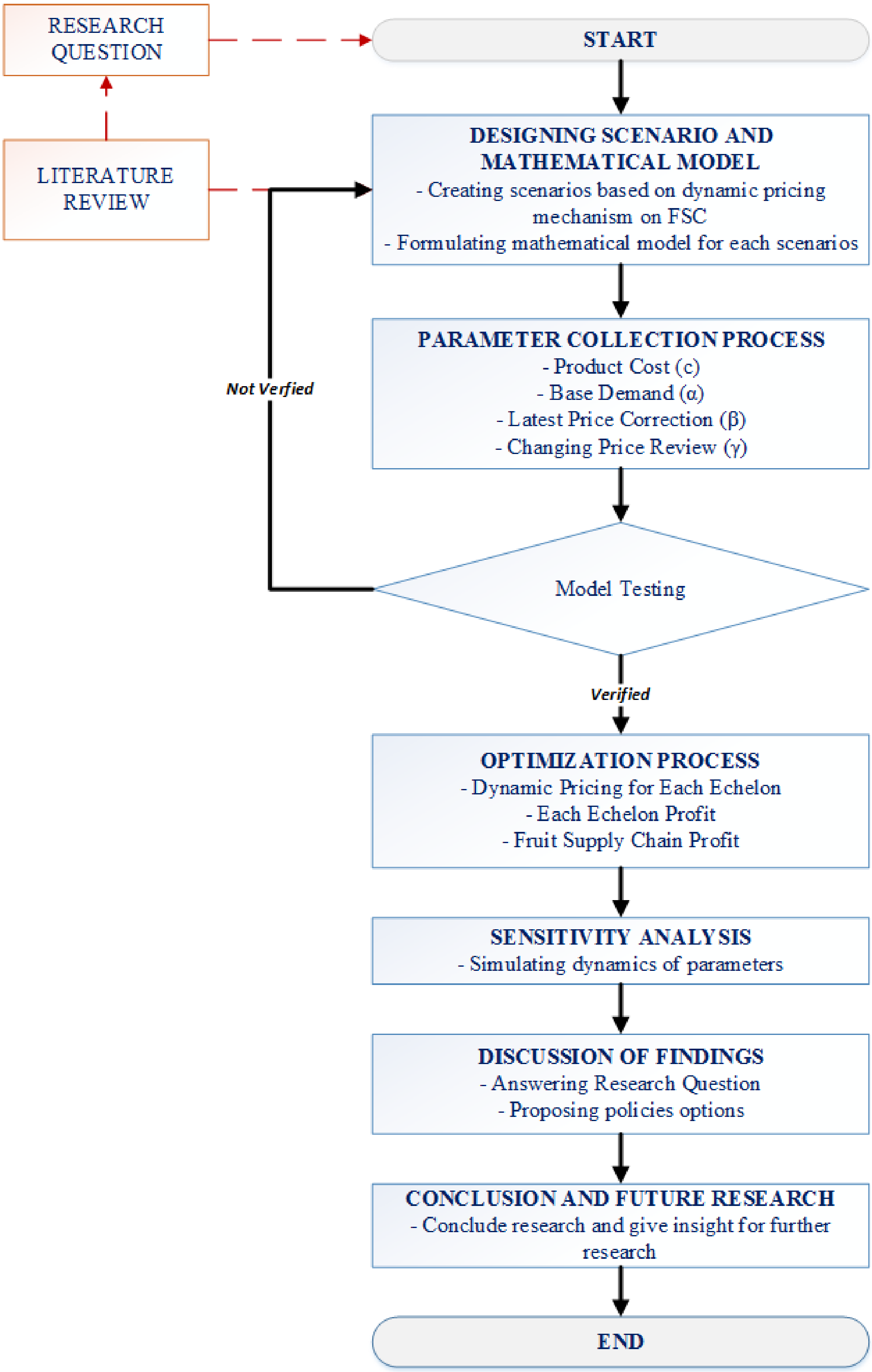


Figure 3.1 Research Flowchart

CHAPTER 4

SCENARIO & MATHEMATICAL FORMULATION DESIGN

In chapter four, scenarios that accommodate dynamic pricing in Fruit Supply Chain will be elaborated. Moreover, mathematical model also be constructed based on each scenario.

4.1 Model Background

Based on subchapter 3.1, known that mathematical formulation will be constructed based on condition of multi pricing did exist on fruit supply chain. This research will accommodate three echelon on fruit supply chain, which are supplier, wholesaler, and retailer that elaborated on several referred literature. Graphical formulation is presented below

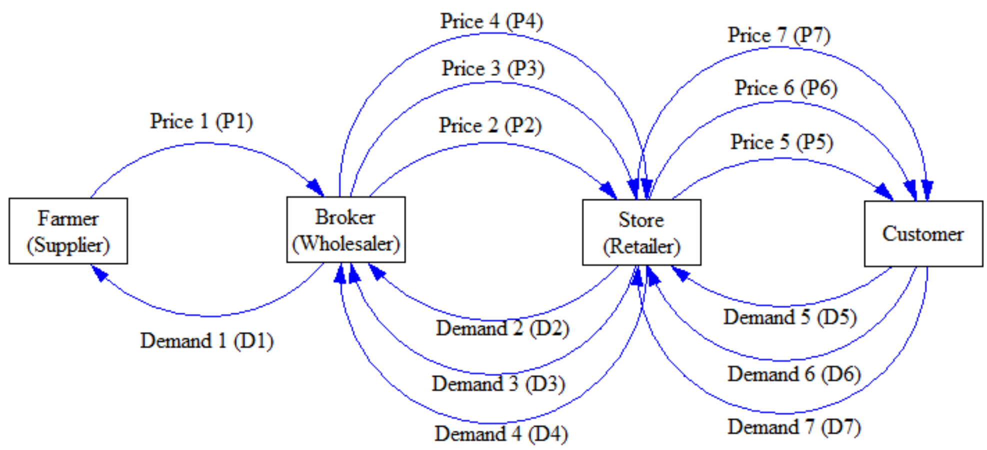


Figure 4.1 Multi Price Scheme on Multi Echelon Fruit Supply Chain

Based on Figure 4.1, it is illustrated that there are different price on wholesaler-retailer and retailer-customer tiers. Wholesaler buy fruit from farmer with price P1. Single price is applied here due to nature of fruit that harvested annually, per semester, or per quarter period. Hence, mostly wholesaler buy from farmer in single price with bulk amount of fruits on its harvest time. Meanwhile, wholesaler can apply multi price for selling their fruits. Wholesaler can establish preliminary commitment with retailers, which they can buy in lower price than common price if retailer place the order in earlier period which called as forward buying, whose price coded as P2. After releasing forward buying price for certain period, wholesaler may release normal price for following period which higher than forward buying price, coded as P3. Last but not least, wholesaler later release lower price than normal price to sale remaining unsold fruits on that period, which called as markdown price, coded as P4.

Scheme explained above also be applied by retailer to treat their customers. Retailer offers retailers lower price to generate more demand in earlier period, whose price coded as P5. After releasing forward buying price for certain period, retailer release normal price for following period which higher than forward buying price, coded as P6. Last but not least, retailer later release lower price than normal price to sale remaining unsold fruits on that period, which called as markdown price, coded as P7.

4.2 Mathematical Formulation Design

Based on Figure 4.1 shown above, Farmer gives an initial price which is coded as P_1, which is price of fruit from farmer to wholesaler. Then, demand is later followed after price had been declared. On following tier, wholesaler resold fruit gathered from farmer to retailer. Selling process is lasted on several periods. First selling period, wholesaler declared forward buying price, which is lower than normal price coded as P_2. Forward buying price must be lower than normal price. After releasing forward buying price, wholesaler launched normal price that must be higher than forward buying, which is coded as P_3. In this price, there will be another demand coded as D_3. Last but not least, there will be another price, which is markdown price. This price is lower than normal price in order to yield more demand for remaining unsold fruits, which is coded as $P_{4.}$ Markdown price also must be lower than normal price, which yield demand which is coded as $D_{4.}$ Then retailer followed same sequence with wholesaler, which is releasing three different prices to customer. On each stage of demand, there will be price correction constant, which represented by β and γ. β represent sensitivity constant to latest price, while

γ represent price differences correction. Referred to previous elaboration, several rules can be gathered. Those conclusions are stated thoroughly below

1. There is sequence of price from farmer to retailer stage, which P_1 to P_7 do exist, where $P_1 \leq P_2 \leq P_3 \geq P_4 \leq P_5 \leq P_6 \geq P_7$. This price sequence reflects condition that price one (P_1), which is price from farmer to wholesaler will be lower or equal to forward buying price from wholesaler to retailer coded as P_2. While in wholesaler, its normal price is the highest price, which is coded as P_3 compare to forward buying price (P_2) and markdown price (P_4). Retailer follows pricing pattern, where normal price (P_6) is higher than forward buying (P_5) and markdown price (P_7).
2. Demand is price dependence. Meaning that demand is generated by price declared by each tier, which are price from current period (P_n) and previous period (P_{n-1}).
3. Product is selling period dependence. Meaning that product bought on forward buying selling period cannot be sold on normal price or markdown price selling period. Another selling period will involve new replenish product on its selling period.
4. Demand is not interconnection to another demand, meaning that there is not influential response between first demand (D_1) and second demand (D_2), first demand (D_1) and third demand (D_3), and second demand (D_2) to third demand (D_3) and so forth.

Below, mathematical formulation for each demand will be elaborated. There are four mathematical formulation represented demand one, which are farmer-wholesaler relation, and demand two to four, which are wholesaler-retailer relation.

$$d_1 = \alpha - \beta * p_1 + \gamma * (c - p_1) \quad \ldots. (4.1)$$

Equation 4.1 explained that demand for the farmer is generated price one (p_1) and product cost (c), where α represents base demand for whole supply chain. Price one (p_1) is price from farmer to wholesaler, which price is singular due to nature of harvesting period. In harvesting period, wholesaler mostly come to farmer’s plant to buy goods in bulk amount.

