WELFARE IMPLICATIONS OF COMPETITION IN A VERTICAL MARKET STRUCTURE: A CASE OF ACCUMULATOR INDUSTRY

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Welfare Implications of Competition in a Vertical Market Structure: A Case of Accumulator Industry

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Thesis Abstract

Sümeyye Yıldız, “Welfare Implications of Competition in a Vertical Market Structure: A Case of Accumulator Industry”

The accumulator industry exhibits a typical example of a vertical market structure, where waste accumulators are collected, then recycled in order to extract lead, which is subsequently used as the main input in the production of new accumulators. Through a theoretical model the thesis analyzes the welfare implications of the extent of competition in such a market structure. It replicates the well-known result that there is an incentive for firms to vertically integrate; yet also shows that enforcing competition is not welfare-enhancing.

Tez Özeti

Sümeyye Yıldız, "Dikey Piyasa Yapısında Rekabetin Sosyal Refaha Etkileri: Akümülator Sanayisi Örneği"

Akümülatör Sanayisi, atık akümülatörlerin toplandığı, içindeki kurşunu çıkarmak için geri dönüşüme tabi tutulduğu, ve çıkan kurşunun yeni akümülatör üretiminde temel girdi olarak kullanıldığı yapısıyla dikey piyasa yapısının tipik bir örneğini segilemektedir. Bu tez, teorik bir model kullanarak böyle bir piyasa yapısında rekabetin kapsamının sosyal refah üzerine etkilerini analiz etmektedir. Şirketlerin dikey olarak birleşme yönünde teşviklerinin olduğunu gösteren çokça kabul görmüş sonucu tekrarlamakla birlikte; rekabete zorlamanın sosyal refahı artırmadığını göstermektedir.

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CONTENTS

CHAPTER 1

INTRODUCTION

Waste accumulators are important sources of lead in the production of new accumulators. The lead inside an accumulator is valuable, which makes its collection and recovery a profitable industry. In Turkey and in many other countries, waste accumulators are collected and recycled in order to extract lead. This recovery process creates a market with three layers, which is organized in a vertical manner. The layers of the market are collectors, recyclers, and accumulator producers. The layers depend each other in terms of the inputs they buy and the outputs they sell.

In vertical market structures, it is commonly observed that one or more firms merge with firms in other layers. This merge is often called as a vertical integration. The literature indicates varying reasons for firms to vertically integrate in order to lower transaction costs, internalize externalities and decrease input-related costs by producing their own inputs due to the technologies they use.

Depending on market characteristics, vertical integration can be beneficial to merging firms, to the market as a whole, or to the society.

There is an added dimension of accumulator recycling: As they contain lead, sulphuric acid and other hazardous materials the whole process needs to be conducted properly in order to minimize the environmental and health-related externalities. Therefore, governments started to implement environmental policies in order to lower the negative impact of waste accumulators in the recovery process. In Turkey, Waste Battery and Accumulator Control (APAK) regulation was launched in 2004 in accordance with the EU directives on the management of waste batteries and accumulators.

The sector responded to this new regulation in an interesting manner: Domestic producers formed their own association, and accumulator importers their own. The producers' association controlling the recycling units formed a vertically-integrated market structure, creating a foreclosure, as a result of which importers started to suffer. Accumulator importers then made an appeal to the Competition Authority, a government-based institution in charge of securing competition in the economy. This structure is found anti-competitive by the Authority, on the basis that any vertical integration would by definition lower social welfare; as a result, the merging firms were heavily punished. Questioning whether this action of the Authority has a theoretical foundation, this thesis is structured on analyzing the welfare implications of vertical integration, and for a given model it shows that vertical integration can indeed increase the social welfare.

The second chapter explains the motivation behind this thesis. The third chapter gives the results in the literature on incentives and consequences of vertical integration; and compares with the results of this thesis. The fourth chapter introduces the model that is used. The fifth chapter uses the model of fourth chapter in order to analyze different market structures, and the sixth chapter derives social welfare in alternative market structures. Chapter seven states the results and the last chapter is the conclusion of the thesis.

CHAPTER 2

MOTIVATION

Accumulators are devices for energy storage with the help of electro-chemical processes. There exist several types of accumulators in terms of the chemicals used inside; however, the most commonly used is lead-acid type of accumulators since they have highest per cost capacity, longest useful time, and a very high recovery ratio. They have very widespread usage, one of which is inside automobiles.

There are two ways of providing lead for accumulator production, from the ores as the primary source or from recycling as the secondary source. Waste accumulators can be recycled, and the alloy of lead after material recovery can be used as the input in producing new accumulators.

Lead inside accumulators is valuable especially in a world where the primary sources are limited. Besides, environmental impact of waste accumulators is significant. Both lead as well as other parts, such as sulphuric acid and plastics, pollute soil, water and air. If lead is not disposed properly it creates severe pollution in water, soil and air. Lead stays in upper 2-5 cm of soil. If lead is mixed in water, it can be cleaned with absorption to organic matter or clays (Tsoulfas et al., 2002). It may be seen in shellfish like mussels. Humans can be exposed to lead through respiration, drinking water or food. The most common way of exposure to lead is through air with lead dusts or through food. Exposure to lead creates problems in human body especially in children. Lead is considered to have nephrotoxic effect (poisoning kidneys), it also creates problems in cardiovascular system and has implications in hypertension. Furthermore, lead can cause reduced vital functions, increased risk of cancer and other diseases, mutations in genetic material, and injuries to fetuses, the nervous system and the brain (Tsoulfas et al., 2002). Lead also creates problems in reproduction. In small children it inhibits growth, causes concentration and learning problems such as hyperactivity (U.S. Environmental Protection Agency, 2010). Other than lead, sulphuric acid which constitutes around 30% of average weight of an accumulator is dangerous for human health. It gives rise to acid burns, changes the acidity of water, hence kills microorganisms and turns into poisonous gas easily by heating. Also, sulphuric acid solution in a waste accumulator contains %70 more lead in weight than in a new accumulator which tremendously increases the harm of sulphuric acid in a waste accumulator. Moreover, the plastic parts of a waste accumulator also pollutes the environment especially water and soil, therefore threatens the lives of organisms.

Therefore, waste accumulators are considered to be in hazardous waste category. These damages created by components of waste accumulators necessitated its collection and proper disposal. The collection and recovery of lead has long been done in the past, since lead is valuable and waste accumulators are the main sources of secondary lead; but there were no regulation. Later, there aroused the need for regulation in the market in order to reduce the cost to environment and human health.

Such concerns about health and environment lead European Union and also other countries like USA to take precautions against the damage that can arise from uncontrolled waste accumulators. As a result, 91/157/EEC, 93/86/EC and 98/101/EC and

2006/66/EC directives are declared by the European Union, which brought several obligations on EU member states. Turkey as a candidate for European Union membership started to have measures on waste management in accordance with EU directives. The Waste Battery and Accumulator Control (APAK) regulation was launched in 2004 as part of Turkey's objective in complying with EU standards on waste management and environment control.

With the launch of the Waste Battery and Accumulator Control (APAK) regulation, in 31.08.2004, new obligations were set on the agents operating in the market in terms of collecting, recycling, and remanufacturing. However, the accumulator producers were seen as the main responsible agents targeted by the regulations. The new obligations have lead accumulator producers to form associations for the follow-up of all the material recovery process.

Turkey is an accumulator producer country especially in terms of automobile accumulators. Turkish accumulator producers can obtain lead either by importing primary lead as there is no pure lead production in Turkey, or acquiring from the recovery of waste accumulators. Considering the heavy cost of importing, the material recovery gains importance in terms of providing lead as the input of accumulator production.

The recovery of waste accumulators has been the main source of acquiring lead for the accumulator producers in Turkey. Therefore, waste accumulators are being collected and recycled, which created a market for these processes with collectors, recyclers and accumulator producers being the agents in this market.

The market for accumulators includes various operations from accumulator production to recycling of waste accumulators. These operations are all interrelated and hence depend the existing of others very much. In Turkey, the waste accumulator market consists of three tiers, namely the accumulator producers, the waste accumulator collectors, and the recyclers. Collectors buy waste accumulators from accumulator retailers or service providers which replace end of life accumulators of consumers with new ones. Then they sell to recyclers and after material recovery the lead is resold as an input to accumulator producers or to other sectors.

The market is structured in a vertical manner that includes three segments. These segments are interrelated in terms of inputs-outputs they use and produce. These three vertical segments of the market can be classified as the accumulator producers, the recyclers, and the collectors. The market is organized as follows:

1. Accumulator Producers: Accumulator producers buy either primary lead from outside that is extracted from the ores or secondary lead from the smelting in the recycling segment of Turkish market to be used in the production of an accumulator.
2. The Recyclers: Recyclers buy waste accumulators from collectors. The wastes are subject to recycling processes to be able to decompose lead, sulfuric acid, plastic parts and other ingredients.
3. The collectors: The collection takes place in two channels:
    a. Retailers’ channel: the retailer of accumulator producers takes used accumulators from consumers when consumers buy new ones.

b. Collectors' channel – the collectors collect accumulators from maintenance services.

The accumulator production in Turkey is approximately 80000 tones/year. There are 49 accumulator producers in the market. However, 3 among 49 have nearly 80% of the market share in production (Yılmaz, 2010; Competition Authority, 2008).

The launch of APAK Regulation in Turkish market brought obligations for all of the agents in the market in terms of collection, transportation, recycling, recovery and disposal of the waste battery and accumulators. Each segment is regulated for their actions according to the obligations they are leaned upon.

The most prominent obligation that the regulation brought is the target in collection of waste accumulators as a percentage of accumulators produced within a year. In order to reach this target as well as fulfill other obligations, the regulation comes along the recommendation of setting up systems for the follow up of all the actions in the market that are subjects of the regulation. Moreover, the ultimate responsibility of the operations and targets is given to accumulator producers and importers of accumulators.

To comply with the directives, nonprofit associations are formed by the producers and the importers. Thus, they formed two associations; Aküder and Tümaküder. All other agents in the market from collectors to recyclers have to join one of these two systems.

One of the systems was organized under Aküder which is formed by lead-acid starter accumulator producers and started in 2005 with 7 members. As of May 2010, Aküder consists of 142 producers and importers and 8 recovery facilities and includes approximately 400 collection points throughout Turkey. Aküder members represent 80%

of Turkish market for accumulator production. In 2009, Aküder members produced 62.118 kg/year (57.004 of this as starter accumulators which are used in automobiles). Aküder constitutes retailers' channel in collection and the members of Aküder formed Aküçev for this purpose. In 2009, Aküder channel has collected 92.65% of accumulators that they sold the previous year.

The second system is organized under Tümaküder, which is formed by tractioner, stationer and other dry type accumulator importers and started with 20 members in 2005. As of 2010 Tümaküder has 105 members and the member companies represent 20% of the total lead production in Turkey. Tümaküder includes 41 licensed temporary storage areas and constitutes the collectors' channel in collection. The collection takes place via collectors only as they do not have a retailer network.

In 2009, 47.449 tons of waste accumulators are collected by Aküder channel and 3.697 tons by Tümaküder channel. 28.496 tons of lead is extracted from the waste accumulators of Aküder channel and 2.218 from Tümaküder channel. The recovered lead constitutes almost 60% of the weight of waste accumulators.

The associations eased the information transfer among the agents and performed as effective platforms for collection and recovery. However, the accordance and the communication between the two channels (Aküder and Tümaküder) were not much successful.

Before the APAK regulation, the market for waste accumulators was working as the following way: collectors were buying waste accumulators from either secondary or main retailers or from maintenance/repair sites, from consumers or from government institutions via auctions. Then they were selling them to recycling facilities. Recyclers were selling lead from recovery to accumulator producers. The prices in all levels were determined by the market conditions, geographical conditions etc.

After the APAK Regulation, the agents in Aküder association gained a lot of power with the effective use of their system in the following way: Aküder members exercised the advantage of having strong retailer networks in collection and also owning recycler sites. The retailers of producers had to obey the rules determined by the producers in the system, even though they are independent organizations. Producers used their retailers for collection and even made them obliged to collect the same amount of waste as the accumulators they sold. Even though the deposit rule applies for consumers in the regulation, Aküçev obligated retailers to pay deposit to producers if they cannot give waste accumulators in the number of accumulators they sold. Therefore, retailers started to collect waste accumulators and started to act as collectors. The waste accumulators are sold to Aküçev with fixed prices set by the system in contrast to the case before APAK, where retailers could sell them with the prices they determine (Competition Authority, 2008). Other collectors in the collection channel which were mainly the members of Tümaküder were small enterprises which did not have an option other than obeying the rules set by the Aküder system since the recycling sites were owned by this system or they were even left outside the market. Moreover, using their power in the market, producers determined prices in all levels from secondary retailers to main retailer, from main retailer to recycler; so did not allow the market to work freely. Therefore, the Aküder association that is managed by the biggest accumulator producers in the production market has started to act as a strong integrated player with its collectors, recyclers and accumulator producers. Other players in all the segments were relatively small and had little or no impact on the rules set by Aküder system.

Considering the activities of channels, it can be concluded that the overall APAK Regulation damaged the market structure and created incentives for cartelization, input foreclosure, price fixing, market sharing and retail price management (RPM) types of activities by the associations. Therefore, Tümaküder members had a complaint about Aküder members for their exercise of power in the market through anti-trust activities. The Competition Authority of Turkey confirmed the anti-trust case. As a result, the responsible agents who were mainly accumulator producers were fined due to their anti-trust activities.

However, Aküder members opposed the decision. There is a disagreement between the regulation and the limits of producer activities. The Ministry of Environment and Forest claimed that the waste accumulators were considered as hazardous waste which was subject to strict regulations and cannot be considered as a commodity; therefore, it cannot be the subject of the Competition Law. The Ministry further said that it is dangerous to consider waste accumulators as a commodity because building competition on hazardous wastes is harmful for human health and environment.

The decision by the Competition Authority relies on the opinion that the collaboration among Aküder members is hindering competition; and less competition is detrimental to society in terms of welfare.

This thesis aims to analyze and model the market structure as well as the anti-trust case in the waste accumulator market in Turkey. Furthermore, the thesis aims to question the decision made by the Competition Authority on the anti-trust case in the Turkish waste accumulator market.

Turkish waste accumulator market exhibits a vertical market structure with three layers. The collaboration among Aküder members which are operating in different layers is similar to a merger of firms in vertical markets. In the thesis, the vertically integrated layers refer to this collaboration of firms. By comparing the production and welfare levels in alternative market structures, the thesis aims to evaluate the decision by the Competition Authority on the merger-like act of Aküder members.