While, demand formula for tier 2 in fruit supply chain, which are wholesaler-retailer relationship. There are three formula represented each periodical demand gathered by price

$$d_2 = \alpha - \beta * p_2 + \gamma * (p_1 - p_2) \qquad \text{.... (4.2)}$$

$$d_3 = \alpha - \beta * p_3 + \gamma * (p_2 - p_3) \qquad \text{.... (4.3)}$$

$$d_4 = \alpha - \beta * p_4 + \gamma * (p_3 - p_4) \qquad \text{.... (4.4)}$$

From equation 4.2 to 4.4, known that there are four different prices involved on tier two. In demand two, demand is influenced by difference of price one, which is buying price of product to farmer and price two, which is first launched price to retailer called forward buying price. This price is higher or equal to price one, to generate profit for wholesaler.

Demand three explained that difference of price involved are price two and three. Price three indicates normal price after wholesaler release forward buying previously. While in demand four, price three and four are involved in the demand equation. Price four will be lower than price three due to beginning of deterioration rate. Hence, wholesaler release markdown price to trigger more demand for selling remaining unsold products.

While, demand formula for tier 3 in fruit supply chain, which are retailer-customer relationship. There are three formula represented each periodical demand gathered by price

$$d_5 = \alpha - \beta * p_5 + \gamma * (p_2 - p_5) \qquad \text{.... (4.5)}$$

$$d_6 = \alpha - \beta * p_6 + \gamma * (p_5 - p_6) \qquad \text{.... (4.6)}$$

$$d_7 = \alpha - \beta * p_7 + \gamma * (p_6 - p_7) \qquad \text{.... (4.7)}$$

Retailer to customer equations will be more or less the same with wholesaler to retailer equations. From equation 4.5 to 4.7, known that there are four different prices involved on tier three. In demand 4.5, demand is influenced by difference of price two, which is first launched price to retailer called forward buying price and price five that is first launched price to customer also called forward buying price. Condition explained above represent condition of demand five that occurred on forward buying period. Price five is higher or equal to price two to generate profit for retailer.

Demand six explained that difference of price involved are price five and six. It indicates normal price after releasing forward buying previously. While in demand seven, price six and seven are involved in the demand equation. This equation indicates markdown price after releasing normal price period previously. Price seven will be lower than price six and less than or equal to price five due to beginning of deterioration rate. Hence, retailer release markdown price to trigger more demand for selling remaining unsold products.

Following after demand mathematical formulation, supply chain profit mathematical formulation will be elaborated. There are three profit function on, which are farmer profit, wholesaler profit, and fruit supply chain profit.

$$\pi_f = (P_1 - C) * D_1 \quad \text{…. (4.8)}$$

$$\pi_w = (P_2 - P_1) * D_2 + (P_3 - P_1) * D_3 + (P_4 - P_1) * D_4 \quad \text{…. (4.9)}$$

$$\pi_r = (P_5 - P_2) * D_5 + (P_6 - P_3) * D_6 + (P_7 - P_4) * D_7 \quad \text{…. (4.10)}$$

$$\pi_{sc} = (P_1 - C) * D_1 + (P_2 - C) * D_2 + (P_3 - C) * D_3 + (P_4 - C) * D_4 + (P_5 - C) * D_5 + (P_6 - C) * D_6 + (P_7 - C) * D_7 \quad \text{…. (4.11)}$$

Equation 4.8 to 4.11 presented above are profit equation for each echelon and whole fruit supply chain profit. Equation 4.8 explained that profit of farmer is difference of unit cost and price from farmer to wholesaler (P_1) multiply demand from wholesaler to farmer (D_1). While in equation 4.9, profit of wholesaler is defined by sum of difference of forward buying, normal price, markdown price and buying price of product multiply by demand two to four. Following equation, equation 4.10 represents retailer profit. Profit of retailer is defined by sum of difference of forward buying, normal, and markdown prices of wholesaler and retailer multiply by demand five to seven. Last but not least, profit supply chain is defined by sum of difference of each price on each tier and cost unit multiply by its demand, that formulated on equation 4.11

Besides equation declared above, constraint that worked on this problem need to be formulated. First constraint is nonlinear constraint. Nonlinear constraint is declared below

$$p_1 * p_2 * p_3 * p_4 * p_5 * p_6 * p_7 \geq 10{,}000{,}000{,}000{,}000{,}000{,}000{,}000{,}000{,}000 \quad \text{…. (4.12)}$$

$$p_1{}^2 + p_2{}^2 + p_3{}^2 + p_4{}^2 + p_5{}^2 + p_6{}^2 + p_7{}^2 = 1{,}600{,}000{,}000 \quad \text{.... (4.13)}$$

Non-linear equation above is making sure optimization will go well. Equation 4.12 represents condition that multiply of each price will be exceed 10,000 billion rupiahs. This condition will trigger the optimization to yield different prices by result. Hence, there may be price value Rp 4,000 but later to be compensated by price value Rp 15,000 in cases. Therefore, equation 4.13 complement previous equation by equalities condition. This equation will give boundary to price combination, that will make sure that sum of square of each prices will not exceed 1,6 million.

Next, constraint is linear constraint. There are two sets of linear constraint design for this optimization process. First linear constraint set is dedicated to wholesaler echelon. The linear constraint is presented as follows:

$$p_1 - p_2 \leq 0 \quad \text{.... (4.14)}$$

$$p_2 - p_3 \leq 0 \quad \text{.... (4.15)}$$

$$-p_3 + p_4 \leq 0 \quad \text{.... (4.16)}$$

Equation 14 to 16 represents dynamic pricing rules. Equation 4.14 indicates condition that price one, which is buying price from farmer will be equal or lower than price two, which is forward buying price. Equation 4.15 indicates condition that price two, which is forward buying price will be lower or equal to price three, which is normal price. Equation 4.16 indicates condition that price three, which is normal price will be higher or equal to price four, which is markdown price.

Second linear constraint set is dedicated to retailer echelon. The linear constraint is presented as follows:

$$p_2 - p_5 \leq 0 \quad \text{.... (4.17)}$$

$$p_3 - p_6 \leq 0 \quad \text{.... (4.18)}$$

$$p_4 - p_7 \leq 0 \quad \text{.... (4.19)}$$

Equation 4.17 to 4.19 presented above are represent dynamic pricing happened on retailer echelon. On equation 4.17, price five on retailer is forward buying price for customer that must be higher than or equal to price two, which is forward buying from wholesaler. Consequently, equation 4.18 and 4.19 indicate normal price and markdown price on retailer must be higher than or equal to normal price and markdown price on wholesaler stage.

$$p_5 - p_6 \leq 0 \quad \text{…. (4.20)}$$

$$-p_6 + p_7 \leq 0 \quad \text{…. (4.21)}$$

$$-p_5 + p_7 \leq 0 \quad \text{…. (4.22)}$$

Equation 4.20 to 4.22 represents dynamic pricing rules. Equation 4.20 indicates condition that price five, which is forward buying price will be lower than or equal to price six, which is normal price. Equation 4.21 indicates condition that price six, which is normal price will be higher than or equal to price seven, which is markdown price. Equation 4.22 indicates condition that price five, which is forward buying price will be higher or equal to price seven, which is markdown price.

Following constraint is also linear constraint, but it express equality aspect of the problem. The equality constraint is declared below

$$p_1 + p_2 + p_3 + \ p_4 + p_5 + p_6 + p_7 = 100{,}000 \quad \text{…. (4.23)}$$

Equality constraint above represented condition that sum of each prices is equal to 100,000. This constraint triggers optimization process to yield unique price and sum of each prices do not excess that value.

Last step, all the equation is scripted into Matlab R2010 in order to optimize the problem. It is assisted by usage of FMINCON function to gather price should be made by each echelon in order to maximize the supply chain profit.

4.3 Scenario Design

Based on mathematical formulation design elaborated on previous chapter, there are two scenarios that can be established. First scenario is establishing fruit supply chain with single price on each echelon for all selling period. Then, challenging scenario or second scenario is establishing multi prices on each echelon. Objective of designing those two scenarios is finding which scenario is more preferable based on its profitability. Hence, two scenarios presented graphically on next page

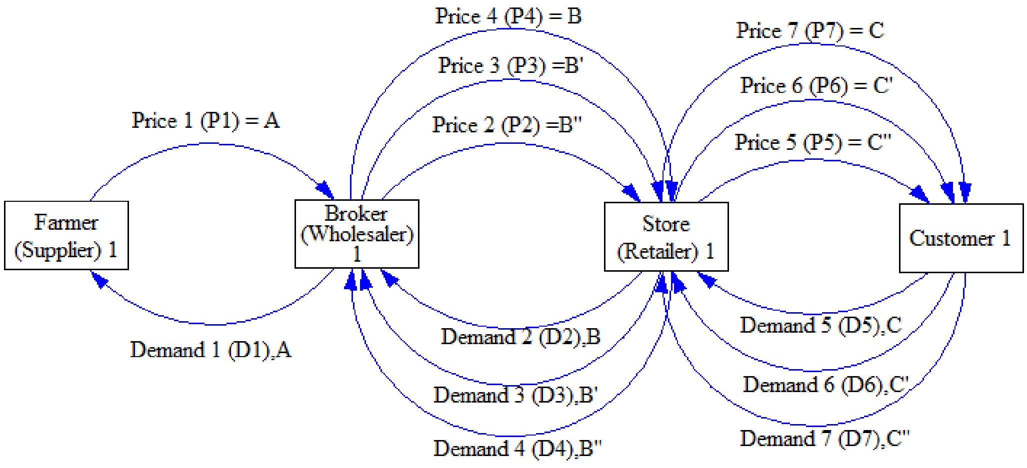


Figure 4.2 Scenario One: Optimization Model with Single Price

Based on Figure 4.2, first scenario is modeled graphically. Farmer will launch single price, which is coded as A. While wholesaler will launch three prices which are B, B’, and B”. Those prices are more or less the same, but there is different of 100-900 Rupiahs of each prices. Hence, there is B’ and B” following after price B. Repeatedly, this price scheme is applied by retailer, that launches C to C” prices. Those prices are assumed on beginning of optimization process.

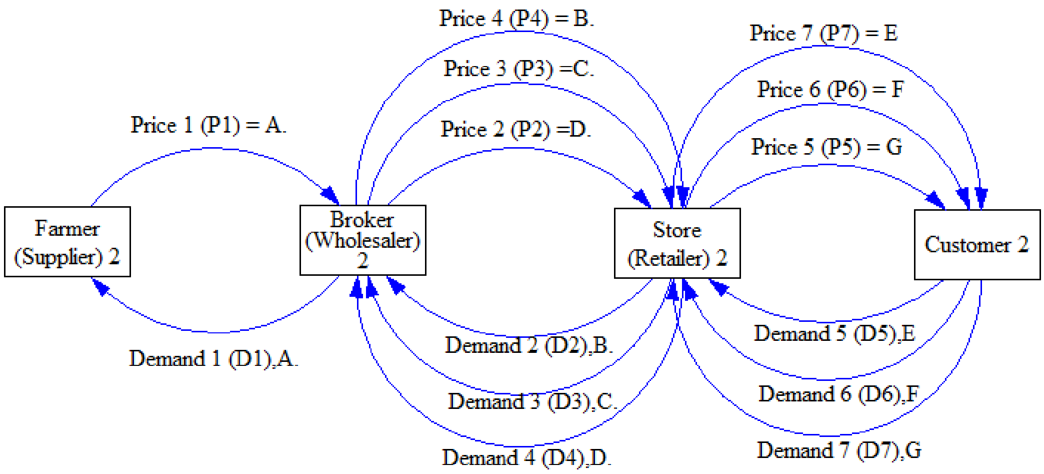


Figure 4.3 Scenario Two: Optimization Model with Dynamic Pricing

Based on Figure 4.3, scenario two challenge first scenario with offering different prices for each selling period. In first tier, farmer release price, coded as price A, which is single price due to harvest periods of fruits. While, Wholesaler could launch different prices for each selling period, where price B dedicated to forward buying, price C for markdown price. Consequently, retailer could establish markup price from wholesaler in different amount on different selling period, where price D for forward buying selling period, price E and F for normal price and markdown price selling period in sequence. It is becoming curiously to figure out which scenario would establish better profitability on FSC.

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CHAPTER 5

OPTIMIZATION PROCESS AND SENSITIVITY ANALYSIS

In chapter five, optimization process and sensitivity analysis will be elaborated. Chapter five consists of subchapters which are related to research design.

5.1 Optimization Process

In this section, mathematical formulation elaborated above will be simulated using initial parameters. It is used α = 50, β = 0.5, γ = 0.05, c = 5000, and initial guess of price $p_1 = 10{,}000$; $p_2 = 12{,}100$; $p_3 = 12{,}500$; $p_4 = 12{,}200$; $p_5 = 15{,}000$; $p_6 = 15{,}900$; $p_7 = 15{,}200$. Result is presented as screen shot below.

```
initial objective: 398651000
Warning: Trust-region-reflective algorithm
does not solve this type of problem, using
active-set algorithm. You could also try
the interior-point or sqp algorithms: set
the Algorithm option to 'interior-point' or
'sqp' and rerun. For more help, see
Choosing the Algorithm in the
documentation.
> In fmincon at 472
  In main2 at 11

Local minimum possible. Constraints satisfied.

fmincon stopped because the predicted change in the objective function
is less than the default value of the function tolerance and constraints
were satisfied to within the default value of the constraint tolerance.

<stopping criteria details>

Active inequalities (to within options.TolCon = 1e-006):
  lower      upper     ineqlin   ineqnonlin
    1                     2
    4                     9
  1.0e+004 *

  Columns 1 through 4

    0.9000    1.1698    1.1698    0.9000

  Columns 5 through 7

    1.7731    2.3142    1.7731

final objective: 553217728.2965
```

Figure 5.1 Optimization Result by Matlab

Mathematical formulation elaborated on chapter four, is deployed into script on Matlab. Then, it results dynamic pricing for wholesaler and retailer. Moreover, prices presented on optimization result insists difference of prices is needed to reach better whole supply chain profit. Hence, research question one has been answered which is presented mathematical formulation and dynamic pricing model for three echelons.

Based on optimization result presented above, known that optimization can answer research question. Moreover, challenge question from chapter one whether dynamic pricing could assist better profit fruit supply chain, is also answered by Figure above. Shown that final objective which is using dynamic pricing scheme yields higher profit compare to initial objective is using single price scheme. Thus, dynamic pricing model is verified to seek better profit supply chain,

5.2 Sensitivity Analysis

There are two sensitivity done on this research. First sensitivity analysis on pricing section. While, second sensitivity analysis is on parameters involved in optimization. Those two sensitivity analysis is thoroughly explained below

5.2.1 Optimization Sensitivity Analysis

In this section, several sensitivity analysis will be presented. First sensitivity analysis is dynamic pricing sensitivity. Based on Figure 5.1, known that result gathered from optimization process is local optimum possible. Therefore, first optimization need to be altered to seek exact local optimum within better profit supply chain circumstances. There is pricing rule applied on this sensitivity, which is common pricing rule mainly used by company from tourism area. Forward buying price, regularly on weekdays, is given lower price which is around 80% from weekend price, which is normal price. This condition also illustrated o first chapter on this thesis. While, markdown price will be around 50% from normal price. This pricing strategy is mainly applied by Bakery Company, where expiration does exist on bakery products. Its pricing rule formulated mathematically as follows

$$p_2 - 0.8 * p_3 = 0 \quad \text{.... (24)}$$

$$-0.5 * p_3 + p_4 = 0 \quad \text{.... (25)}$$

On first sensitivity, the equation must be converted as vector then scripted as equalities equation on matlab. Script and optimization result is presented as follows

```
Aeq=[1 1 1 1 1 1 1;0 1 -0.8 0 0 0 0;0 0 -0.5 1 0 0 0];
beq=[100000;0;0];
```

Figure 5.2 Equalities Equation Script

```
Local minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in
feasible directions, to within the default value of the function tolerance,
and constraints were satisfied to within the default value of the constraint tolerance.

<stopping criteria details>

Active inequalities (to within options.TolCon = 1e-006):
  lower      upper     ineqlin   ineqnonlin
    1                     9
    4
  1.0e+004 *

  Columns 1 through 4

    0.8000    1.2800    1.6000    0.8000

  Columns 5 through 7

    1.5934    2.3332    1.5934

final objective: 554081522.6789
```

Figure 5.3 First Modified Optimization Result

Based on Figure 5.3 presented above, final objective value is higher than preliminary optimization. Meaning that, this modified optimization is verified to seek better supply chain profit. Moreover, result gathered from this optimization is not possibilities of local optimum due to the objective function is non-decreasing on feasible directions. Wholesaler could apply dynamic pricing with scheme explained before, which was 80 – 50 from Price three. While, retailer could apply dynamic pricing, where price five and price seven is on the same position in Rp 15,934 with Rp 23,332 as normal price. Last but not least, farmer should reduce the initial price from Rp 10,000 to Rp 8,000. Therefore, it could become an aberration for farmer in spite of better profit for whole supply chain.

Second modified optimization try to solve first modified optimization and also attempt to achieve better supply chain profit. Following modification also using the pricing rule, but it is not scripted as equalization. Therefore, pricing scheme is scripted on non-equalization equation.

$$p_2 - 0.8 * p_3 \leq 0 \quad \text{.... (26)}$$

$$-0.5 * p_3 + p_4 \leq 0 \quad \text{.... (27)}$$

$$p_5 - 0.8 * p_6 \leq 0 \quad \text{.... (28)}$$

$$-0.5 * p_6 + p_7 \leq 0 \quad \text{.... (29)}$$

This modification is triggering the optimization to seek value of price which less than or equal to 0.8 – 0.5 of price three and price six, where those two prices are normal price. Hence, decision can be made by echelons by reviewing dynamic pricing and impact to whole supply chain profit. The non-equalization script and optimization result are presented as follow

```
A=[1 -1 0 0 0 0 0;0 1 -0.8 0 0 0 0;0 0 -0.5 1 0 0 0;0 1 0 0 -1 0 0;
0 0 1 0 0 -1 0;0 0 0 1 0 0 -1;0 0 0 0 1 -0.8 0;0 0 0 0 0 -0.5 1;0 0 0 0 1 0 -1];
b=[0; 0; 0; 0; 0; 0; 0; 0; 0];
```

Figure 5.4 Non-Equalization Equations Script

```
Local minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in
feasible directions, to within the default value of the function tolerance,
and constraints were satisfied to within the default value of the constraint tolerance.

<stopping criteria details>

Active inequalities (to within options.TolCon = 1e-006):
  lower      upper     ineqlin   ineqnonlin
               6          3
                          4
                          8
                          9
  1.0e+004 *

    1.0649    1.2000    1.9567    0.9784    1.2000    2.4000    1.2000

final objective: 559190067.1447
```

Figure 5.5 Second Modified Optimization Result

Based on Figure 5.5 presented above, final objective of second modified optimization value is higher than first optimization. Meaning that, this second modified optimization assist supply chain profit to better stage. Moreover, result gathered from this optimization is also local optimum that is fulfill all constraints due to the objective function is non-decreasing on feasible directions. By this optimization result, farmer is given bit higher price than initial price, in Rp 10,649 position. Wholesaler could apply dynamic pricing but not with exact 80 – 50 from normal price, the dynamic pricing scheme will be Rp 12,00 for forward buying, Rp 19,567 for normal price then decrease to Rp 9,784, which bit lower than price one, which is purchasing price from farmer. While, retailer place the same price for forward buying and markdown price on Rp 12,000 position, with Rp 24,000 on normal price.

5.2.2 Parameter Sensitivity Analysis

There are several parameters involved on optimization process, which are α, γ, β, and c. Those parameters are assumed on single value when optimization process began. Therefore, parameters value need to be tested on sensitivity analysis individually and simultaneously. It is needed to present effect of parameter value changes on each echelon profit and whole supply chain profit.