CHAPTER 3

LITERATURE REVIEW

Vertical markets are related in such a manner that one market depends on the other in terms of its inputs. The input or intermediate good producer market is called ‘upstream’ and the market that buys input from upstream to produce the final output is called ‘downstream’. Firms operating in these markets may decide to merge and this merger is called ‘vertical integration’ (Perry, 1989; Churh & Ware, 2000; Carlton & Perloff, 2000; Martin, 1993).

Firms may have many incentives to vertically integrate. Perry (1989) discusses varying reasons why a firm may find vertical integration to be beneficial. He states that *technological economies, transactional economies, and market imperfections* are the three determinants of vertical integration. Firms may lower costs by directly producing inputs due to the technology that is used. Firms may avoid part of the transactional costs by integrating. Integration may help firms to guarantee the supply of the input, to create barriers to entry in order to keep dominance, to be able to price discriminate or to increase rivals’ costs. Moreover, externalities can be internalized by integration such as retail service externality. There can be differences among services of different retailers of a product which is eliminated if the producing firm integrates with retailers and maintain a minimum level of quality in service. Integration can help correct the problem arising from imperfect competition that prevents firms to reach profit maximizing price levels. Integration may help eliminate imperfect or asymmetric information problem. Vertical integration helps downstream to obtain private information such as production costs of upstream in making investment decisions.

In the literature it is a well-established fact that vertical integration by monopolies in upstream and downstream is a good way to eliminate part of the inefficiency arising from monopolies. The inefficiency due to successive monopolies in vertically related markets is called ‘double monopoly markup’ (Carlton & Perloff, 2000) or ‘double marginalization’ (Church & Ware, 2000). Monopolies set their prices above their marginal costs. This difference creates inefficiency which is called as ‘monopoly markup’ in the literature. In vertical markets, if both the upstream and downstream firms are monopolies, then it means that both firms will set their prices above their marginal costs, thus monopoly markup will arise in both upstream and downstream markets. Vertical integration is a way to eliminate these double markups. If the firms are vertically integrated, the input price (the price of the good that is produced by the upstream) is determined at the marginal cost, thus integration will eliminate one of the markups. The elimination of double markups will be beneficial for both the consumers and the producers. Double marginalization problem is also considered as an externality (Church & Ware, 2000, pp. 686-687). There are two margins; one by downstream as retail margin and one by upstream as wholesale margin. The externality occurs because the downstream retailer does not take into account the upstream wholesale margin when setting its price. Thus the retailer price will be too high than profit maximizing level of joint profits. However, if the firms are vertically integrated, then the price will be determined at the level that maximizes both upstream and downstream profits.

If there is perfect competition in downstream with fixed proportions production function (impossible to substitute one good for another), there will be no need to vertically integrate as the resulting profits will be the same as a vertically integrated firm. And a price change in upstream directly reflects as a cost to downstream and hence to consumer prices. So upstream monopoly can perfectly control downstream. Carlton and Perloff explains the issue as ‘the reason that the non-integrated monopoly can control the downstream price perfectly is that the downstream firms cannot substitute away from the input produced by the monopoly’ (Carlton & Perloff, 2000, p.392). However, in variable proportions production function, it is not possible to control downstream perfectly as they can substitute away from the input produced by upstream, so the upstream monopoly has the incentive to vertically integrate. Since the final price may rise or fall after such an integration, the welfare effect is ambiguous.

Vertical integration has been a controversial issue in antitrust cases. There are many cases where the Courts found the integration as an anti-competitive act and punished the integrating firms. The reason in such cases was that vertical integration will result in market foreclosure and the resulting situation is considered as welfare diminishing. Economists have contrary studies on the impact of vertical integration on the market structure, on the profitability of the firms, on the consumer surpluses and on the welfare of the society.

Vertical integration can lead to anticompetitive behaviors and market foreclosure according to Comanor (1967); Ordover, Saloner and Salop (1990); and Chen (2001). Ordover, Saloner and Salop (1990) show that vertical integration creates anticompetitive market foreclosure in equilibrium. Comanor (1967) argues that vertical integration may result in anticompetitive behaviors other than foreclosure channel. He states that the anticompetitive consequences of vertical mergers are related to market structure and behaviors. However, according to Salinger (1988) and Chen (2001), vertical integration does not always result in market foreclosure. Salinger (1988) analyses the impact of vertical mergers on the unintegrated firms in the industry and shows that vertical integration does not always cause market foreclosure. Chen (2001) points out that vertical integration causes collusive behaviors but he further argues that the integration does not always lead to foreclosure and the unintegrated downstream firm may choose to buy input from integrated firm which is integrated with a cost-efficient upstream.

Vertical integration can be profitable for the firms in the market. Ordover, Saloner and Salop (1990) investigate the consequences of integration in terms of profitability of foreclosure in a model with differentiated products and price-setting, and conclude that foreclosure is profitable in the market if the gain of unintegrated upstream exceeds the loss of the downstream. Chen (2001) shows that vertical integration will yield higher efficiency, in his work where he investigates the impact of vertical mergers on pricing incentives of downstream firms and considers the strategic behaviors of both upstream and downstream firms. However, there are studies which show that the profitability of integration does not always occur. According to Hamilton and Mqasqas(1996), it is not always profitable for individual firms and hence there is not always a profit incentive to integrate. They make the distinction between firm level and industry level analysis and state that the type of the analysis, the size of the conjectural variation and the market structure is important in the profitability of integration.

Consumers can benefit from vertical integration. According to Chen (2001), consumers benefit from efficiency gain that occurs after integrating with a cost-efficient supplier, if the switch cost from less efficient to more efficient supplier is small. If the switching cost is high, consumers can even benefit if there is product differentiation. Salinger (1988) shows that when there is no foreclosure, the integration results in lower final good prices which increase the welfare of the consumers. However, depending on the case, the integration makes the intermediate good prices rise which result in higher final good prices that means consumers do not benefit from elimination of double marginalization due to vertical integration. In the model by Ordover, Saloner and Salop (1990), the output prices rise after integration with foreclosure, therefore consumers' benefit reduces and moreover the net effect is negative meaning a decrease in social welfare.

In the literature, there are controversial results on the impact of vertical integration on welfare. According to the Hamilton and Mqasqas (1996), integration is beneficial for the society as a whole. However, Ordover, Saloner and Salop (1990) show that even though firms make higher profits after integration, the reduction in consumer surplus due to higher prices surpasses higher profits, hence the net effect is negative meaning a decrease in social welfare. Hamilton and Mqasqas (1996) use conjectural variation (CV) models to show that vertical integration always increases the output produced, decreases prices and increases economic welfare due to elimination of double marginalization. Linnemer (2002) points out that integration can increase or decrease welfare depending on the market share of the integrating firm. He shows that vertical integration by a dominant upstream firm when there is Cournot competition in downstream is welfare enhancing due to the elimination of inefficiency in input costs when high input costs refer to high market share. The gain in welfare arises when the market share of the firm is high, however if a firm with a low market share integrates, the result will be welfare diminishing.

The results in this thesis are in line with the results of Hamilton and Mqasqas (1996) and Linnemer (2002) in terms of welfare impact. One of the conclusions of the thesis is that; when there is a market where successive monopolies in each segment integrate and create a single monopoly that operates in all segments, vertical integration results in higher social welfare. Also, for a market where a group of firms integrate and there remains another group of firms which do not, vertical integration is again socially beneficial. In terms of consumers' benefits, consequences in these cases are parallel to the welfare consequences and similar to Chen (2001). Moreover, the thesis extends the argument of Salinger (1988) who says lower final good prices, and hence higher consumers' benefit occurs if there is not foreclosure, but in the thesis the increase in consumers' surplus occurs even there is foreclosure. However, a combination of vertical and horizontal integration of imperfectly competitive vertical markets into a single monopoly may result in higher or lower welfare, and consumers' benefit in this case is not straightforward and depends on market characteristics. Analyzing in terms of profitability, the thesis shows that there is an incentive for firms to vertically integrate as the integrating firms increase their profits. However, the nonintegrated firms are affected negatively.

CHAPTER 4

THE MODEL

The waste accumulator market consists of three segments, namely the accumulator producers, the waste accumulator collectors, and the recyclers. There is a vertical relationship among the segments in which accumulator producers being in the downstream, collectors being in the upstream, and recyclers being in the middle segment. The agents in the segments are dependent on agents on other segments in terms of inputs they use and outputs they sell. The input-output exchange is such that: collectors buy waste accumulators from accumulator retailers or service providers which replace end-of-life accumulators of consumers with new ones, then they sell to recyclers and after material recovery the lead is resold to accumulator producers (or to other sectors) to be used as an input. The market is assumed to be a closed market, hence there is no import or export.

The three segments of the market - from upstream to the down- are;

1. The Collectors

There are two collectors, $k \in \{1,2\}$, operating in the collection segment of the market. The collectors' input and output are the waste (w) itself since they do not process the waste collected. They collect waste accumulators from retailers or maintenance services and sell them to recyclers with a price of p_c. A quadratic cost function for collecting waste accumulators is assumed. As the number of waste collected increases, the cost to collect an additional waste will be higher because collectors will need to go to further distances to find the waste. Then, the cost function for a collector becomes;

$$C_k^c(w_k) = \frac{1}{2} c_c w_k^2 \qquad \textit{for} \quad k = \{1,2\}, \tag{1}$$

where $c_c > 0$, and the profit function for a collector is;

$$\Pi_k^c(w_k) = p_c w_k - \frac{1}{2} c_c w_k^2 \qquad \textit{for} \quad k = \{1,2\}. \tag{2}$$

Marginal cost pricing is assumed in this layer which suits Turkish accumulator market. In Turkey, there are many firms operating in collection layer, also the technology in collection is simple. The entry to the collection market is easy and therefore any profit above perfect competition level would attract more firms to enter to the market until the firms will make zero profit in equilibrium.

2. The Recylers

There are two recyclers, $j \in \{1,2\}$, in the recycling segment and they extract lead from waste accumulators. They use waste accumulators (w) that they bought from collection segment as an input for recycling and sell the extracted lead (l) to the accumulator producers' segment. The lead produced is assumed to be homogenous. One unit of waste accumulator, w_j, is bought with the price of p_c from the collectors. The production function for recycling lead is $l_j = h(w_j, y_j) = \gamma \min\{w_j, y_j\}$, where $\gamma \in (0,1)$. In the production function, w_j stands for waste used as an input, y_j stands for composite inputs other than waste that are used in recycling process, and γ is the technology-specific parameter. We assume that the decisive input for recycling is waste since it is relatively more scarce and it is the main ingredient for the recycling process. Let $c_r > 0$ be the unit price of composite input y_j.

The cost minimization problem of recycler j is;

$$\min_{w_j, y_j} p_c w_j + c_r y_j \tag{3}$$

$$s.t. \quad l_j = \gamma \min\{w_j, y_j\}$$

$$w_j \geq 0, y_j \geq 0.$$

From the above cost minimization problem, the conditional factor demand functions for w_j and y_j are $w_j = y_j = \dfrac{l_j}{\gamma}$, and the total cost of a recycler is;

$$C_j^r(l_j) = p_c \frac{l_j}{\gamma} + c_r \frac{l_j}{\gamma} \qquad for \quad j = \{1,2\}. \tag{4}$$

The recyclers sell one unit of lead with the price p_r to the accumulator producers, so the profit function of a recycler is;

$$\Pi_j^r(l_j) = p_r l_j - (p_c + c_r)\frac{l_j}{\gamma} \qquad for \quad j = \{1,2\}. \tag{5}$$

3. Automotive Accumulator Producers

There are two firms, $i \in \{1,2\}$, producing homogeneous products. Each firm buys lead (l) from the recycling segment, uses lead and other chemicals and plastics to produce accumulators (q), and sells the accumulators that is produced to final consumers.

Let q_i be the quantity of accumulators produced by firm i, and P_a be the price of an accumulator. The consumers' demand for accumulator is represented by an inverse demand function $P_a(Q) = \alpha - Q$, where $Q = q_1 + q_2$.

The accumulator producer *i* buys l_i amounts of lead from the recycling layer with the price of p_r to be used as an input. Other inputs used in the production are denoted as z_i and obtainable from a competitive market at a price of $c_a > 0$. The production function for accumulator production exhibits constant returns to scale feature and it is represented as $q_i = f(l_i, z_i) = \min\{l_i, z_i\}$. Again, we assume that the decisive input for the production is lead since it is relatively more scarce and it is the main ingredient for accumulator production.

The cost minimization problem that a producer solves is;

$$\min_{l_i, z_i} p_r l_i + c_a z_i \tag{6}$$

$$s.t. \quad q_i = \min\{l_i, z_i\}$$

$$l_i \geq 0, z_i \geq 0.$$

From the cost minimization, the conditional factor demands for l_i and z_i are $l_i = z_i = q_i$, and we have the cost function for a producer as follows;

$$C_i^a(q_i) = p_r q_i + c_a q_i \qquad for \quad i = \{1,2\}, \tag{7}$$

and the profit function of an accumulator producer i becomes;

$$\Pi_i^a(q_i) = P_a q_i - (p_r + c_a) q_i \qquad for \quad i = \{1,2\}. \tag{8}$$

CHAPTER 5

MARKET STRUCTURES IN THE MODEL

We will be checking for four market structures. Successive Monopolies (SM) market structure is the case where there are monopolies in each layer of the market. In the Fully Integrated (FI) market structure, there is one monopolistic firm operating in all layers of the market. Fully Disintegrated (FD) market structure is the case where there are two firms for each layer. In the Semi-Integrated (SI) market structure, there is an integrated firm which operates in all layers on the one side of the market and there is one independent firm for each layer on the other side of the market.

Successive Monopolies (SM)

In this market structure, we assume that there is only one firm operating in each layer. The firms in accumulator production and recycling segments are monopolies. In the collection segment there is a firm which makes marginal cost pricing; this assumption is equivalent to the assumption that there is perfectly-competitive collection segment with many firms operating.

To solve the resulting output levels in this market structure, we use a backward induction method, starting from the downstream firm.

1. Accumulator Producers;

There is a monopolistic firm producing accumulators, thus $Q = q$. The profit maximization problem for the producer is then;

$$\max_{q} (\alpha - q)q - (p_r + c_a)q \tag{9}$$

$$s.t. \quad q \geq 0.$$

The first order condition for the maximization problem (9) is;

$$\alpha - 2q - p_r - c_a = 0. \tag{10}$$

The resulting output level is;

$$q = \frac{\alpha - p_r - c_a}{2}. \tag{11}$$

From the equation above, we can obtain the derived inverse demand for recyclers as;

$$p_r = \alpha - c_a - 2q. \tag{12}$$

Given the cost minimization, accumulator producer's conditional factor demand for lead is $q = l$, and the inverse derived demand function of lead that the recyclers face becomes;

$$p_r = \alpha - c_a - 2l. \tag{13}$$

2. Recyclers;

There is only one recycler which determines how much lead to produce to maximize its profit. The maximization problem of the monopolistic recycler is;

$$\max_{l} p_r l - (p_c + c_r)\frac{l}{\gamma} \tag{14}$$

$$s.t. \quad l \geq 0.$$

By inserting the derived inverse demand function (13) from accumulator producer's problem, the optimization problem (14) becomes;

$$\max_{l} (\alpha - c_a - 2l)l - (p_c + c_r)\frac{l}{\gamma} \tag{15}$$

$$s.t. \quad l \geq 0.$$

Hence, the first order condition is;

$$\alpha - c_a - 4l - \frac{p_c + c_r}{\gamma} = 0, \tag{16}$$

yielding the quantity of lead supplied as;

$$l = \frac{\gamma(\alpha - c_a) - p_c - c_r}{4\gamma}. \tag{17}$$

Given the conditional factor demand function for waste, $l = \gamma w$, and the equation (17), the derived inverse demand function of waste accumulators is;

$$p_c = \gamma(\alpha - c_a) - c_r - 4\gamma^2 w. \tag{18}$$

3. Collectors;

Similarly, there is only one firm operating in this segment; however, it is assumed that the collector acts perfectly competitive. Thus, it will produce at $P = MC$. The problem that the collector solves is;

$$\max_{w} \; p_c w - \frac{1}{2} c_c w^2 \tag{19}$$

$$s.t. \quad w \geq 0.$$

Then, the first order condition is;

$$p_c - c_c w = 0. \tag{20}$$

Substituting (18) into (20), the first order condition becomes;

$$\gamma(\alpha - c_a) - c_r - 4\gamma^2 w - c_c w = 0. \tag{21}$$

Solving for w yields the optimal waste collected by this firm as (letting $W = w$);

$$W^{SM} = \frac{\gamma(\alpha - c_a) - c_r}{4\gamma^2 + c_c}. \tag{22}$$

Recall the conditional factor demand $q = l$ and $l = \gamma w$, so $q = \gamma w$. Then, the optimal accumulator production in the Successive Monopolies market structure is;

$$Q^{SM} = \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{4\gamma^2 + c_c}. \tag{23}$$

We assume $\alpha - c_a - \frac{c_r}{\gamma}$ to be positive, hence $\alpha > c_a + \frac{c_r}{\gamma}$ should hold. Since α is the maximum price that the consumers are willing to pay, and $c_a + \frac{c_r}{\gamma}$ is the marginal cost of recycling and accumulator production, the assumption is meaningful as the marginal cost of producing cannot be higher than the maximum price that the consumers are willing to pay, otherwise the producers do not produce.

As expected, an increase in the prices of composite inputs will lead to reduction in the amounts produced.

$$\frac{\partial Q^{SM}}{\partial c_a} < 0, \frac{\partial Q^{SM}}{\partial c_r} < 0. \tag{24}$$

Fully Integrated Market (FI)

In this case we assume that there is a monopoly in the market which operates in collecting wastes, recycling them and then producing accumulators.

The monopolistic firm is dealing with collecting wastes, recycling them and producing lead, and producing accumulators by using the lead it has produced. Therefore, the firm is maximizing the profits related to all the segments. The objective function for the monopolistic firm is therefore the sum of all the profits in the segments;

$$\Pi^{FI} = \Pi^{a} + \Pi^{r} + \Pi^{c}. \tag{25}$$

Since there is only one firm, we eliminate the subscripts, k, j or i, which indicate single separate firms. We insert the cost minimization outcomes from recycling and accumulator production where $l = \gamma w = \gamma y$ for the former and $q = l = z$ for the latter. Then, equation (25) becomes;

$$\Pi^{FI}(q) = P_a q - (p_r + c_a)q + p_r q - (p_c + c_r)\frac{q}{\gamma} + p_c \frac{q}{\gamma} - \frac{1}{2}c_c(\frac{q}{\gamma})^2. \tag{26}$$

Simplifying (26), we have the following objective function to maximize the profits for the monopoly;

$$\max_{q} \Pi^{FI}(q) = P_a q - \frac{1}{2}c_c(\frac{q}{\gamma})^2 - c_r \frac{q}{\gamma} - c_a q \tag{27}$$

$$s.t. \quad q \geq 0,$$

where q is the quantity of accumulators produced, and $P_a = \alpha - q$ is the inverse demand function for accumulators. The first term reflects the firm's profits from selling the accumulators, the second term $\frac{1}{2}c_c(\frac{q}{\gamma})^2$ is the cost of collection to the monopolist, the third term $c_r \frac{q}{\gamma}$ is the cost of recyling, and the last term $c_a q$ is the cost of processing lead for accumulator production.

The first order condition of this maximization problem is;

$$\alpha - 2q - c_c \frac{q}{\gamma^2} - \frac{c_r}{\gamma} - c_a = 0, \tag{28}$$

$$\alpha - \frac{c_r}{\gamma} - c_a = 2q + c_c \frac{q}{\gamma^2},$$

$$= q(2 + \frac{c_c}{\gamma^2}).$$

Since there is only one agent in this market, the total production is equal to the production of the agent, $Q = q$. Then, the optimal quantity of accumulators produced is;

$$Q^{FI} = \frac{\alpha - \frac{c_r}{\gamma} - c_a}{2 + \frac{c_c}{\gamma^2}},$$

$$Q^{FI} = \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{2\gamma^2 + c_c}, \tag{29}$$

Using the cost minimization problem of accumulator production that $q = l = z$, the optimal waste collected becomes;

$$W^{FI} = \frac{\gamma(\alpha - c_a) - c_r}{2\gamma^2 + c_c}. \tag{30}$$

As expected, increase in the prices of composite inputs will lead to reduction in the amounts produced.

$$\frac{\partial Q^{FI}}{\partial c_a} < 0, \frac{\partial Q^{FI}}{\partial c_r} < 0. \tag{31}$$

Fully Disintegrated Market (FD)

In this structural setup, the market consists of three independent layers each with two agents. The layers are collectors, recyclers and accumulator producers as before.

In the collection layer, the two agents are applying marginal cost pricing where agents make zero profit. The price in this layer is determined according to the $P = MC$ equation.

In the other layers, recycling and production, the agents are playing a Cournot's game. One could also consider the interaction in the Bertrand sense. However, since producers and recyclers are operating under a capacity constraint, the equilibrium of a

Bertrand's game would coincide with that of Cournot's game (Kreps and Scheinkman, 1983).

Since we have vertically related markets, we solve the maximization problems by using the backward induction, starting from the downstream, the accumulator producers.

1. Accumulator Producers;

There are two accumulator producers, $i \in \{1,2\}$, which determine how much to produce given the demand they faced. The maximization problem for a producer is then,

$$\max_{q_i} (\alpha - Q)q_i - (p_r + c_a)q_i \tag{32}$$

$$s.t. \quad q_i \geq 0,$$

where $Q = q_1 + q_2$ for our duopoly case.

By solving the maximization problem, we have the first order condition as;

$$\alpha - q_{-i} - 2q_i - (p_r - c_a) = 0, \tag{33}$$

and the response function of firm i is;

$$q_i = \frac{\alpha - q_{-i} - p_r - c_a}{2}.$$

Since we assumed the producers to be identical, the solution is symmetric for both of the agents, so each firm i produces;

$$q_i = \frac{\alpha - p_r - c_a}{3}. \tag{34}$$

Therefore, the total quantity of accumulators produced for Fully Disintegrated market structure is;

$$Q^{FD} = \frac{2}{3}(\alpha - p_r - c_a). \tag{35}$$

The producers pay p_r to recyclers for a unit of lead they buy in order to produce accumulators. So, we can extract the inverse demand function of lead for recyclers using the equation (35) and the result of the cost minimization problem of accumulator producers, that $q = l$, as;

$$p_r = \alpha - c_a - \frac{3}{2}L. \tag{36}$$

2. Recyclers;

There are two recyclers, $j \in \{1,2\}$, which determine how much lead to produce and hence how much waste to use as the input. A recycler maximizes her profits with the demand she faces and cost she incurs. The maximization problem of a recycler is;

$$\max_{l_j} p_r l_j - (p_c + c_r)\frac{l_j}{\gamma} \tag{37}$$

$$s.t. \quad l_j \geq 0.$$

The first term reflects the profits from selling the lead to accumulator producers, and the second term is the cost of buying and processing wastes to the recycler. By inserting the inverse demand function (36), the optimization problem becomes;

$$\max_{l_j} (\alpha - c_a - \frac{3}{2}L)l_j - (p_c + c_r)\frac{l_j}{\gamma} \tag{38}$$

$$s.t. \quad l_j \geq 0.$$

Hence, the first order condition is;

$$\alpha - c_a - \frac{3}{2}l_{-j} - 3l_j - \frac{p_c + c_r}{\gamma} = 0, \tag{39}$$

resulting with the response function for firm j ;

$$l_j = \frac{\alpha - c_a - \frac{3}{2} l_{-j} - \frac{p_c + c_r}{\gamma}}{3}.$$

Since we have symmetric equilibrium and two identical agents;

$$l_j = \frac{\alpha - c_a - \frac{3}{2}\left[\frac{\alpha - c_a - \frac{3}{2} l_j - \frac{p_c + c_r}{\gamma}}{3}\right] - \frac{p_c + c_r}{\gamma}}{3},$$

$$3l_j = \alpha - c_a - \frac{1}{2}\left(\alpha - c_a - \frac{3}{2} l_j - \frac{p_c + c_r}{\gamma}\right) - \frac{p_c + c_r}{\gamma},$$

$$3l_j = \frac{2\alpha - 2c_a - \alpha + c_a + \frac{3}{2} l_j + \frac{p_c + c_r}{\gamma} - 2\frac{p_c + c_r}{\gamma}}{2}$$

$$6l_j = \alpha - c_a - \frac{3}{2} l_j - \frac{p_c + c_r}{\gamma},$$

$$\frac{9}{2}l_j = \alpha - c_a - \frac{p_c + c_r}{\gamma}.$$

The optimal amount of lead produced by a recyler, $j \in \{1,2\}$, becomes;

$$l_j = \frac{2}{9}[\alpha - c_a - \frac{p_c + c_r}{\gamma}]. \tag{40}$$

The total lead produced by recylers for a market with two identical firms operating in recycling segment which is $L^{FD} = l_1 + l_2$ becomes;

$$L^{FD} = \frac{4}{9}[\alpha - c_a - \frac{p_c + c_r}{\gamma}]. \tag{41}$$

Again, applying the backward induction method in order to extract the inverse demand function of waste accumulators that collectors face, we have;

$$\frac{9}{4}L = \frac{\gamma(\alpha - c_a) - p_c - c_r}{\gamma},$$

$$\frac{9}{4}\gamma L = \gamma(\alpha - c_a) - c_r - p_c,$$

$$p_c = \gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma L. \tag{42}$$

Hence, from the cost minimization of recyclers where we have $l = \gamma w$, the inverse demand function of waste accumulators that collectors face becomes;

$$p_c = \gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2 W. \tag{43}$$

3. Collectors;

At the collectors level, we have two identical agents, $k \in \{1,2\}$, who set their prices equal to marginal costs. The resulting level of optimal waste collection can be extracted according to the $P = MC$ equation. The cost of collection is increasing with the number of wastes, hence we have a quadratic cost function for a collector as $\frac{1}{2}c_c w_k^2$, then the marginal cost becomes $c_c w_k$. By equating price to marginal cost, we have;

$$\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2 W = c_c w_k, \tag{44}$$

where $W = w_1 + w_2$.

Then;

$$\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2(w_k + w_{-k}) = c_c w_k,$$

$$\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2 w_{-k} = c_c w_k + \frac{9}{4}\gamma^2 w_k,$$

$$= w_k(c_c + \frac{9}{4}\gamma^2).$$

Hence, the response function of a collector, $k \in \{1,2\}$, is;

$$w_k = \frac{\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2 w_{-k}}{c_c + \frac{9}{4}\gamma^2}. \tag{45}$$

Since we have two identical agents, we have symmetric results for w_{-k}; therefore;

$$w_k = \frac{\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2[\frac{\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2 w_k}{c_c + \frac{9}{4}\gamma^2}]}{c_c + \frac{9}{4}\gamma^2},$$

$$w_k = \frac{\gamma(\alpha - c_a) - c_r - \frac{9}{4}\gamma^2[\frac{4\gamma(\alpha - c_a) - 4c_r - 9\gamma^2 w_k}{4c_c + 9\gamma^2}]}{\frac{4c_c + 9\gamma^2}{4}},$$

$$w_k = \frac{\frac{4(4c_c + 9\gamma^2)(\gamma(\alpha - c_a) - c_r) - 9\gamma^2[4\gamma(\alpha - c_a) - 4c_r - 9\gamma^2 w_k]}{4(4c_c + 9\gamma^2)}}{\frac{4c_c + 9\gamma^2}{4}},$$

$$w_k = \frac{(16c_c + 36\gamma^2)(\gamma(\alpha - c_a) - c_r) - 36\gamma^2(\gamma(\alpha - c_a) - c_r) + 81\gamma^4 w_k}{(4c_c + 9\gamma^2)^2},$$

$$w_k(1 - \frac{81\gamma^4}{(4c_c + 9\gamma^2)^2}) = \frac{16c_c(\gamma(\alpha - c_a) - c_r)}{(4c_c + 9\gamma^2)^2}.$$

The optimal waste collected by one of the agents is therefore;

$$w_k = \frac{16c_c(\gamma(\alpha - c_a) - c_r)}{(4c_c + 9\gamma^2)^2 - 81\gamma^4},$$

$$w_k = \frac{16c_c(\gamma(\alpha - c_a) - c_r)}{(4c_c + 9\gamma^2 - 9\gamma^2)(4c_c + 9\gamma^2 + 9\gamma^2)},$$

$$w_k = \frac{4(\gamma(\alpha - c_a) - c_r)}{(4c_c + 18\gamma^2)}. \tag{46}$$

Then, the total waste collection $W^{FD} = w_1 + w_2$ in this market becomes;

$$W^{FD} = \frac{8(\gamma(\alpha - c_a) - c_r)}{(4c_c + 18\gamma^2)}. \tag{47}$$

From cost minimization problems we know $q = l$ and $l = \gamma w$, so $q = \gamma w$ also holds. Then, the optimal accumulator production in the Fully Disintegrated market structure is;

$$Q^{FD} = \frac{8(\gamma^2(\alpha - c_a) - \gamma c_r)}{(4c_c + 18\gamma^2)}. \tag{48}$$

As expected, an increase in the prices of composite inputs will lead to a reduction in the amounts produced.

$$\frac{\partial Q^{FD}}{\partial c_a} < 0, \frac{\partial Q^{FD}}{\partial c_r} < 0. \tag{49}$$

Semi-Integrated Market (SI)

In this market structure we observe two types of formations. On the one side of the market, we observe an integrated firm similar to Fully Integrated case, where a single agent operates as collector, recycler and producer. On the other side of the market, each layer has a separate agent who operates just in his own layer, i.e. we have one agent as collector, another one as recycler, and one as producer. The integrated formation competes with separate-agents formation on the other side of the market. One could envision different types of competition for the semi-integrated market structure as well, such as the integrated side purchasing recycled lead from the non-integrated side. However, the current set-up reflects the post-APAK structure emerged in Turkish market better, as Aküder, acting under Aküçev, foreclosed its market to its members, banning them to make trade with outsiders.