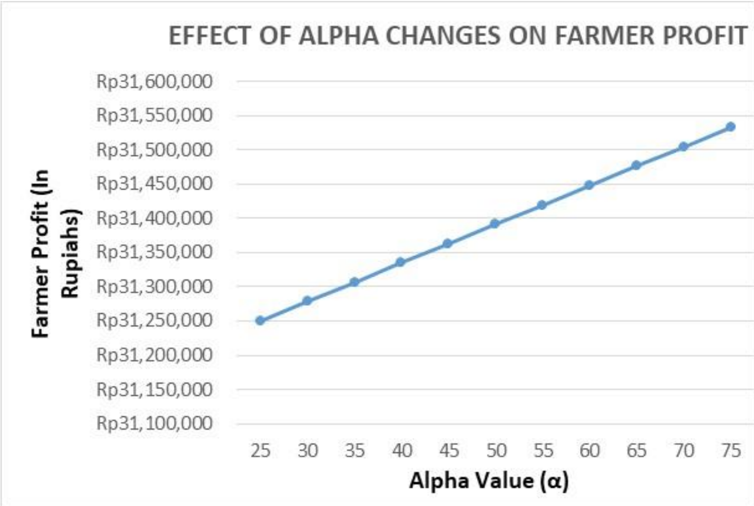

Figure 5.6 Alpha Changes on Farmer Profit

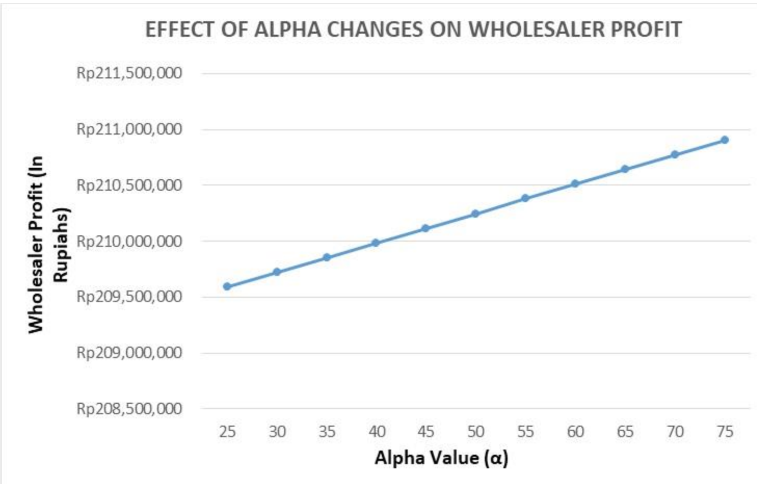

Figure 5.7 Alpha Changes on Wholesaler Profit

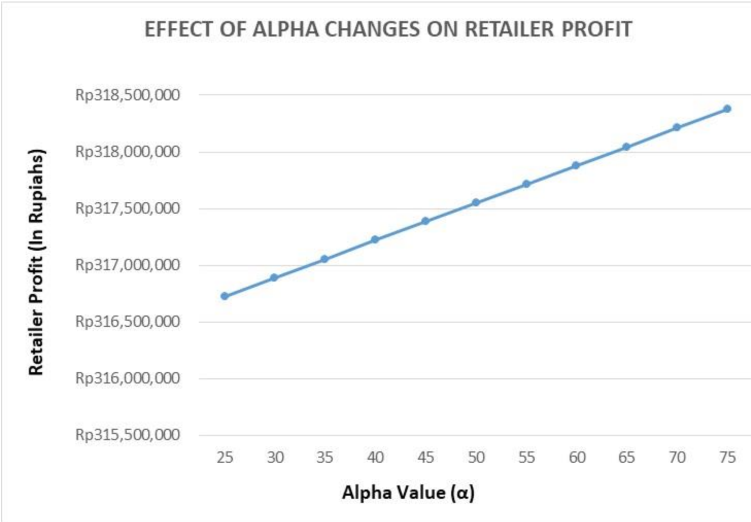

Figure 5.8 Alpha Changes on Retailer Profit

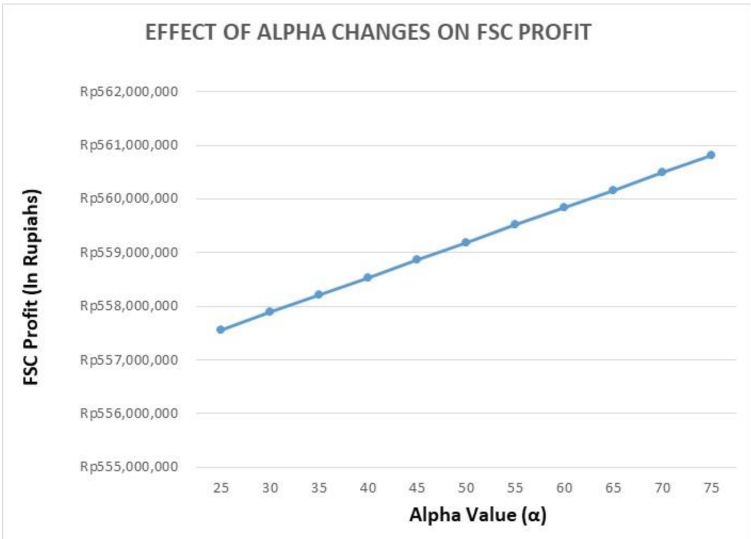

Figure 5.9 Alpha Changes on FSC Profit

First four Figures, which are Figure 5.6 to 5.9, presents effect of alpha changes on Echelon Profit and FSC Profit. Based on Figures presented above, it can be concluded that higher alpha will trigger higher profit. Alpha represent base demand for FSC, meaning that base demand is assumption of preliminary demand. Hence, the higher base demand placed, it can trigger higher profit for each echelon profit and whole FSC profit. Further discussion will be elaborated on next chapter.

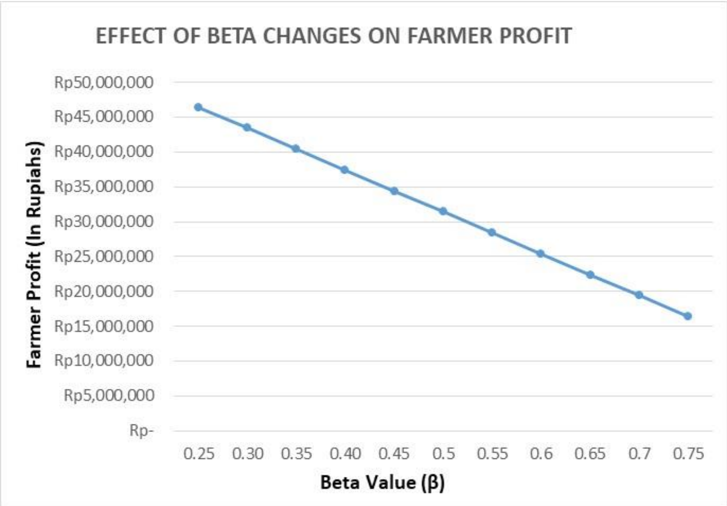

Figure 5.10 Beta Changes on Farmer Profit

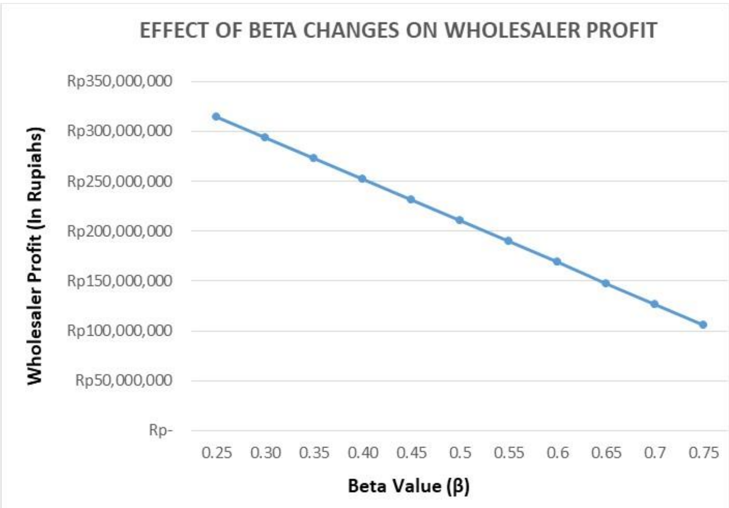

Figure 5.11 Beta Changes on Wholesaler Profit

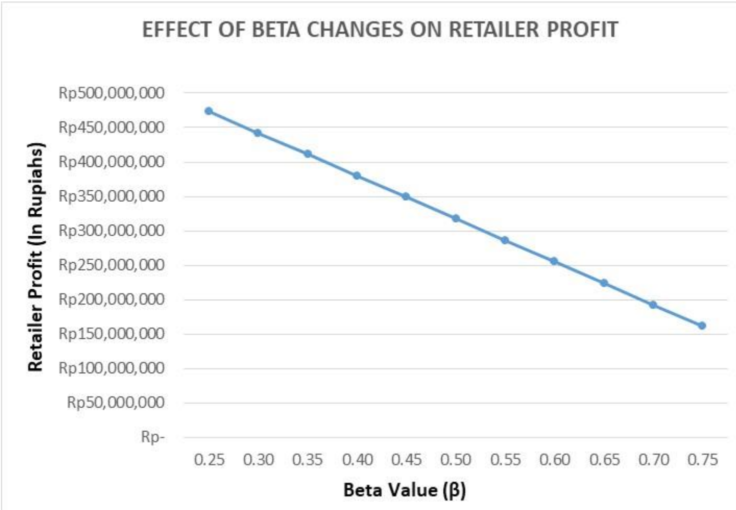

Figure 5.12 Beta Changes on Retailer Profit

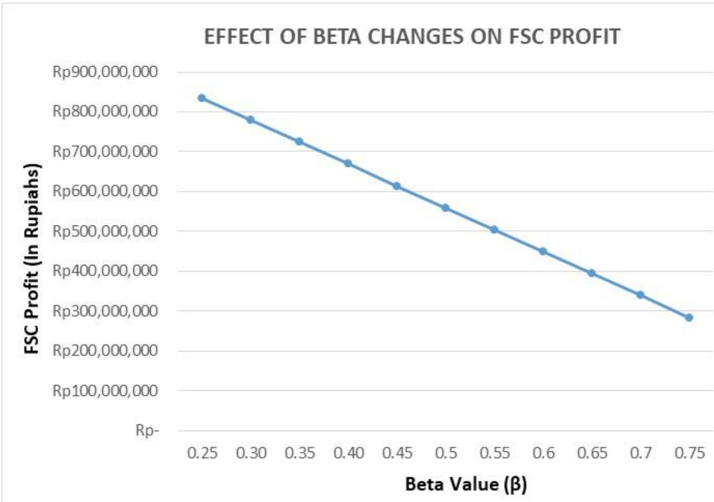

Figure 5.13 Beta Changes on FSC Profit

Following four Figures, which are Figure 5.10 to 5.13, presents effect of beta changes on Echelon Profit and FSC Profit. Based on Figures presented above, it can be concluded that higher beta will trigger lower profit. Beta represent sensitivity parameter of latest price, which has range from 0.1 to 1. It means more sensitive customer to latest price will decrease potential profit could achieve by echelons and whole FSC. Further discussion will be elaborated on next chapter.