Integrated Side of the Market

In this side, the integrated firm is called 'Firm-1'. The firm has a similar objective function with the firm in Fully Integrated market structure. However, the demand that the firms face depends not only on its own production level but also on the production from the non-integrated side of the market. Therefore, the firm's problem can be written as;

$$\max_{q_1} P_a q_1 - \frac{1}{2} c_c (\frac{q_1}{\gamma})^2 - c_r \frac{q_1}{\gamma} - c_a q_1 \tag{50}$$

$$s.t. \quad q_1 \geq 0,$$

where $P_a = \alpha - Q$, and $Q = q_1 + q_2$. Here, q_1 denotes the production of the firm in the integrated side, and q_2 denotes the production of the non-integrated side of the market.

By solving the maximization problem of the integrated firm, the first order condition is;

$$\alpha - 2q_1 - q_2 - c_c (\frac{q_1}{\gamma^2}) - \frac{c_r}{\gamma} - c_a = 0, \tag{51}$$

$$q_1 (2 + \frac{c_c}{\gamma^2}) = \alpha - q_2 - \frac{c_r}{\gamma} - c_a.$$

Therefore, the response function of Firm-1 is;

$$q_1 = \frac{\alpha - q_2 - \frac{c_r}{\gamma} - c_a}{2 + \frac{c_c}{\gamma^2}}. \tag{52}$$

Non-Integrated Side of the Market

There are separate firms operating at each layer. The firm in the accumulator production layer is in Cournot competition with Firm-1. The recycler firm is a monopoly on the non-integrated side of the market. The collector firm is a single firm but it is applying marginal cost pricing.

(a) Accumulator Producer;

The problem of the accumulator producer is;

$$\max_{q_2} P_a q_2 - (p_r + c_a) q_2 \tag{53}$$

$$s.t. \quad q_2 \geq 0.$$

Hence the first order condition is;

$$\alpha - q_1 - 2q_2 - p_r - c_a = 0. \tag{54}$$

The response function of accumulator producer on the non-integrated side becomes;

$$q_2 = \frac{\alpha - q_1 - p_r - c_a}{2}. \tag{55}$$

We derive the inverse demand for lead from the equations above by using the conditional factor demand function as $l_2 = q_2$, we have;

$$p_r = \alpha - c_a - q_1 - 2l_2. \tag{56}$$

(b) Recycler;

The problem of the recycler is;

$$\max_{l_2} p_r l_2 - (p_c + c_r)\frac{l_2}{\gamma} \tag{57}$$

$$s.t. \quad l_2 \geq 0,$$

where l_2 is the amount of lead produced in this layer by the recycler. The price at which the recycler can sell lead is determined by (56), the derived inverse demand for lead. By substituting (56) into the problem (57), its first order condition becomes;

$$\alpha - c_a - q_1 - 4l_2 = \frac{p_c + c_r}{\gamma}. \tag{58}$$

Using factor demand function $l_2 = \gamma w_2$, the inverse demand for waste is derived from the above equation as;

$$p_c = \gamma(\alpha - c_a - q_1) - 4\gamma^2 w_2 - c_r, \tag{59}$$

where w_2 is the waste collected on the non-integrated side of the market.

(c) Collector;

The objective function for the collector in this layer is;

$$\max_{w_2} p_c w_2 - \frac{1}{2} c_c w_2^2 \tag{60}$$

$$s.t. \quad w_2 \geq 0.$$

We assume that there is only one firm in this layer of non-integrated side but the firm applies marginal cost pricing. The price is derived from recycler's layer as in the equation (59), and the marginal cost is $c_c w_2$; so the marginal cost pricing condition becomes;

$$\gamma(\alpha - c_a - q_1) - 4\gamma^2 w_2 - c_r - c_c w_2 = 0, \tag{61}$$

$$\gamma(\alpha - c_a - q_1) - c_r = w_2(c_c + 4\gamma^2). \tag{62}$$

The waste collected and sold in this side of the market is;

$$w_2 = \frac{\gamma(\alpha - c_a - q_1) - c_r}{c_c + 4\gamma^2}. \tag{63}$$

Using the conditional factor demand functions $q_2 = l_2$ and $l_2 = \gamma w_2$, the response function of accumulators produced on the non-integrated side of the market becomes;

$$q_2 = \frac{\gamma^2(\alpha - c_a - q_1) - \gamma c_r}{c_c + 4\gamma^2}. \tag{64}$$

Substituting (64) into equation (52), we have;

$$q_1 = \frac{\alpha - \frac{c_r}{\gamma} - c_a - [\frac{\gamma^2(\alpha - c_a - q_1) - \gamma c_r}{c_c + 4\gamma^2}]}{2 + \frac{c_c}{\gamma^2}}, \tag{65}$$

$$q_1 = \frac{\frac{(c_c + 4\gamma^2)(\alpha - \frac{c_r}{\gamma} - c_a) - \gamma^2(\alpha - c_a - \frac{c_r}{\gamma}) + \gamma^2 q_1}{c_c + 4\gamma^2}}{2 + \frac{c_c}{\gamma^2}},$$

$$q_1 = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{(4\gamma^2 + c_c)(2\gamma^2 + c_c)} + \frac{\gamma^4 q_1}{(4\gamma^2 + c_c)(2\gamma^2 + c_c)},$$

$$q_1[1 - \frac{\gamma^4}{(4\gamma^2 + c_c)(2\gamma^2 + c_c)}] = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{(4\gamma^2 + c_c)(2\gamma^2 + c_c)},$$

$$q_1[\frac{7\gamma^4 + 6\gamma^2 c_c + c_c^2}{8\gamma^4 + 6\gamma^2 c_c + c_c^2}] = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{8\gamma^4 + 6\gamma^2 c_c + c_c^2}.$$

Hence, the accumulator produced on the integrated side of the market becomes;

$$q_1^{SI} = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}. \tag{66}$$

Since $\alpha - c_a - \frac{c_r}{\gamma}$ is positive, $q_1^{SI} > 0$ holds.

Inserting (66) into the equation (64), we have;

$$q_2 = \frac{\gamma^2(\alpha - c_a - \frac{c_r}{\gamma}) - \gamma^2[\frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}]}{4\gamma^2 + c_c},$$

$$q_2 = \frac{\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})}{4\gamma^2 + c_c}[1 - \frac{\gamma^2(3\gamma^2 + c_c)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}].$$

Hence, the accumulator produced on the non-integrated side of the market becomes;

$$q_2^{SI} = \frac{\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})(\gamma^2 + c_c)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}. \quad (67)$$

The total production in Semi-Integrated Market Structure is $Q^{SI} = q_1^{SI} + q_2^{SI}$;

$$Q^{SI} = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2} + \frac{\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})(\gamma^2 + c_c)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2},$$

$$Q^{SI} = \frac{\gamma^2(4\gamma^2 + 2c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}. \quad (68)$$

CHAPTER 6

SOCIAL WELFARE IN ALTERNATIVE MARKET STRCUTURES

Social welfare is calculated as total surplus (TS), which is the sum of producers' and consumers' surpluses. Producers' surplus (PS) is calculated as the total profits of agents in the market, and consumers' surplus (CS) is calculated as $\frac{Q^2}{2}$, where Q is the total production in the market. [1]

Successive Monopolies

The total profit in the Successive Monopolies market structure is the sum of profits in accumulator production, recycling and collection segments.

$$\Pi^{SM} = \Pi^a + \Pi^r + \Pi^c,$$

$$\Pi^{SM} = P_a q - (p_r + c_a) q + p_r l - (p_c + c_r)\frac{l}{\gamma} + p_c w - \frac{1}{2} c_c\ w^2. \qquad (69)$$

[1] In calculating the total surplus, the firms are only considered as producers. Their role as a buyer of input from an upstream, hence as a consumer, is not taken into account in the consumers' surplus. By consumers, just the end users of new accumulators are meant.

By inserting conditional factor demand functions into the equation (69) and simplifying we obtain;

$$\Pi^{SM} = (\alpha - q)q - c_a q - c_r \frac{q}{\gamma} - \frac{1}{2} c_c \frac{q^2}{\gamma^2},$$

$$\Pi^{SM} = q(\alpha - c_a - \frac{c_r}{\gamma}) - q^2 (1 + \frac{c_c}{2\gamma^2}). \tag{70}$$

Inserting Q^{SM} from the equation (23) into the above equation, the profit becomes;

$$\Pi^{SM} = \frac{\gamma^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{4\gamma^2 + c_c} - \frac{\gamma^4 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{(4\gamma^2 + c_c)^2} \frac{(2\gamma^2 + c_c)}{2\gamma^2},$$

$$\Pi^{SM} = \frac{\gamma^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{4\gamma^2 + c_c} (1 - \frac{2\gamma^2 + c_c}{2(4\gamma^2 + c_c)}),$$

$$\Pi^{SM} = \frac{\gamma^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2 (6\gamma^2 + c_c)}{2(4\gamma^2 + c_c)^2}. \tag{71}$$

In order to find social welfare we need to calculate total surplus as;

$$TS^{SM} = \Pi^{SM} + CS^{SM} = q(\alpha - c_a - \frac{c_r}{\gamma}) - q^2(1 + \frac{c_c}{2\gamma^2}) + \frac{q^2}{2}, \tag{72}$$

$$TS^{SM} = q(\alpha - c_a - \frac{c_r}{\gamma}) - q^2(1 + \frac{c_c}{2\gamma^2} - \frac{1}{2}). \tag{73}$$

Inserting Q^{SM} from the equation (23) into the above equation, we proceed as;

$$TS^{SM} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{4\gamma^2 + c_c} - \frac{\gamma^4(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(4\gamma^2 + c_c)^2}\frac{(\gamma^2 + c_c)}{2\gamma^2},$$

$$TS^{SM} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(7\gamma^2 + c_c)}{2(4\gamma^2 + c_c)^2}. \tag{74}$$

Fully Integrated Market

The profits of the Fully Integrated market structure is simply the profit of the monopoly, that deals with accumulator production, recycling and collection. Hence, the profit function is;

$$\Pi^{FI}(q) = P_a q - \frac{1}{2} c_c (\frac{q}{\gamma})^2 - c_r \frac{q}{\gamma} - c_a q, \quad (75)$$

$$\Pi^{FI} = q(\alpha - c_a - \frac{c_r}{\gamma}) - q^2 (1 + \frac{c_c}{2\gamma^2}).$$

Inserting Q^{FI} from the equation (29) into the above equation, we proceed as;

$$\Pi^{FI} = \frac{\gamma^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{2\gamma^2 + c_c} - \frac{\gamma^4 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{(2\gamma^2 + c_c)^2} \frac{(2\gamma^2 + c_c)}{2\gamma^2},$$

$$\Pi^{FI} = \frac{\gamma^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{2\gamma^2 + c_c} (1 - \frac{2\gamma^2 + c_c}{2(2\gamma^2 + c_c)}),$$

$$\Pi^{FI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{2(2\gamma^2 + c_c)^2}. \tag{76}$$

The total surplus in Fully Integrated market structure is;

$$TS^{FI} = q(\alpha - c_a - \frac{c_r}{\gamma}) - q^2(1 + \frac{c_c}{2\gamma^2} - \frac{1}{2}).$$

Inserting Q^{FI} from the equation (29) into the above equation, we proceed as;

$$TS^{FI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{2\gamma^2 + c_c} - \frac{\gamma^4(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(2\gamma^2 + c_c)^2}\frac{(\gamma^2 + c_c)}{2\gamma^2},$$

$$TS^{FI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{2\gamma^2 + c_c}(1 - \frac{\gamma^2 + c_c}{2(2\gamma^2 + c_c)}).$$

Therefore, the total surplus in this market structure is;

$$TS^{FI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(3\gamma^2 + c_c)}{2(2\gamma^2 + c_c)^2}. \tag{77}$$

Fully Disintegrated Market

There are two symmetric parts in the Fully Disintegrated market structure each with an accumulator producer, a recycler and a collector. The profits by one part of the market is the sum of profits of the corresponding accumulator, recyler and collector similar to the Successive Monopolies case.

$$\Pi_i^{FD} = \Pi_i^a + \Pi_i^r + \Pi_i^c \tag{78}$$

$$\Pi_i^{FD} = P_a q_i - (p_r + c_a) q_i + p_r l_i - (p_c + c_r)\frac{l_i}{\gamma} + p_c w_i - \frac{1}{2} c_c w_i^2,$$

where $P_a = \alpha - Q$, and $Q = 2q_i$, since the parts are symmetric.

By inserting the conditional factor demand functions and after eliminations we proceed as;

$$\Pi_i^{FD} = (\alpha - 2q_i) q_i - c_a q_i - c_r \frac{q_i}{\gamma} - \frac{1}{2} c_c \frac{{q_i}^2}{\gamma^2},$$

$$\Pi_i^{FD} = q_i (\alpha - c_a - \frac{c_r}{\gamma}) - q_i^2 (2 + \frac{c_c}{2\gamma^2}).$$

Inserting $q_i^{FD} = \frac{Q^{FD}}{2}$ from the equation (48) into the above equation, we proceed as;

$$\Pi_i^{FD} = \frac{4\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{18\gamma^2 + 4c_c} - \frac{16\gamma^4(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(18\gamma^2 + 4c_c)^2} \frac{(4\gamma^2 + c_c)}{2\gamma^2},$$

$$\Pi_i^{FD} = \frac{4\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{18\gamma^2 + 4c_c}(1 - \frac{2(4\gamma^2 + c_c)}{18\gamma^2 + 4c_c}),$$

$$\Pi_i^{FD} = \frac{4\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(10\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}. \tag{79}$$

The total profits in this market structure, hence the producers' surplus, is twice of profits of one part;

$$\Pi^{FD} = \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(10\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}. \tag{80}$$

The total surplus in Fully Disintegrated market structure is;

$$TS^{FD} = 2q_i(\alpha - c_a - \frac{c_r}{\gamma}) - 2q_i^2(2 + \frac{c_c}{2\gamma^2}) + \frac{(2q_i)^2}{2}, \tag{81}$$

$$TS^{FD} = 2q_i(\alpha - c_a - \frac{c_r}{\gamma}) - 2q_i^2(2 + \frac{c_c}{2\gamma^2} - 1).$$

Inserting Q^{FD} from the equation (48) into the above equation, we proceed as;

$$TS^{FD} = 2\frac{4\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{18\gamma^2 + 4c_c} - 2\frac{16\gamma^4(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(18\gamma^2 + 4c_c)^2}\frac{(2\gamma^2 + c_c)}{2\gamma^2},$$

$$TS^{FD} = \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{18\gamma^2 + 4c_c}(1 - \frac{2(2\gamma^2 + c_c)}{18\gamma^2 + 4c_c}),$$

$$TS^{FD} = \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}. \tag{82}$$

The profit of integrated side is;

$$\Pi_1^{SI} = P_a q_1 - \frac{1}{2} c_c (\frac{q_1}{\gamma})^2 - c_r \frac{q_1}{\gamma} - c_a q_1, \tag{83}$$

$$\Pi_1^{SI} = \alpha q_1 - q_1^2 - q_1 q_2 - \frac{1}{2} c_c \frac{q_1^2}{\gamma^2} - \frac{c_r}{\gamma} q_1 - c_a q_1,$$

$$\Pi_1^{SI} = q_1(\alpha - c_a - \frac{c_r}{\gamma}) - q_1^2 (1 + \frac{c_c}{2\gamma^2}) - q_1 q_2 .$$

Inserting q_1^{SI} and q_2^{SI} from equation (66) and (67), respectively, into the above equation, we proceed as;

$$\Pi_1^{SI} = \frac{\gamma^2 (3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2}{7\gamma^4 + 6\gamma^2 c_c + c_c^2} - \frac{\gamma^4 (3\gamma^2 + c_c)^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2}{(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2} (\frac{2\gamma^2 + c_c}{2\gamma^2})$$

$$- \frac{\gamma^4 (\gamma^2 + c_c)(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2},$$

$$\Pi_1^{SI} = \frac{\gamma^2(3\gamma^2+c_c)(\alpha-\frac{c_r}{\gamma}-c_a)^2}{7\gamma^4+6\gamma^2c_c+c_c^2}[1-\frac{(3\gamma^2+c_c)(2\gamma^2+c_c)}{2(7\gamma^4+6\gamma^2c_c+c_c^2)}-\frac{\gamma^2(\gamma^2+c_c)}{7\gamma^4+6\gamma^2c_c+c_c^2}],$$

$$\Pi_1^{SI} = \frac{\gamma^2(3\gamma^2+c_c)(\alpha-\frac{c_r}{\gamma}-c_a)^2}{7\gamma^4+6\gamma^2c_c+c_c^2}[\frac{6\gamma^4+5\gamma^2c_c+c_c^2}{2(7\gamma^4+6\gamma^2c_c+c_c^2)}],$$

$$\Pi_1^{SI} = \frac{\gamma^2(3\gamma^2+c_c)(\alpha-\frac{c_r}{\gamma}-c_a)^2(6\gamma^4+5\gamma^2c_c+c_c^2)}{2(7\gamma^4+6\gamma^2c_c+c_c^2)^2}. \tag{84}$$

The total profit in non-integrated side is the sum of profits in accumulator production, recycling and collection segments;

$$\Pi_2^{SI} = \Pi_2^a + \Pi_2^r + \Pi_2^c, \tag{85}$$

$$\Pi_2^{SI} = P_a q_2 - (p_r + c_a)q_2 + p_r l_2 - (p_c + c_r)\frac{l_2}{\gamma} + p_c w_2 - \frac{1}{2}c_c w_2^2.$$

By inserting the cost minimization results and simplifying we obtain;

$$\Pi_2^{SI} = (\alpha - q_1 - q_2)q_2 - c_a q_2 - c_r \frac{q_2}{\gamma} - \frac{1}{2}c_c \frac{q_2}{\gamma^2},$$

$$\Pi_2^{SI} = q_2(\alpha - c_a - \frac{c_r}{\gamma}) - q_2^2(1 + \frac{c_c}{2\gamma^2}) - q_1 q_2.$$

Inserting q_1^{SI} and q_2^{SI} from equation (66) and (67), respectively, into the above equation, we proceed as;

$$\Pi_2^{SI} = \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2}{7\gamma^4 + 6\gamma^2 c_c + c_c^2} - \frac{\gamma^4(\gamma^2 + c_c)^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}(\frac{2\gamma^2 + c_c}{2\gamma^2})$$
$$- \frac{\gamma^4(\gamma^2 + c_c)(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2}{(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2},$$

$$\Pi_2^{SI} = \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}[1 - \frac{(\gamma^2 + c_c)(2\gamma^2 + c_c)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)} - \frac{\gamma^2(3\gamma^2 + c_c)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}],$$

$$\Pi_2^{SI} = \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}\left[\frac{6\gamma^4 + 7\gamma^2 c_c + c_c^2}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)}\right],$$

$$\Pi_2^{SI} = \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 7\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}. \tag{86}$$

The producers' surplus is the sum of the profits from integrated and non-integrated sides of the market, $PS^{SI} = \Pi_1^{SI} + \Pi_2^{SI}$;

$$PS^{SI} = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 5\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}$$

$$+ \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 7\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2},$$

$$PS^{SI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(24\gamma^6 + 34\gamma^4 c_c + 16\gamma^2 c_c^2 + 2c_c^3)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}. \tag{87}$$

The consumers' surplus is $\frac{(Q^{SI})^2}{2}$ as;

$$CS^{SI} = \frac{1}{2}\left[\frac{\gamma^2(4\gamma^2 + 2c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}\right]^2, \tag{88}$$

$$CS^{SI} = \frac{\gamma^4(4\gamma^2 + 2c_c)^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}. \tag{89}$$

Therefore, total surplus in the Semi-Integrated market structure is;

$$TS^{SI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}[24\gamma^6 + 34\gamma^4 c_c + 16\gamma^2 c_c^2 + 2c_c^3 + \gamma^2(4\gamma^2 + 2c_c)^2],$$

$$TS^{SI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(40\gamma^6 + 50\gamma^4 c_c^2 + 20\gamma^2 c_c^2 + 2c_c^3)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}. \tag{90}$$

CHAPTER 7

THE RESULTS

Proposition 1. $Q^{FI} > Q^{SM}$ *and* $TS^{FI} > TS^{SM}$.

Proof 1. The production levels in Fully Integrated and Successive Monopolies structures are respectively;

$$Q^{FI} = \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{2\gamma^2 + c_c}, \tag{91}$$

$$Q^{SM} = \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{4\gamma^2 + c_c}. \tag{92}$$

Comparing the results, we have $Q^{FI} > Q^{SM}$ if and only if;

$$\frac{\gamma^2(\alpha - c_a) - \gamma c_r}{2\gamma^2 + c_c} > \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{4\gamma^2 + c_c}.$$

Since we assumed $\gamma^2(\alpha - c_a) - \gamma c_r$ to be positive, we can proceed as;

$$4\gamma^2 + c_c > 2\gamma^2 + c_c,$$

$$2\gamma^2 > 0. \tag{93}$$

Inequality (93) holds since we have assumed γ to be positive. ■

The total surpluses in the Fully Integrated and Successive Monopolies market structures are respectively;

$$TS^{FI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(3\gamma^2 + c_c)}{2(2\gamma^2 + c_c)^2}, \tag{94}$$

$$TS^{SM} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(7\gamma^2 + c_c)}{2(4\gamma^2 + c_c)^2}. \tag{95}$$

$TS^{FI} > TS^{SM}$ if and only if;

$$\frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(3\gamma^2 + c_c)}{2(2\gamma^2 + c_c)^2} > \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(7\gamma^2 + c_c)}{2(4\gamma^2 + c_c)^2},$$

$$\frac{3\gamma^2 + c_c}{4\gamma^4 + 4\gamma^2 c_c + c_c^2} > \frac{7\gamma^2 + c_c}{16\gamma^4 + 8\gamma^2 c_c + c_c^2},$$

$$(3\gamma^2 + c_c)(16\gamma^4 + 8\gamma^2 c_c + c_c^2) > (7\gamma^2 + c_c)(4\gamma^4 + 4\gamma^2 c_c + c_c^2),$$

$$48\gamma^6 + 40\gamma^4 c_c + 11\gamma^2 c_c^2 + c_c^3 > 28\gamma^6 + 32\gamma^4 c_c + 11\gamma^2 c_c^2 + c_c^3,$$

$$20\gamma^6 + 8\gamma^4 c_c > 0. \tag{96}$$

Equation (96) holds since we have assumed γ and c_c to be positive. ■

The accumulator production, hence the waste collected, and welfare in the Fully Integrated market structure is higher than that of the Successive Monopolies market structure. This stems from the well-known term called 'double monopoly markup' (Carlton and Perloff, 2000) or 'double marginalization' (Church and Ware, 2000) in Industrial Organization.

Double monopoly markup (or double marginalization) occurs when monopolies in both upstream and downstream set their prices above their marginal costs (which is called as ‘monopoly markup’) without taking into account the other. This doubling of markups means doubling of inefficiency. However, when firms integrate, the markup is applied once, hence one of the inefficiencies is eliminated. Therefore, integration is socially beneficial.

The 3-D representation of total surpluses given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 1[2]. As seen from the graph, $TS^{FI} > TS^{SM}$. According to the figure[3], $TS^{FI} > TS^{SM}$ holds.

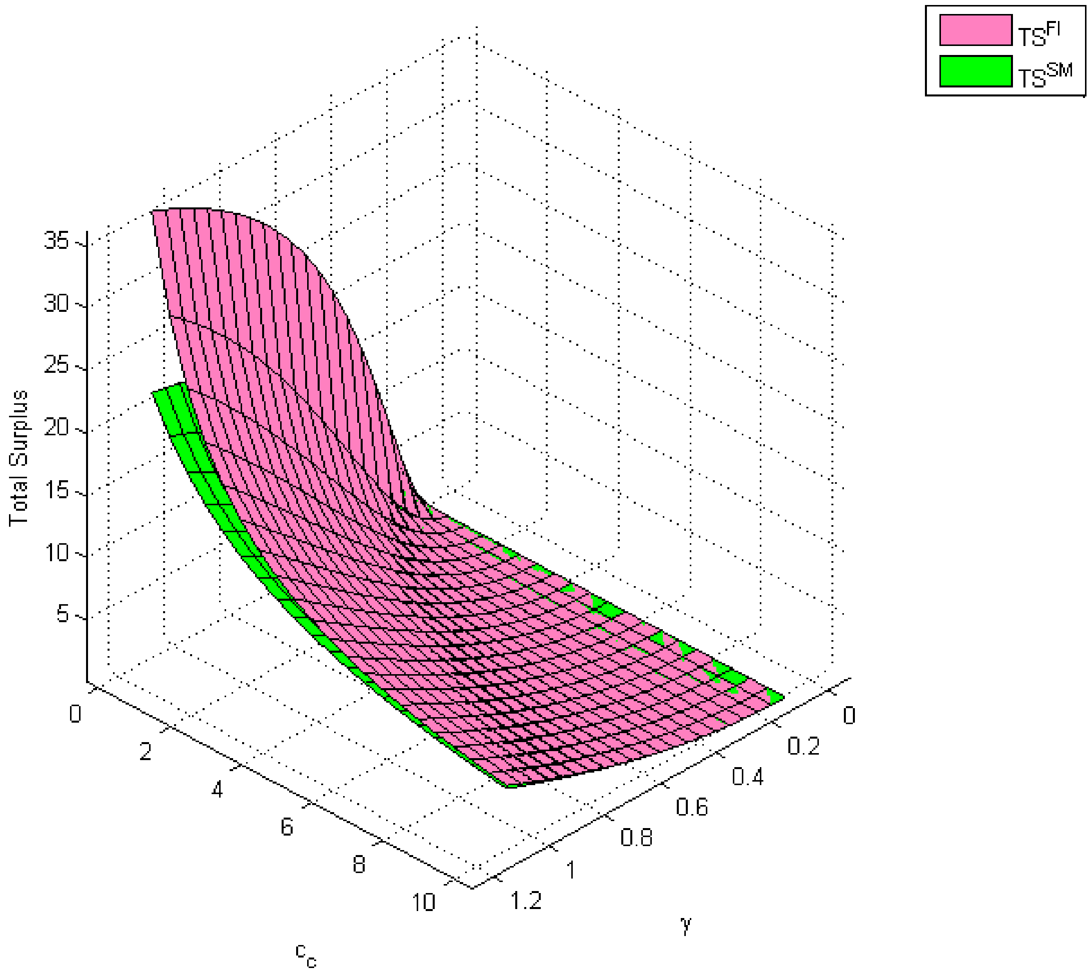

Figure 1: $TS^{FI} > TS^{SM}$

[2] Although γ is restricted to take values no greater than 1 in the model, the graphs are depicted for $0.1 < \gamma < 1.1$ for expositional purpose.

[3] The area where the colors are intertwined is the range where the two total surpluses are close, however the inequality still holds.

Proposition 2. $Q^{FD} > Q^{SM}$ *and* $TS^{FD} > TS^{SM}$.