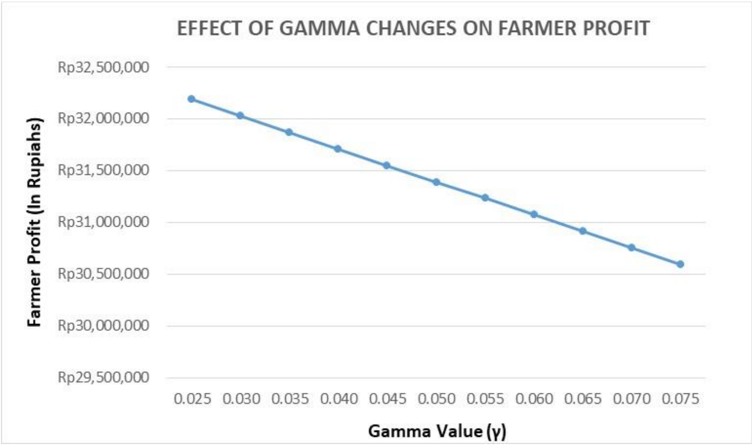

Figure 5.14 Gamma Changes on Farmer Profit

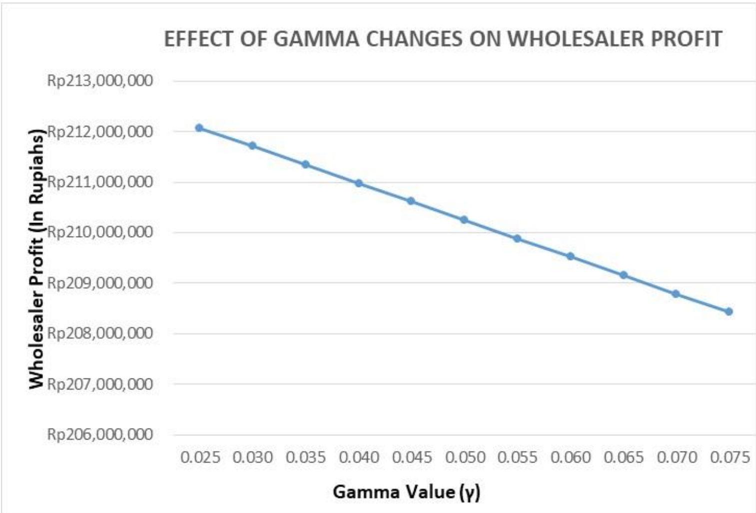

Figure 5.15 Gamma Changes on Wholesaler Profit

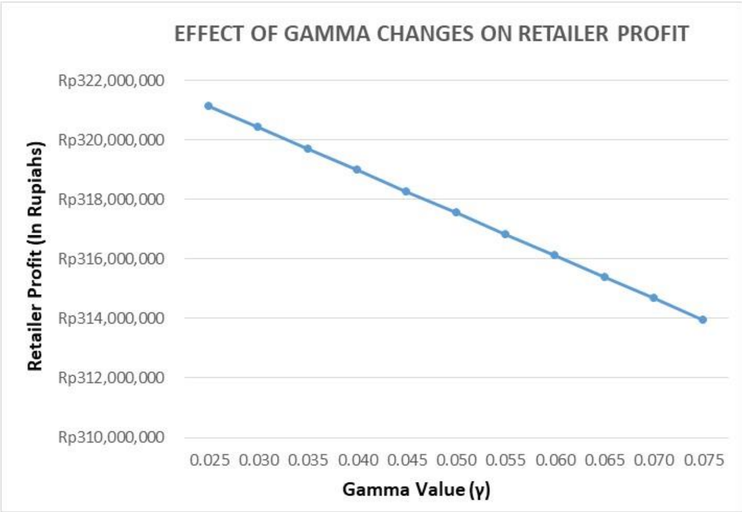

Figure 5.16 Gamma Changes on Retailer Profit

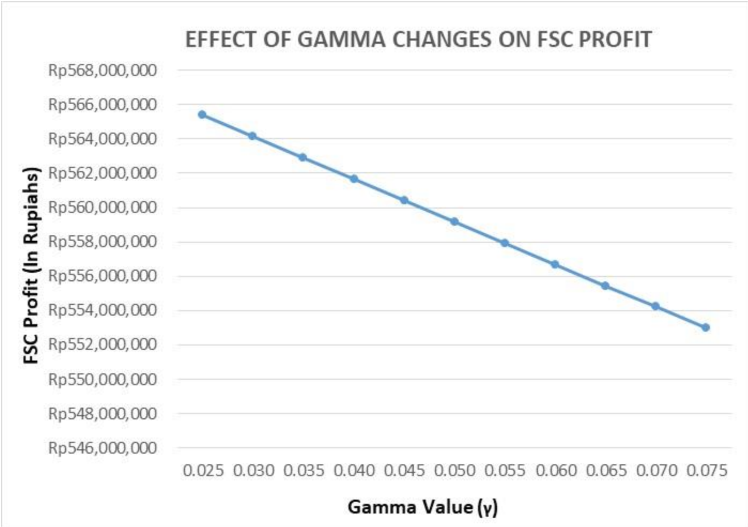

Figure 5.17 Gamma Changes on FSC Profit

Following four Figures, which are Figure 5.14 to 5.17, presents effect of gamma changes on Echelon Profit and FSC Profit. Gamma represent sensitivity parameter of price reviewing, which has range from 0.01 to 0.09. Based on Figures presented above, generally it can be concluded that higher beta will trigger lower profit, which was on the same page with beta. It means more sensitive customer to review price changes will decrease potential profit could achieve by echelons and whole FSC.

Nevertheless, there is further discussion referred to demand equation that will be elaborated on next chapter. Following table will highlight sensitivity analysis figures presented above.

Table 5.1 Sensitivity Analysis Highlight

Parameter	Parameter Changes	Profit Difference			Profit Changes (%)		
		Farmer	Wholesaler	Retailer	Farmer	Wholesaler	Retailer
α	-20%	Rp 31,334,721	Rp 209,982,693	Rp 317,220,000	-0.18	-0.13	-0.10
	Threshold	Rp 31,391,211	Rp 210,114,448	Rp 317,385,000	0	0	0
	+20%	Rp 31,447,701	Rp 210,246,203	Rp 317,550,000	**0.18**	0.13	0.10
β	-20%	Rp 37,406,831	-Rp 168,662,289	Rp 251,830,118	19.16	**19.78**	**19.65**
	Threshold	Rp 34,399,021	-Rp 189,454,246	Rp 231,038,161	0	0	0
	+20%	Rp 31,391,211	-Rp 210,246,203	Rp 210,246,203	-19.16	-19.78	-19.65
γ	-20%	Rp 31,710,323	-Rp 209,517,367	Rp 210,975,040	**1.02**	**0.35**	**0.45**
	Threshold	Rp 31,550,767	-Rp 209,881,785	Rp 210,610,621	0	0	0
	+20%	Rp 31,391,211	-Rp 210,246,203	Rp 210,246,203	-1.02	-0.35	-0.45

Based on Table 5.1 presented above, each parameter has different effect to FSC players’ profitability. Higher alpha will beneficial to farmer represented by higher profit changes to compare to other players. While, beta parameter that represents latest price review sensitivity constant, gives more profitability tendency to wholesaler. Nevertheless, beta can also useful to retailer due to higher profit changes when lower beta is set. Last but not least, lower gamma will give higher profitability tendency to farmer. While, changes of beta gives lower impact for wholesaler and retailer compare to farmer. This condition can be approached by anomaly effect of gamma to demand that will be comprehensively elaborated on chapter six.

CHAPTER 6

DISCUSSION OF FINDINGS

In chapter six, further analysis and discussion of optimization and sensitivity analysis will be elaborated. There are two discussion will be explained thoroughly, which are optimization process and sensitivity analysis outcome.

6.1 Optimization Process Outcome

Based on chapter 5.1, several research question has been answered, one of it is mathematical formulation and model has been captured the application of dynamic pricing. Initial price that used in optimization presenting common condition that seller used single price for all selling period. Based on optimization, dynamic pricing offer an option that each echelon could lower their price on forward buying and markdown price. Nevertheless, the lower price on beginning and end of selling period can be compensated by normal price when the fruit is on well-consumed condition.

Figure 6.1 Banana Price per June 2017

Figure 6.1 shown above captured condition of banana selling period on one of well know Retailer Company on Indonesia. Their offer banana on single price, for that package banana (no scaling process), for all selling period. Fruit like banana, has lifetime period before it ends as deteriorated product. Hence, retailer should be smart to push selling of deteriorative product such as fruit to prevent it is unsold, which can be overcame by applying forward buying. In example, based on Figure 5.5, retailer can offer Rp 12,000 per kg of banana when banana still on raw condition. Raw condition can be determined by color of banana skin and gentleness of banana fruit body. This price push demand into earlier period, therefore it can be used to prevent risk of unsold product. Then, retailer could begin mark up the price when there is indication of banana soon to be on well-consumed period. Again, based on Figure 5.5 retailer should offer Rp 24,000 per kg of banana. This price still way too low from banana price on convenience store that observed by author. It indicates that retailer may could play price since market acceptance level price still higher than threshold price. Last but not least, when fruits is indicating over well-consumed period, that can be determined by changes of banana fruit skin and gentleness of its fruit body as well, retailer could give lower price that commonly half price than normal price or just cost of goods sold price. This step also prevent risk of unsold product like forward buying price.