Proof 2. The production levels in the Fully Disintegrated and Successive Monopolies structures are respectively;

$$Q^{FD} = \frac{8(\gamma^2(\alpha - c_a) - \gamma c_r)}{18\gamma^2 + 4c_c}, \tag{97}$$

$$Q^{SM} = \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{4\gamma^2 + c_c}. \tag{98}$$

Comparing the results, we have $Q^{FD} > Q^{SM}$ if and only if;

$$\frac{8(\gamma^2(\alpha - c_a) - \gamma c_r)}{18\gamma^2 + 4c_c} > \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{4\gamma^2 + c_c}.$$

Since we assumed $\gamma^2(\alpha - c_a) - \gamma c_r$ to be positive, we can proceed as;

$$8(4\gamma^2 + c_c) > 18\gamma^2 + 4c_c,$$

$$32\gamma^2 + 8c_c > 18\gamma^2 + 4c_c,$$

$$14\gamma^2 + 4c_c > 0. \tag{99}$$

Equation (99) holds since we have assumed γ and c_c to be positive.

The total surpluses in the Fully Disintegrated and Successive Monopolies market structures are respectively;

$$TS^{FD} = \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}, \tag{100}$$

$$TS^{SM} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(7\gamma^2 + c_c)}{2(4\gamma^2 + c_c)^2}. \tag{101}$$

$TS^{FD} > TS^{SM}$ if and only if;

$$\frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2} > \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(7\gamma^2 + c_c)}{2(4\gamma^2 + c_c)^2},$$

$$16(14\gamma^2 + 2c_c)(4\gamma^2 + c_c)^2 > (7\gamma^2 + c_c)(18\gamma^2 + 4c_c)^2,$$

$$16(224\gamma^6 + 112\gamma^4 c_c + 14\gamma^2 c_c^2 + 32\gamma^4 c_c + 16\gamma^2 c_c^2 + 2c_c^3) > (7\gamma^2 + c_c)(16c_c^2 + 324\gamma^4 + 144\gamma^2 c_c),$$

$$3584\gamma^6 + 2304\gamma^4 c_c + 480\gamma^2 c_c^2 + 32c_c^3 > 2268\gamma^6 + 1332\gamma^4 c_c + 256\gamma^2 c_c^2 + 16c_c^3,$$

$$1316\gamma^6 + 972\gamma^4 c_c + 224\gamma^2 c_c^2 + 16c_c^3 > 0. \qquad (102)$$

Equation (102) holds since we have assumed γ and c_c to be positive. ■

The accumulator production, hence the waste collected, and welfare in the Fully Disintegrated market structure is higher than that of the Successive Monopolies market structure. Introducing some level of competition to the each and every segments of the market is socially beneficial.

The 3-D representation of total surpluses given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 2. According to the figure, $TS^{FD} > TS^{SM}$ holds.

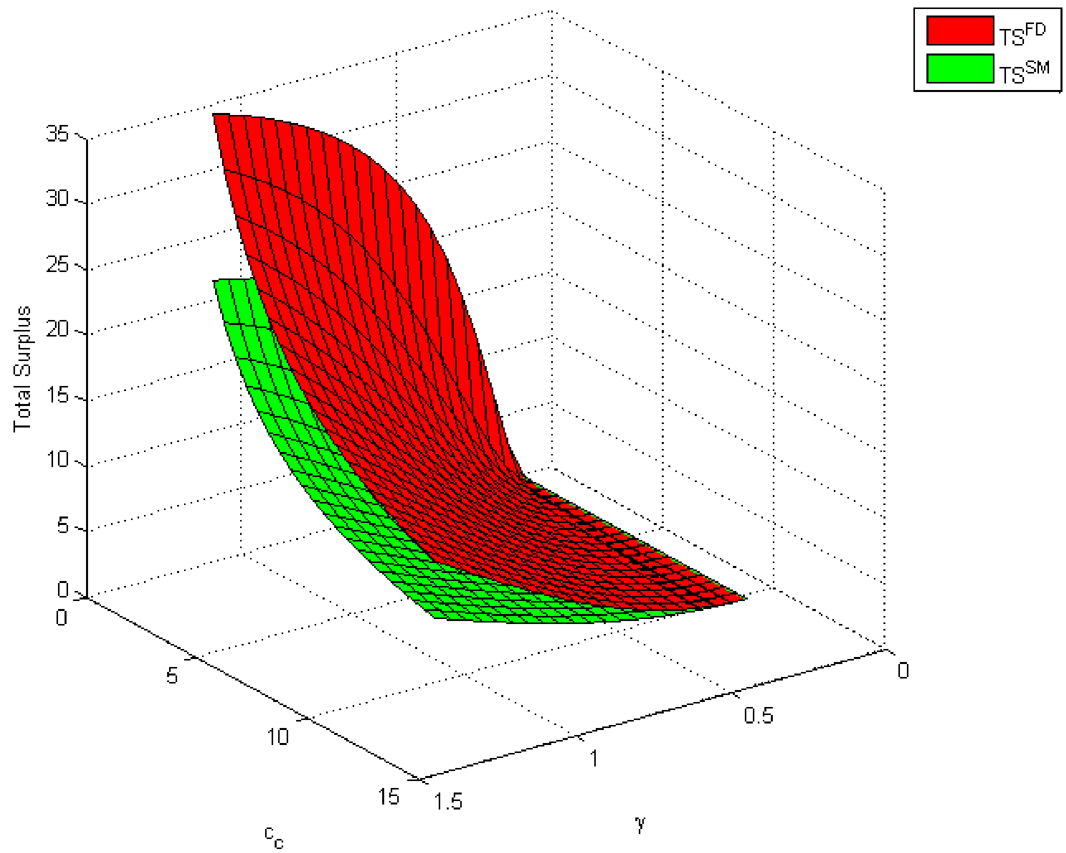

Figure 2: $TS^{FD} > TS^{SM}$

Proposition 3. $Q^{FD} > Q^{FI}$ *if* $2c_c > \gamma^2$, $TS^{FD} > TS^{FI}$ *if* $67\gamma^4 c_c + 40\gamma^2 c_c^2 + 4c_c^3 > 19\gamma^6$

Proof 3. The production levels in the Fully Disintegrated and Fully Integrated structures are respectively;

$$Q^{FD} = \frac{8(\gamma^2(\alpha - c_a) - \gamma c_r)}{18\gamma^2 + 4c_c}, \tag{103}$$

$$Q^{FI} = \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{2\gamma^2 + c_c}. \tag{104}$$

Comparing the results, we have $Q^{FD} > Q^{FI}$ if and only if,

$$\frac{8(\gamma^2(\alpha - c_a) - \gamma c_r)}{18\gamma^2 + 4c_c} > \frac{\gamma^2(\alpha - c_a) - \gamma c_r}{2\gamma^2 + c_c}.$$

Since we assumed $\gamma^2(\alpha - c_a) - \gamma c_r$ to be positive, we can proceed as;

$$8(2\gamma^2 + c_c) > 18\gamma^2 + 4c_c,$$

$$16\gamma^2 + 8c_c > 18\gamma^2 + 4c_c,$$

$$2c_c > \gamma^2. \tag{105}$$

Equation (105) holds except for low levels of c_c when γ is high.

The total surpluses in the Fully Disintegrated and the Fully Integrated market structures are respectively;

$$TS^{FD} = \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}, \tag{106}$$

$$TS^{FI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(3\gamma^2 + c_c)}{2(2\gamma^2 + c_c)^2}. \tag{107}$$

$TS^{FD} > TS^{FI}$ if and only if;

$$\frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2} > \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(3\gamma^2 + c_c)}{2(2\gamma^2 + c_c)^2},$$

$$\frac{8(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2} > \frac{3\gamma^2 + c_c}{2(2\gamma^2 + c_c)^2},$$

$$16(14\gamma^2 + 2c_c)(4\gamma^4 + 4\gamma^2 c_c + c_c^2) > (3\gamma^2 + c_c)(324\gamma^4 + 144\gamma^2 c_c + 16c_c^2),$$

$$1024\gamma^4 c_c + 896\gamma^6 + 352\gamma^2 c_c^2 + 32c_c^3 > 972\gamma^6 + 756\gamma^4 c_c + 192\gamma^2 c_c^2 + 16c_c^3,$$

$$268\gamma^4 c_c + 160\gamma^2 c_c^2 + 16c_c^3 > 76\gamma^6, \tag{108}$$

$$67\gamma^4 c_c + 40\gamma^2 c_c^2 + 4c_c^3 > 19\gamma^6. \ \blacksquare \tag{109}$$

The accumulator production, hence the waste collected, is higher in the Fully Disintegrated market structure than in the Fully Integrated market structure if $2c_c > \gamma^2$. The welfare in the Fully Disintegrated market structure is higher than in the Fully Integrated market structure if $67\gamma^4 c_c + 40\gamma^2 c_c^2 + 4c_c^3 > 19\gamma^6$.

Increasing the level of competition in the market is a better solution than integrating in terms of production and social welfare if $67\gamma^4 c_c + 40\gamma^2 c_c^2 + 4c_c^3 > 19\gamma^6$.

Inequalities (105) and (109) hold except for low collection cost (c_c) when lead-extraction rate (γ) is high. However, one would expect that, as the conventional theory predicts, increasing competition in the market would always promote total welfare by increasing the level of production. However, recall that the collection segment operates under diseconomies of scale due to the quadratic cost assumption. Therefore, if the demand for waste accumulator is higher due to higher demand for accumulators, the marginal cost, hence the price of waste accumulator, turns out to be higher. While the consumer surplus increases with increasing competition, the producers surplus decreases due to increasing costs. If the cost parameter c_c is sufficiently large relative to γ, then the loss from higher input prices brought by increased production under diseconomies of scale will be weighted out by the benefit arising from increased consumers' surplus due to competition, hence total surplus under full disintegration will be higher than total surplus under full integration. Otherwise, we will end up in an unconventional outcome where total surplus under full disintegration will be lower than full integration.

The 3-D representation of total quantities given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 3. According to the figure, $Q^{FD} > Q^{FI}$ holds except for low c_c and high γ.

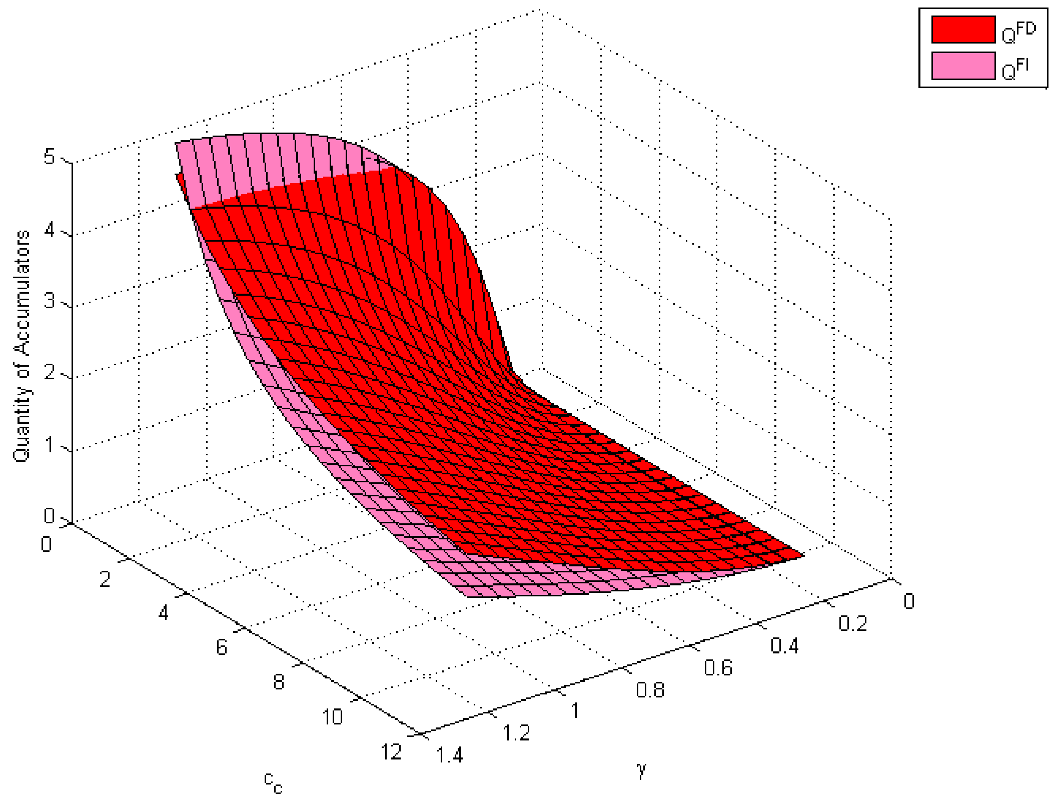

Figure 3: $Q^{FD} > Q^{FI}$

The 3-D representation of total surpluses given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 4. According to the figure $TS^{FD} > TS^{FI}$ holds except for low c_c and high γ.