Besides prices, profit value is also need to be discussed. Based on optimization process known that supply chain profit growing better. Thing need to be discussed is prices involved on each profit. On first modified optimization model, FSC profit can be reach value Rp 554 milion rupiahs, with pricing rules 80-50% on wholesaler stage, and decreasing farmer price 20% lower than initial price. While second modified optimization model could lead to better FSC profit in value Rp 559 million rupiahs. On this scheme, there is no 80%-50% pricing rules, but markdown price of wholesaler bit lower than buying price from farmer. Several consideration need to be elaborated here that is whatever the FSC profit considered by its player the decision still depend on the market. Meaning that, FSC players could take first modified optimization model, where farmer regain the price from Rp 8,000 to Rp 10,000 as long as wholesaler still willing to buy it and wholesaler market (retailer) tend to purchase markup price from wholesaler. Consequently, FSC players could take second modified optimization where it yields better FSC profit. Wholesaler also could regain their markdown price as long as retailer still willing to buy it and retailer market (customer) tend to purchase it. There are several thing can be concluded from here, which are

1. Dynamic pricing condition and its profit can be achieved by collaboration within FSC players, which its market need to be observed due to their obligation to adjust optimization done by FSC players
2. Dynamic pricing is worth to try due to this scheme can yield better whole supply chain profit. Besides, dynamic pricing is closer to the reality, where customer tend to purchase fruit in good condition. Hence, retailer could offer markdown price for fruit which start to deteriorate to prevent unsold product risks. Moreover, retailer also need to push forward buying with also offer price lower than normal price to prevent abundant amount of fruit start to deteriorate in markdown price selling period.

6.2 Sensitivity Analysis Outcome

Following discussion is about parameter sensitivity analysis outcome. Known that each parameter has different effect on FSC players' profitability. Summary of sensitivity analysis table is presented below

Table 6.1 Summary of Sensitivity Analysis

Parameter	**Parameter Changes**	**Profit Changes (%)**		
		Farmer	**Wholesaler**	**Retailer**
α = 50	-20%	-0.18	-0.13	-0.10
	Threshold	0	0	0
	+20%	**0.18**	0.13	0.10
β = 0.5	-20%	19.16	**19.78**	**19.65**
	Threshold	0	0	0
	+20%	-19.16	-19.78	-19.65
γ = 0.05	-20%	**1.02**	**0.35**	**0.45**

	Threshold	0	0	0
	+20%	-1.02	-0.35	-0.45

Based on Table 6.1 above, alpha has more positive impact to farmer profit reflected by higher profit changes compare to wholesaler and retailer. It can be elaborated that farmer uses a single price to sell product to wholesaler. Hence, higher alpha, which is higher base demand placed by wholesaler to farmer, will raise the profit for farmer. Nevertheless, in real condition there are several consideration, which are nature of product and also market condition. Fruit product has nature to become deteriorative product in the end. Moreover, market condition can be so fluctuated. In previous chapter dynamic pricing assist to demand pushing, in the other side macro-economic condition that cannot be controlled. Commonly, fruit is bought in 50 kg amount from farmer on harvesting period which was set as initial base demand that used on the optimization. Based on consideration explained above, FSC players should consider certain number as a base demand to achieve targeted FSC profit.

Next parameter is beta. Based on Table 6.1 above, lower beta will give higher profit changes to wholesaler and retailer that come in second than farmer. Beta is represented latest price sensitivity, which is more related to wholesaler and retailer due to dynamic pricing scheme application. On dynamic pricing, there are several prices which can be lower or higher to one another. Declaring latest price has an impact to customer perception whether latest price is affordable or not. Beta parameter try to capture customer sensitivity to latest price. From previous paper, which is Maiti & Giri (2016), valued default beta in 0.5. It insisted that customer sensitivity to latest price has great portion to effect demand for FSC players. Less than 0.5 value, demand will be higher and so does profit. In the other hand, the higher 0.5 value of beta, which is customer very sensitive to latest price declared or released by FSC players.

Condition explained above reflects real market condition. Higher latest price, may decrease customer willingness to pay. While, on lower latest price, it may increase customer willingness to pay. Nevertheless, FSC players applies higher price under condition of good condition fruit, which is period that has been waiting for by customer. While lower price is applied on before and after-good condition of fruit. This mechanism is compensated each other. Customer is given few options to buy before or after-good condition of fruit with lower price or good condition of fruit with higher price. Hence, FSC players should take an option to offer small gap between normal price and under normal price, remind that purpose of lowering the price to push demand to forward buying and prevent outdated fruits.

Last but not least is gamma. Gamma has unique impact on optimization. Based on Figure 6.2, gamma has positive impact to yield demand to FSC players. Nevertheless, Table 6.1 shows that lower gamma can give positive impact to higher profit changes to FSC players, especially farmer.

$$d_n = \alpha - \beta * p_n + \gamma * (c - p_n)$$

Figure 6.2 Demand Equation

In farmer stage, this redundancy happened due to different of price offered to wholesaler. Gamma represents price correction from earlier price to latest price operate on its system. In farmer, due to application of single price, selling price to wholesaler directly minus by cost of product. Since selling price higher than cost of product, this price correction will increase the profitability where its price correction amplified by gamma.

In wholesaler and retailer stage, this redundancy happened due to application of dynamic pricing scheme. In example, on retailer stage different price of forward buying price to normal price, will be noted as negative reviewed by customer due to higher latest price than previous price. In the other hand, changes of normal price to markdown price will be noted as positive reviewed by customer due to decreasing price from previous prices. Gamma will amplify both of negative and positive review. In this dynamic pricing scheme, there is four negative review happened, two on each wholesaler and retailer, but only two positive review happened, one on each wholesaler and retailer. It can be concluded that gamma is following dynamic pricing scheme, which can be amplified both of negative or positive review of prices from customer. One consideration need to be discussed, whether beta and gamma that captured as most sensitive parameter. From recent optimization, higher constant of beta make it as most sensitives compare to lower constant of gamma. Nevertheless, further market research need to be done to select which of those two parameters is the most influential for fruit supply chain. It can be indicated that on FSC, reviewing of price changes due to nature of product, can be considered as more sensitive compare to reviewing of latest price. Hence, higher constant can be given to gamma than beta.

CHAPTER 7
CONCLUSION AND FUTURE RESEARCH SUGGESTION

Finally, after research has been done, conclusion can be made. Moreover, drawback of recent research also generate idea to be overcame on future research. There are two section will be explained on this chapter, which are conclusion and future research suggestion section.

7.1 Conclusion

From chapter five and six, several ideas can be underlined to be served as conclusion. Several conclusion are presented as follows

1. A set of mathematical model has been proposed to address dynamic pricing for FSC players to achieve better profitability. Dynamic pricing is urgent to be done due to nature of fruit product, where deteriorative period does exist. Hence, in order to avoid unsold product due to became deteriorated, dynamic pricing could become solution to push demand in several selling period, which are forward buying, normal price, and markdown price period compare to single price for all selling period, that is already proved by optimization.
2. Optimization parameters has their own effect on FSC profit. Alpha which is base demand could trigger higher demand for FSC players. Nevertheless, amount of base demand need to be considered due to nature of product and market condition. While, beta give negative impact on FSC profit, where it represent customer sensitivity to latest price, which is also considered as most sensitive parameter on optimization process. In addition, gamma could give both positive and negative impact depend on dynamic pricing scheme, which is could be considered as candidate to become most sensitive parameter on FSC.
3. FSC players could gather better profit supply chain, which affected by dynamic of demand due to dynamic pricing. Demand function reflect that customer preference to buy is more affected to latest price (β) than

difference of latest price compare to previous price (γ). Hence, FSC players should prepare marketing technique for releasing latest price to their customer.

7.2 Future Research Suggestion

There are several suggestion that can be considered for future research, that is judgement or rules that apply for beta and gamma in order to capture price resulted from optimization process. Hence, constant of beta and gamma will follow price set by FSC players that represent customer or market sensitivity. Moreover, more consideration on mathematical formulation and model, in example inventory consideration and dynamic of base demand to enrich optimization result that could assist FSC players better.

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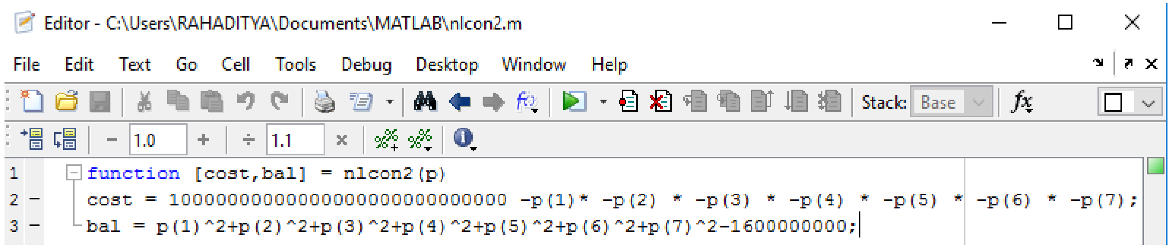
APPENDIX A

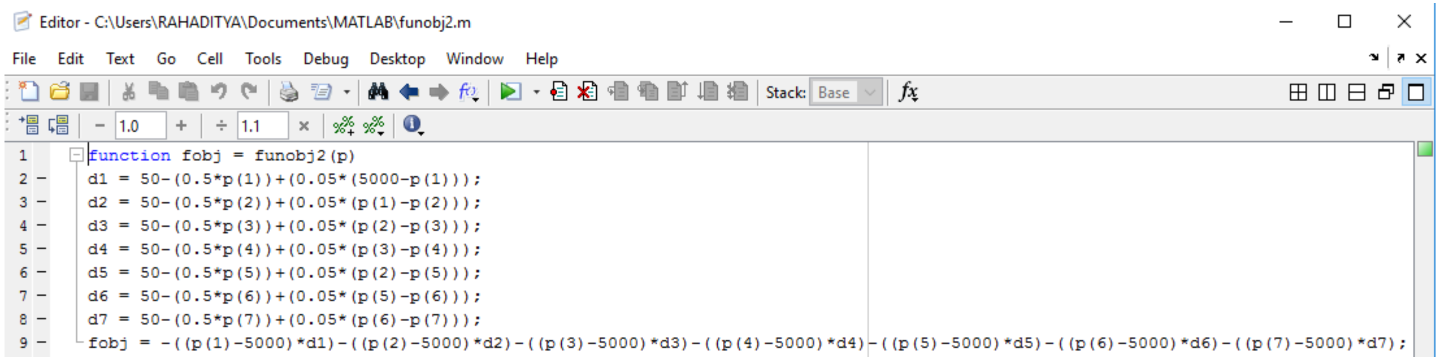
OPTIMIZATION SCRIPT ON MATLAB

Non-Linear Constraint Script



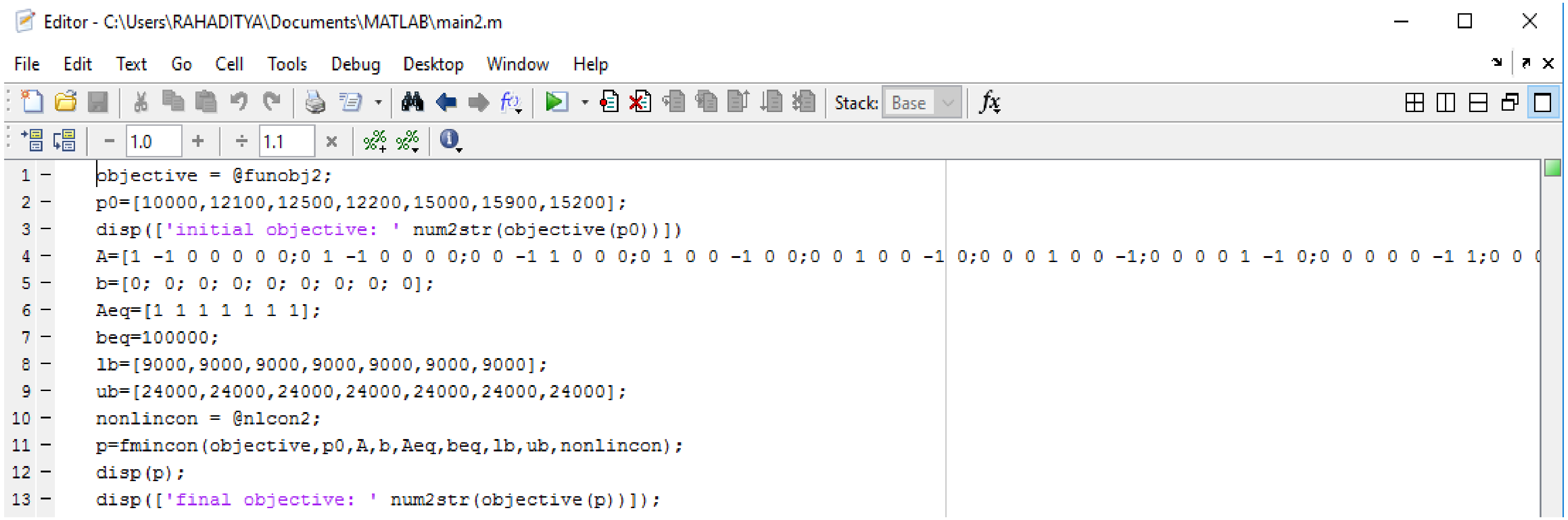
```
function [cost,bal] = nlcon2(p)
cost = 10000000000000000000000000000 -p(1)* -p(2) * -p(3) * -p(4) * -p(5) * -p(6) * -p(7);
bal = p(1)^2+p(2)^2+p(3)^2+p(4)^2+p(5)^2+p(6)^2+p(7)^2-1600000000;
```

Demand & Objective Function Script



```
function fobj = funobj2(p)
d1 = 50-(0.5*p(1))+(0.05*(5000-p(1)));
d2 = 50-(0.5*p(2))+(0.05*(p(1)-p(2)));
d3 = 50-(0.5*p(3))+(0.05*(p(2)-p(3)));
d4 = 50-(0.5*p(4))+(0.05*(p(3)-p(4)));
d5 = 50-(0.5*p(5))+(0.05*(p(2)-p(5)));
d6 = 50-(0.5*p(6))+(0.05*(p(5)-p(6)));
d7 = 50-(0.5*p(7))+(0.05*(p(6)-p(7)));
fobj = -((p(1)-5000)*d1)-((p(2)-5000)*d2)-((p(3)-5000)*d3)-((p(4)-5000)*d4)-((p(5)-5000)*d5)-((p(6)-5000)*d6)-((p(7)-5000)*d7);
```

Linear Constraint & Equalities and Main Script (1st Optimization)



Linear Constraint & Equalities and Main Script (1st Modification)

Editor - C:\Users\RAHADITYA\Documents\MATLAB\main5.m

```
objective = @funobj2;
p0=[10000,12100,12500,12200,15000,15900,15200];
disp(['initial objective: ' num2str(objective(p0))])
A=[1 -1 0 0 0 0 0;0 1 -1 0 0 0 0;0 0 -1 1 0 0 0;0 1 0 0 -1 0 0;0 0 1 0 0 -1 0;0 0 0 1 0 0 -1;0 0 0 0 1 -1 0;0 0 0 0 0 -1 1;0 0
b=[0; 0; 0; 0; 0; 0; 0; 0; 0];
Aeq=[1 1 1 1 1 1 1;0 1 -0.8 0 0 0 0;0 0 -0.5 1 0 0 0];
beq=[100000;0;0];
lb=[8000,8000,8000,8000,8000,8000,8000];
ub=[24000,24000,24000,24000,24000,24000,24000];
nonlincon = @nlcon2;
p=fmincon(objective,p0,A,b,Aeq,beq,lb,ub,nonlincon);
disp(p);
disp(['final objective: ' num2str(objective(p))]);
```

Linear Constraint & Equalities and Main Script (2nd Modification)