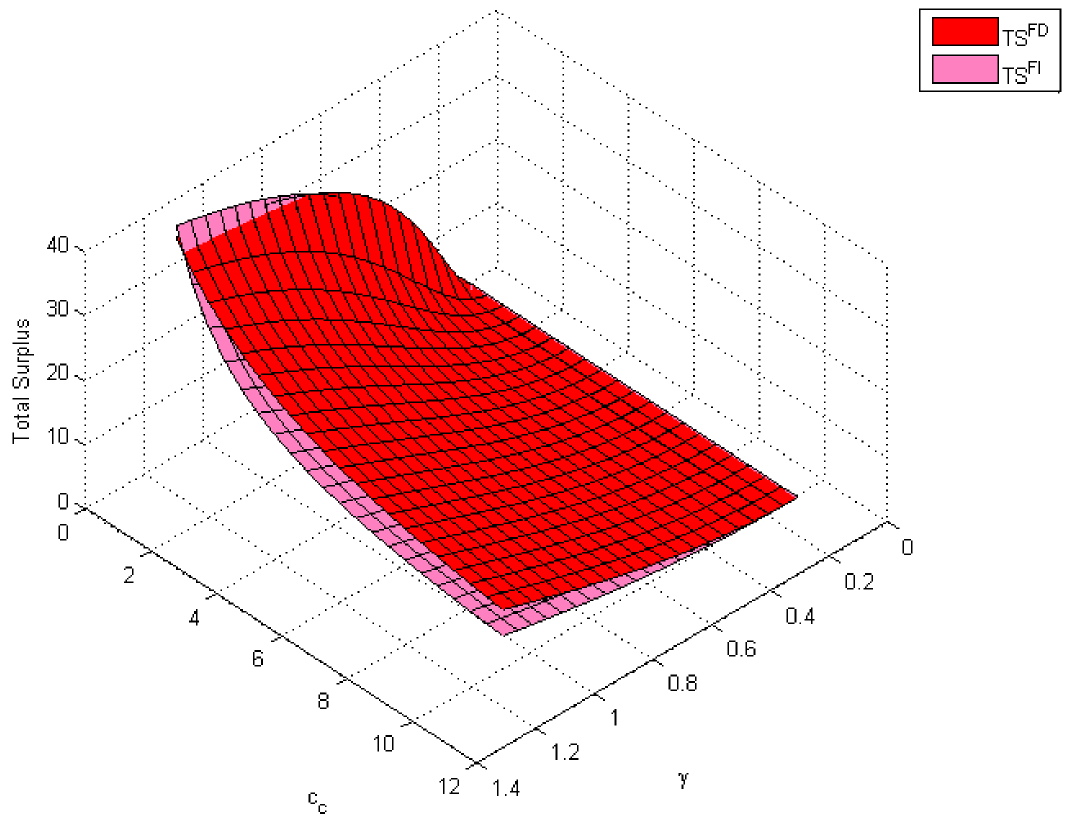

Figure 4: $TS^{FD} > TS^{FI}$

The following figure (Figure 5) shows that the set of (c_c, γ), $2c_c - \gamma^2 > 0$, where $TS^{FD} > TS^{FI}$ is inclusive of the set of (c_c, γ), $67\gamma^4 c_c + 40\gamma^2 c_c^2 + 4c_c^3 - 19\gamma^6 > 0$, where $Q^{FD} > Q^{FI}$. This means that the condition (105) is more restrictive than the condition (109), and hence (105) implies (109).

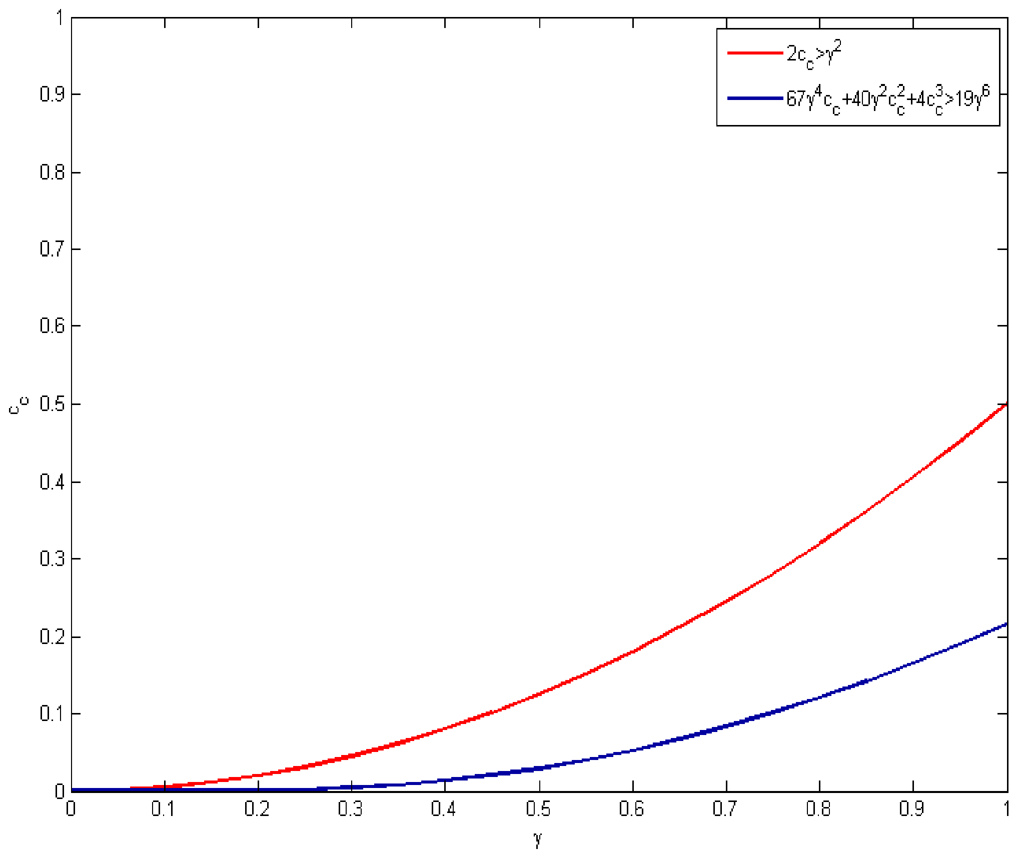

Figure 5. $2c_c - \gamma^2 > 0 \Rightarrow 67\gamma^4 c_c + 40\gamma^2 c_c^2 + 4c_c^3 - 19\gamma^6 > 0$

Proposition 4. $q_1^{SI} > q_i^{FD} > q_2^{SI}$, $Q^{SI} > Q^{FD}$.

Proof 4. The production levels in the integrated and non-integrated parts of the Semi-Integrated Market structure and in one part of the Fully Disintegrated Market structure are respectively;

$$q_1^{SI} = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}, \tag{110}$$

$$q_2^{SI} = \frac{\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})(\gamma^2 + c_c)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}, \tag{111}$$

$$q_i^{FD} = \frac{4\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})}{18\gamma^2 + 4c_c}. \tag{112}$$

$q_1^{SI} > q_i^{FD}$ if and only if;

$$\frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2} > \frac{4\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})}{18\gamma^2 + 4c_c}.$$

Since we assumed γ and $\gamma^2(\alpha - c_a) - \gamma c_r$ to be positive, we can proceed as;

$$\frac{3\gamma^2 + c_c}{7\gamma^4 + 6\gamma^2 c_c + c_c^2} > \frac{4}{18\gamma^2 + 4c_c},$$

$$(3\gamma^2 + c_c)(18\gamma^2 + 4c_c) > 4(7\gamma^4 + 6\gamma^2 c_c + c_c^2),$$

$$54\gamma^4 + 30\gamma^2 c_c + 4c_c^2 > 28\gamma^4 + 24\gamma^2 c_c + 4c_c^2,$$

$$26\gamma^4 + 6\gamma^2 c_c > 0. \tag{113}$$

Equation (113) holds since we assumed γ and c_c to be positive numbers.

$q_i^{FD} > q_2^{SI}$ if and only if;

$$\frac{4\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})}{18\gamma^2 + 4c_c} > \frac{\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})(\gamma^2 + c_c)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}.$$

Since we assumed γ and $\gamma^2(\alpha - c_a) - \gamma c_r$ to be positive, we can proceed as;

$$\frac{4}{18\gamma^2 + 4c_c} > \frac{\gamma^2 + c_c}{7\gamma^4 + 6\gamma^2 c_c + c_c^2},$$

$$4(7\gamma^4 + 6\gamma^2 c_c + c_c^2) > (\gamma^2 + c_c)(18\gamma^2 + 4c_c),$$

$$28\gamma^4 + 24\gamma^2 c_c + 4c_c^2 > 18\gamma^4 + 22\gamma^2 c_c + 4c_c^2,$$

$$10\gamma^4 + 2\gamma^2 c_c > 0. \tag{114}$$

Equation (114) holds since we assumed γ and c_c to be positive numbers.

Hence, $q_1^{SI} > q_i^{FD} > q_2^{SI}$.

The total productions in the Fully Disintegrated market structure and the Semi-Integrated market structure are respectively;

$$Q^{FD} = \frac{8\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})}{18\gamma^2 + 4c_c}, \tag{115}$$

$$Q^{SI} = \frac{\gamma^2(4\gamma^2 + 2c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2}. \tag{116}$$

$Q^{SI} > Q^{FD}$ if and only if;

$$\frac{\gamma^2(4\gamma^2 + 2c_c)(\alpha - \frac{c_r}{\gamma} - c_a)}{7\gamma^4 + 6\gamma^2 c_c + c_c^2} > \frac{8\gamma^2(\alpha - c_a - \frac{c_r}{\gamma})}{18\gamma^2 + 4c_c}.$$

Since we assumed γ and $\gamma^2(\alpha - c_a) - \gamma c_r$ to be positive, we can proceed as;

$$(4\gamma^2 + 2c_c)(18\gamma^2 + 4c_c) > 8(7\gamma^4 + 6\gamma^2 c_c + c_c^2),$$

$$72\gamma^4 + 52\gamma^2 c_c + 8c_c^2 > 56\gamma^4 + 48\gamma^2 c_c + 8c_c^2,$$

$$16\gamma^4 + 4\gamma^2 c_c > 0. \tag{117}$$

Equation (117) holds since we assumed γ and c_c to be positive numbers. ■

The production in the integrated part of the Semi-Integrated market structure is higher than the production in one part of the Fully Disintegrated market structure. The production by the non-integrated side of the Semi-Integrated market structure is the lowest. The total production in the Fully Disintegrated market structure is higher than in the Semi-Integrated.

The 3-D representation of total quantities given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 6. According to the figure, $Q^{SI} > Q^{FD}$ holds within the given range.

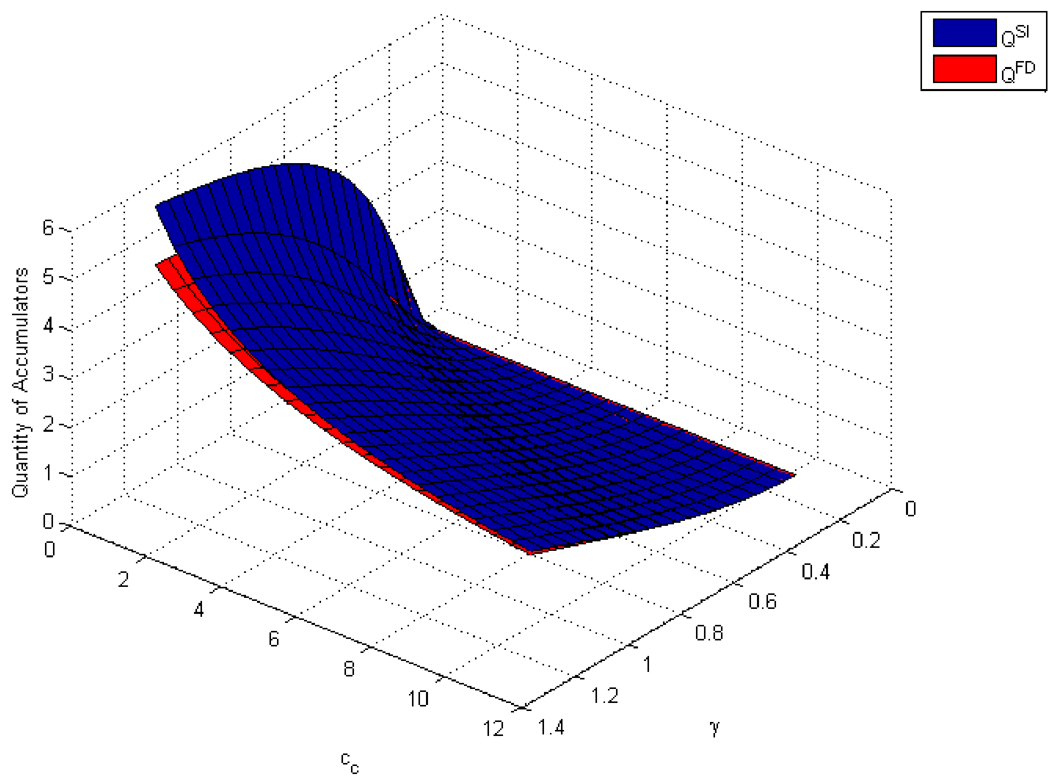

Figure 6: $Q^{SI} > Q^{FD}$

Proposition 5. $\Pi_1^{SI} > \Pi_i^{FD} > \Pi_2^{SI}$.

Proof 5. Recall the profits of integrated and non-integrated sides of the Semi-Integrated market structure;

$$\Pi_1^{SI} = \frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 5\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}, \tag{118}$$

$$\Pi_2^{SI} = \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 7\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}. \tag{119}$$

$\Pi_1^{SI} > \Pi_2^{SI}$ if and only if;

$$\frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 5\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2} > \frac{\gamma^2(\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 7\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}.$$

Since we assumed γ, c_c and $(\alpha - c_a - \frac{c_r}{\gamma})$ to be positive, we can proceed as;

$$(3\gamma^2 + c_c)(6\gamma^4 + 5\gamma^2 c_c + c_c^2) > (\gamma^2 + c_c)(6\gamma^4 + 7\gamma^2 c_c + c_c^2),$$

$$18\gamma^6 + 21\gamma^4 c_c + 8\gamma^2 c_c^2 + c_c^3 > 6\gamma^6 + 13\gamma^4 c_c + 8\gamma^2 c_c^2 + c_c^3,$$

$$12\gamma^6 + 8\gamma^4 c_c > 0. \tag{120}$$

Equation (120) holds since we assumed γ and c_c to be positive numbers.

Recall the total profits by one part of the Fully Disintegrated market structure;

$$\Pi_i^{FD} = \frac{4\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(10\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}. \tag{121}$$

$\Pi_1^{SI} > \Pi_i^{FD}$ if and only if;

$$\frac{\gamma^2(3\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2(6\gamma^4 + 5\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2} > \frac{4\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(10\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2},$$

$$\frac{(3\gamma^2 + c_c)(6\gamma^4 + 5\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2} > \frac{4(10\gamma^2 + 2c_c)}{(4c_c + 18\gamma^2)^2},$$

$$(4c_c + 18\gamma^2)^2 (3\gamma^2 + c_c)(6\gamma^4 + 5\gamma^2 c_c + c_c^2) > 2(40\gamma^2 + 8c_c)(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2,$$

$$5832\gamma^{10} + 9396\gamma^8 c_c + 5904\gamma^6 c_c^2 + 1812\gamma^4 c_c^3 + 272\gamma^2 c_c^4 + 16c_c^5 >$$

$$3920\gamma^{10} + 7504\gamma^8 c_c + 5344\gamma^6 c_c^2 + 1760\gamma^4 c_c^3 + 272\gamma^2 c_c^4 + 16c_c^5,$$

$$1912\gamma^{10} + 1892\gamma^8 c_c + 560\gamma^6 c_c^2 + 52\gamma^4 c_c^3 > 0. \tag{122}$$

Equation (122) holds since we assumed γ and c_c to be positive numbers.