Editor - C:\Users\RAHADITYA\Documents\MATLAB\main3.m

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```
objective = @funobj2;
p0=[10000,12100,12500,12200,15000,15900,15200];
disp(['initial objective: ' num2str(objective(p0))])
A=[1 -1 0 0 0 0 0;0 1 -0.8 0 0 0 0;0 0 -0.5 1 0 0 0;0 1 0 0 -1 0 0;0 0 1 0 0 -1 0;0 0 0 1 0 0 -1;0 0 0 0 1 -0.8 0;0 0 0 0 0 -0.5
b=[0; 0; 0; 0; 0; 0; 0; 0; 0];
Aeq=[1 1 1 1 1 1 1];
beq=100000;
lb=[9000,9000,9000,9000,9000,9000,9000];
ub=[24000,24000,24000,24000,24000,24000,24000];
nonlincon = @nlcon2;
p=fmincon(objective,p0,A,b,Aeq,beq,lb,ub,nonlincon);
disp(p);
disp(['final objective: ' num2str(objective(p))]);
```

APPENDIX B

ALPHA CHANGES ON FRUIT SUPPLY CHAIN PROFIT

Tabulation Recap of Alpha Changes on FSC Profit

Percentage	Alpha	Farmer Profit	Wholesaler Profit	Retailer Profit	FSC Profit
-50%	25	Rp 31,249,986	Rp 209,587,428	Rp 316,725,000	Rp 557,562,414
-40%	30	Rp 31,278,231	Rp 209,719,183	Rp 316,890,000	Rp 557,887,414
-30%	35	Rp 31,306,476	Rp 209,850,938	Rp 317,055,000	Rp 558,212,414
-20%	40	Rp 31,334,721	Rp 209,982,693	Rp 317,220,000	Rp 558,537,414
-10%	45	Rp 31,362,966	Rp 210,114,448	Rp 317,385,000	Rp 558,862,414
Initial	50	Rp 31,391,211	Rp 210,246,203	Rp 317,550,000	Rp 559,187,414
10%	55	Rp 31,419,456	Rp 210,377,958	Rp 317,715,000	Rp 559,512,414
20%	60	Rp 31,447,701	Rp 210,509,713	Rp 317,880,000	Rp 559,837,414
30%	65	Rp 31,475,946	Rp 210,641,468	Rp 318,045,000	Rp 560,162,414
40%	70	Rp 31,504,191	Rp 210,773,223	Rp 318,210,000	Rp 560,487,414
50%	75	Rp 31,532,436	Rp 210,904,978	Rp 318,375,000	Rp 560,812,414

LOOKUP RANGE		
COST		5000
PRICE	P1	10649
	P2	12000
	P3	19567
	P4	9784
	P5	12000
	P6	24000
	P7	12000

Demand Elasticity Due to Alpha Changes (Demand 1 & Demand 2)

DEMAND ELASTICITY			
D1	= 50-(0.5*p(1))+(0.05*(5000-p(1)))	5531.95	25
		5536.95	30
		5541.95	35
		5546.95	40
		5551.95	45
		5556.95	50
		5561.95	55
		5566.95	60
		5571.95	65
		5576.95	70
		5581.95	75

DEMAND ELASTICITY			
D2	= 50-(0.5*p(2))+(0.05*(p(1)-p(2)))	5992.55	25
		5997.55	30
		6002.55	35
		6007.55	40
		6012.55	45
		6017.55	50
		6022.55	55
		6027.55	60
		6032.55	65
		6037.55	70
		6042.55	75

Demand Elasticity Due to Alpha Changes (Demand 3 & Demand 4)

DEMAND ELASTICITY			
D3	= 50-(0.5*p(3))+(0.05*(p(2)-p(3)))	10086.85	25
		10091.85	30
		10096.85	35
		10101.85	40
		10106.85	45
		10111.85	50
		10116.85	55
		10121.85	60
		10126.85	65
		10131.85	70
		10136.85	75

DEMAND ELASTICITY			
D4	= 50-(0.5*p(4))+(0.05*(p(3)-p(4)))	4327.85	25
		4332.85	30
		4337.85	35
		4342.85	40
		4347.85	45
		4352.85	50
		4357.85	55
		4362.85	60
		4367.85	65
		4372.85	70
		4377.85	75

Demand Elasticity Due to Alpha Changes (Demand 5 & Demand 6)

DEMAND ELASTICITY			
D5	= 50-(0.5*p(5))+(0.05*(P(2)-p(5)))	5925	25
		5930	30
		5935	35
		5940	40
		5945	45
		5950	50
		5955	55
		5960	60
		5965	65
		5970	70
		5975	75

DEMAND ELASTICITY			
D6	= 50-(0.5*p(6))+(0.05*(p(5)-p(6)))	12525	25
		12530	30
		12535	35
		12540	40
		12545	45
		12550	50
		12555	55
		12560	60
		12565	65
		12570	70
		12575	75

Demand Elasticity Due to Alpha Changes (Demand 7)

DEMAND ELASTICITY			
D7	= 50-(0.5*p(7))+(0.05*(p(6)-p(7)))	5325	25
		5330	30
		5335	35
		5340	40
		5345	45
		5350	50
		5355	55
		5360	60
		5365	65
		5370	70
		5375	75

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APPENDIX C

BETA CHANGES ON FRUIT SUPPLY CHAIN PROFIT

Tabulation Recap of Beta Changes on FSC Profit

Percentage	Beta	Farmer Profit	Wholesaler Profit	Retailer Profit	FSC Profit
-50%	0.25	Rp 46,430,261	Rp 314,205,990	Rp 473,550,000	Rp 834,186,250
-40%	0.30	Rp 43,422,451	Rp 293,414,032	Rp 442,350,000	Rp 779,186,483
-30%	0.35	Rp 40,414,641	Rp 272,622,075	Rp 411,150,000	Rp 724,186,716
-20%	0.40	Rp 37,406,831	Rp 251,830,118	Rp 379,950,000	Rp 669,186,949
-10%	0.45	Rp 34,399,021	Rp 231,038,161	Rp 348,750,000	Rp 614,187,181
Initial	0.5	Rp 31,391,211	Rp 210,246,203	Rp 317,550,000	Rp 559,187,414
10%	0.55	Rp 28,383,401	Rp 189,454,246	Rp 286,350,000	Rp 504,187,647
20%	0.6	Rp 25,375,590	Rp 168,662,289	Rp 255,150,000	Rp 449,187,879
30%	0.65	Rp 22,367,780	Rp 147,870,332	Rp 223,950,000	Rp 394,188,112
40%	0.7	Rp 19,359,970	Rp 127,078,374	Rp 192,750,000	Rp 339,188,345
50%	0.75	Rp 16,352,160	Rp 106,286,417	Rp 161,550,000	Rp 284,188,577

LOOKUP RANGE		
COST		5000
PRICE	P1	10649
	P2	12000
	P3	19567
	P4	9784
	P5	12000
	P6	24000
	P7	12000

Demand Elasticity Due to Beta Changes (Demand 1 & Demand 2)

DEMAND ELASTICITY			
D1	= 50-(0.5*p(1))+(0.05*(5000-p(1)))	8219.20	0.25
		7686.75	0.30
		7154.30	0.35
		6621.85	0.40
		6089.40	0.45
		5556.95	0.50
		5024.50	0.55
		4492.05	0.60
		3959.60	0.65
		3427.15	0.70
		2894.70	0.75

DEMAND ELASTICITY			
D2	= 50-(0.5*p(2))+(0.05*(p(1)-p(2)))	9017.55	0.25
		8417.55	0.30
		7817.55	0.35
		7217.55	0.40
		6617.55	0.45
		6017.55	0.50
		5417.55	0.55
		4817.55	0.60
		4217.55	0.65
		3617.55	0.70
		3017.55	0.75

Demand Elasticity Due to Beta Changes (Demand 3 & Demand 4)

DEMAND ELASTICITY			
D3	= 50-(0.5*p(3))+(0.05*(p(2)-p(3)))	15003.60	0.25
		14025.25	0.30
		13046.90	0.35
		12068.55	0.40
		11090.20	0.45
		10111.85	0.50
		9133.50	0.55
		8155.15	0.60
		7176.80	0.65
		6198.45	0.70
		5220.10	0.75

DEMAND ELASTICITY			
D4	= 50-(0.5*p(4))+(0.05*(p(3)-p(4)))	6798.85	0.25
		6309.65	0.30
		5820.45	0.35
		5331.25	0.40
		4842.05	0.45
		4352.85	0.50
		3863.65	0.55
		3374.45	0.60
		2885.25	0.65
		2396.05	0.70
		1906.85	0.75

Demand Elasticity Due to Beta Changes (Demand 5 & Demand 6)

DEMAND ELASTICITY			
D5	= 50-(0.5*p(5))+(0.05*(p(2)-p(5)))	8950.00	0.25
		8350.00	0.30
		7750.00	0.35
		7150.00	0.40
		6550.00	0.45
		5950.00	0.50
		5350.00	0.55
		4750.00	0.60
		4150.00	0.65
		3550.00	0.70
		2950.00	0.75

DEMAND ELASTICITY			
D6	= 50-(0.5*p(6))+(0.05*(p(5)-p(6)))	18550.00	0.25
		17350.00	0.30
		16150.00	0.35
		14950.00	0.40
		13750.00	0.45
		12550.00	0.50
		11350.00	0.55
		10150.00	0.60
		8950.00	0.65
		7750.00	0.70
		6550.00	0.75

Demand Elasticity Due to Beta Changes (Demand 7)

DEMAND ELASTICITY			
D7	= 50-(0.5*p(7))+(0.05*(p(6)-p(7)))	8350.00	0.25
		7750.00	0.30
		7150.00	0.35
		6550.00	0.40
		5950.00	0.45
		5350.00	0.50
		4750.00	0.55
		4150.00	0.60
		3550.00	0.65
		2950.00	0.70
		2350.00	0.75

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APPENDIX D

GAMMA CHANGES ON FRUIT SUPPLY CHAIN PROFIT

Tabulation Recap of Gamma Changes on FSC Profit

Percentage	Gamma	Farmer Profit	Wholesaler Profit	Retailer Profit	FSC Profit
-50%	0.025	Rp 32,188,991	Rp 212,068,294	Rp 321,150,000	Rp 565,407,284
-40%	0.030	Rp 32,029,435	Rp 211,703,876	Rp 320,430,000	Rp 564,163,310
-30%	0.035	Rp 31,869,879	Rp 211,339,458	Rp 319,710,000	Rp 562,919,336
-20%	0.040	Rp 31,710,323	Rp 210,975,040	Rp 318,990,000	Rp 561,675,362
-10%	0.045	Rp 31,550,767	Rp 210,610,621	Rp 318,270,000	Rp 560,431,388
Initial	0.050	Rp 31,391,211	Rp 210,246,203	Rp 317,550,000	Rp 559,187,414
10%	0.055	Rp 31,231,655	Rp 209,881,785	Rp 316,830,000	Rp 557,943,440
20%	0.060	Rp 31,072,099	Rp 209,517,367	Rp 316,110,000	Rp 556,699,466
30%	0.065	Rp 30,912,543	Rp 209,152,949	Rp 315,390,000	Rp 555,455,492
40%	0.070	Rp 30,752,987	Rp 208,788,531	Rp 314,670,000	Rp 554,211,518
50%	0.075	Rp 30,593,431	Rp 208,424,113	Rp 313,950,000	Rp 552,967,543

LOOKUP RANGE		
COST		5000
PRICE	P1	10649
	P2	12000
	P3	19567
	P4	9784
	P5	12000
	P6	24000
	P7	12000

Demand Elasticity Due to Gamma Changes (Demand 1 & Demand 2)

DEMAND ELASTICITY			
D1	= 50-(0.5*p(1))+(0.05*(5000-p(1)))	5698.18	0.25
		5669.93	0.30
		5641.69	0.35
		5613.44	0.40
		5585.20	0.45
		5556.95	0.50
		5528.71	0.55
		5500.46	0.60
		5472.22	0.65
		5443.97	0.70
		5415.73	0.75

DEMAND ELASTICITY			
D2	= 50-(0.5*p(2))+(0.05*(p(1)-p(2)))	6051.33	0.25
		6044.57	0.30
		6037.82	0.35
		6031.06	0.40
		6024.31	0.45
		6017.55	0.50
		6010.80	0.55
		6004.04	0.60
		5997.29	0.65
		5990.53	0.70
		5983.78	0.75

Demand Elasticity Due to Gamma Changes (Demand 3 & Demand 4)

DEMAND ELASTICITY			
D3	= 50-(0.5*p(3))+(0.05*(p(2)-p(3)))	10301.03	0.25
		10263.19	0.30
		10225.36	0.35
		10187.52	0.40
		10149.69	0.45
		10111.85	0.50
		10074.02	0.55
		10036.18	0.60
		9998.35	0.65
		9960.51	0.70
		9922.68	0.75

DEMAND ELASTICITY			
D4	= 50-(0.5*p(4))+(0.05*(p(3)-p(4)))	4108.28	0.25
		4157.19	0.30
		4206.11	0.35
		4255.02	0.40
		4303.94	0.45
		4352.85	0.50
		4401.77	0.55
		4450.68	0.60
		4499.60	0.65
		4548.51	0.70
		4597.43	0.75

Demand Elasticity Due to Gamma Changes (Demand 5 & Demand 6)

DEMAND ELASTICITY			
D5	= 50-(0.5*p(5))+(0.05*(p(2)-p(5)))	5950.00	0.25
		5950.00	0.30
		5950.00	0.35
		5950.00	0.40
		5950.00	0.45
		5950.00	0.50
		5950.00	0.55
		5950.00	0.60
		5950.00	0.65
		5950.00	0.70
		5950.00	0.75

DEMAND ELASTICITY			
D6	= 50-(0.5*p(6))+(0.05*(p(5)-p(6)))	12850.00	0.25
		12790.00	0.30
		12730.00	0.35
		12670.00	0.40
		12610.00	0.45
		12550.00	0.50
		12490.00	0.55
		12430.00	0.60
		12370.00	0.65
		12310.00	0.70
		12250.00	0.75

Demand Elasticity Due to Gamma Changes (Demand 7)

DEMAND ELASTICITY			
D7	= 50-(0.5*p(7))+(0.05*(p(6)-p(7)))	5050.00	0.25
		5110.00	0.30
		5170.00	0.35
		5230.00	0.40
		5290.00	0.45
		5350.00	0.50
		5410.00	0.55
		5470.00	0.60
		5530.00	0.65
		5590.00	0.70
		5650.00	0.75

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AUTHOR’S BIOGRAPHY

Rahaditya Dimas Prihadianto, The Author, was born in Jember, May 25th 1992. He finished undergraduate degree on Industrial Engineering Department in Sepuluh Nopember Institute of Technology with 3.55 of GPA score made him appreciated with cumlaude predicate. Research on Fruit Supply Chain, especially on coffee was his first research for undergraduate completion. Recently, he attempted to finish his master degree on Industrial Engineering Department in Sepuluh Nopember Institute of Technology. His second research is inline with his previous research, which is Fruit Supply Chain. Currently, he research dynamic pricing for managing product selling on fruit supply chain as one of requirement for Master Degree completion. He also complement his knowledge with certification and professional activity. He had 533 of ITP TOEFL Certification Score and experience become junior consultant on Consultancy Project between Indonesia and Swiss Universities. Beside academic aspect, he also had several working experience in various areas, both service and manufacturing areas. Further enquiries according to this research or author experiences feel free to contact by email on prihadianto@gmail.com.

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