$\Pi_i^{FD} > \Pi_2^{SI}$ if and only if;

$$\frac{4\gamma^2 (\alpha - \frac{c_r}{\gamma} - c_a)^2 (10\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2} > \frac{\gamma^2 (\gamma^2 + c_c)(\alpha - \frac{c_r}{\gamma} - c_a)^2 (6\gamma^4 + 7\gamma^2 c_c + c_c^2)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2},$$

$$\frac{4(10\gamma^2+2c_c)}{(4c_c+18\gamma^2)^2} > \frac{(\gamma^2+c_c)(6\gamma^4+7\gamma^2 c_c+c_c^2)}{2(7\gamma^4+6\gamma^2 c_c+c_c^2)^2},$$

$$2(40\gamma^2+8c_c)(7\gamma^4+6\gamma^2 c_c+c_c^2)^2 > (4c_c+18\gamma^2)^2(\gamma^2+c_c)(6\gamma^4+7\gamma^2 c_c+c_c^2),$$

$$3920\gamma^{10}+7504\gamma^8 c_c+5344\gamma^6 c_c^2+1760\gamma^4 c_c^3+272\gamma^2 c_c^4+16c_c^5 >$$
$$1944\gamma^{10}+5076\gamma^8 c_c+4560\gamma^6 c_c^2+1684\gamma^4 c_c^3+272\gamma^2 c_c^4+16c_c^5,$$

$$1796\gamma^{10}+2428\gamma^8 c_c+784\gamma^6 c_c^2+76\gamma^4 c_c^3 > 0. \tag{123}$$

Equation (123) holds since we assumed γ and c_c to be positive numbers. ■

The profit in the integrated part is higher than the profit in the non-integrated part of the Semi-Integrated market structure.

The profit in integrated part of the Semi-Integrated market structure is higher than the profit in one part of Fully Disintegrated market structure.

The profit in one part of the Fully Disintegrated market structure is higher than the total profit of the non-integrated side of the Semi-Integrated market structure.

The 3-D representation of profits, Π_1^{SI} and Π_2^{SI}, given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 7. According to the figure[4], $\Pi_1^{SI} > \Pi_2^{SI}$ holds within the given range.

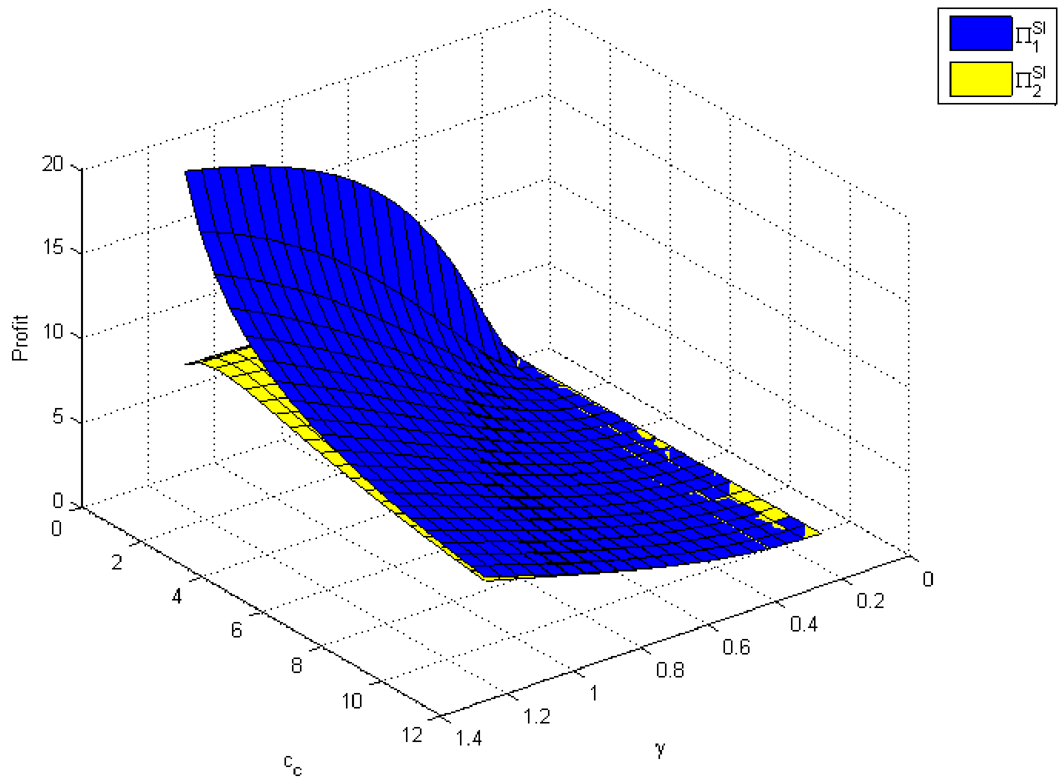

Figure 7: $\Pi_1^{SI} > \Pi_2^{SI}$

[4] The area where the colors are intertwined is the range where the two profits are close, however the inequality still holds.

The 3-D representation of profits, Π_1^{SI} and Π_i^{FD}, given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 8. According to the figure[5], $\Pi_1^{SI} > \Pi_i^{FD}$ holds within the given range.

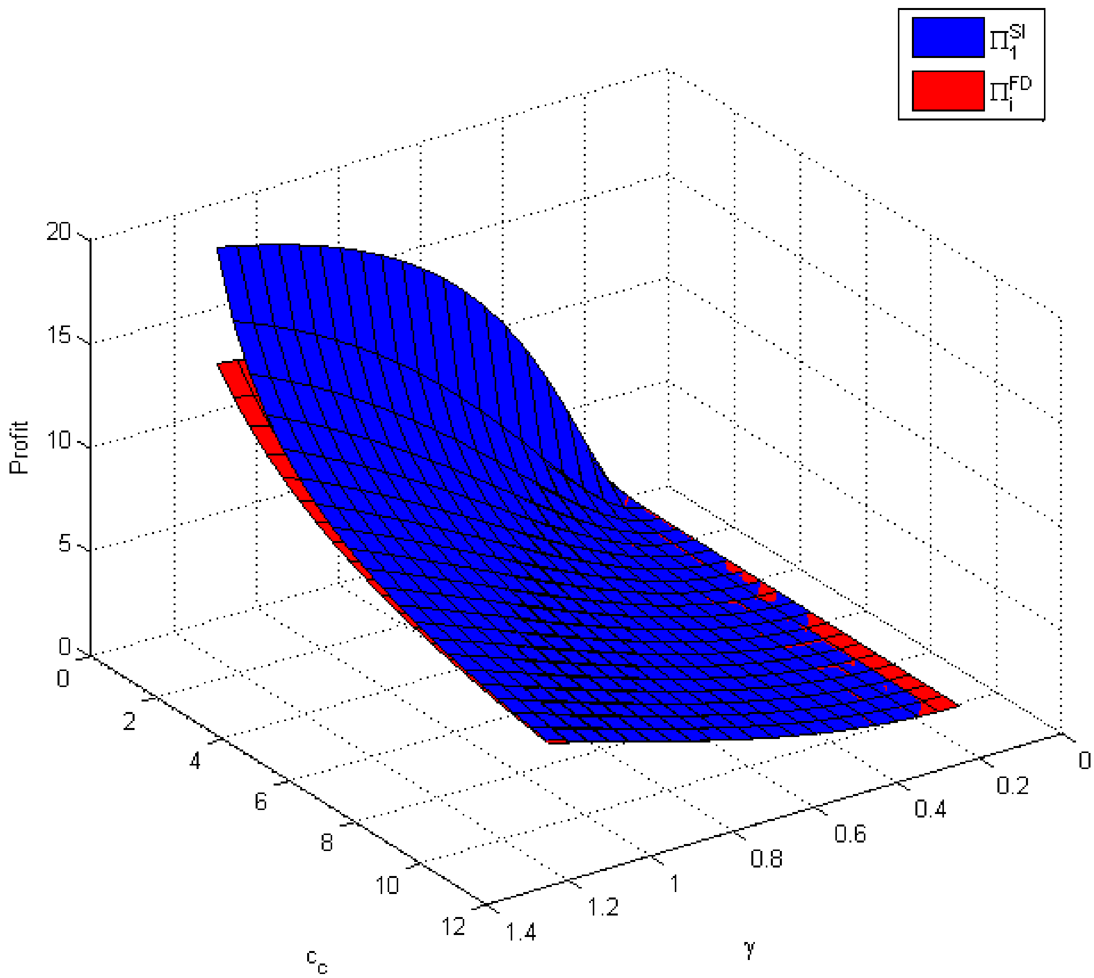

Figure 8: $\Pi_1^{SI} > \Pi_i^{FD}$

[5] The area where the colors are intertwined is the range where the two profits are close, however the inequality still holds.

The 3-D representation of profits, Π_i^{FD} and Π_2^{SI}, given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 9. According to the figure[6], $\Pi_i^{FD} > \Pi_2^{SI}$ holds within the given range.

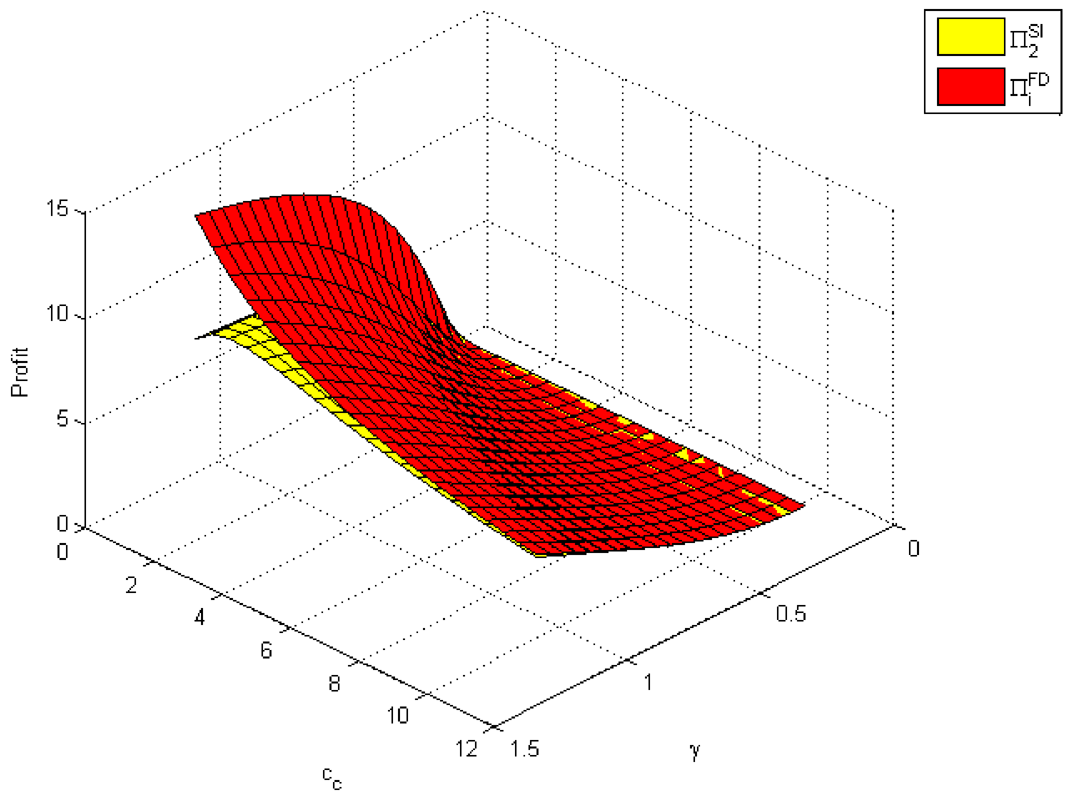

Figure 9: $\Pi_i^{FD} > \Pi_2^{SI}$

[6] The area where the colors are intertwined is the range where the two profits are close, however the inequality still holds.

Proposition 6. $TS^{SI} > TS^{FD}$.

Proof 6. The total surpluses in the Fully Disintegrated and Semi-Integrated market structures are respectively;

$$TS^{FD} = \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2}, \tag{124}$$

$$TS^{SI} = \frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(40\gamma^6 + 50\gamma^4 c_c + 20\gamma^2 c_c^2 + 2c_c^3)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2}. \tag{125}$$

$TS^{SI} > TS^{FD}$ if and only if;

$$\frac{\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(40\gamma^6 + 50\gamma^4 c_c + 20\gamma^2 c_c^2 + 2c_c^3)}{2(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2} > \frac{8\gamma^2(\alpha - \frac{c_r}{\gamma} - c_a)^2(14\gamma^2 + 2c_c)}{(18\gamma^2 + 4c_c)^2},$$

$$(40\gamma^6 + 50\gamma^4 c_c + 20\gamma^2 c_c^2 + 2c_c^3)(18\gamma^2 + 4c_c)^2 > 16(14\gamma^2 + 2c_c)(7\gamma^4 + 6\gamma^2 c_c + c_c^2)^2,$$

$$12960\gamma^{10} + 21960\gamma^{8}c_c + 14320\gamma^{6}c_c^{2} + 4328\gamma^{4}c_c^{3} + 608\gamma^{2}c_c^{4} + 32c_c^{5} >$$

$$10976\gamma^{10} + 20384\gamma^{8}c_c + 13888\gamma^{6}c_c^{2} + 4288\gamma^{4}c_c^{3} + 608\gamma^{2}c_c^{4} + 32c_c^{5},$$

$$1984\gamma^{10} + 1576\gamma^{8}c_c + 432\gamma^{6}c_c^{2} + 40\gamma^{4}c_c^{3} > 0. \tag{126}$$

Equation (126) holds since we assumed γ and c_c to be positive numbers. ■

The welfare in the Fully Disintegrated market structure is higher than in the Semi-Integrated market structure. This result is significant in the sense that it falsifies the decision by Competition Authority. Competition Authority punished the members of Aküder because they collaborated as if they are vertically integrated, the implicit assumption by this punishment is that such vertical integrated will reduce social welfare. However, Proposition 6 indicates the opposite result that vertical integrated by a group in the industry is indeed welfare-enhancing. It might be expected that integration by one side is welfare diminishing because the competition in the industry is lowered. However, in this case, the efficiency gain from integration (a similar argument as the 'double monopoly markup' can be made in successive oligopolies as double oligopoly dead weight losses) dominates the inefficiency arising from lower competition, hence the resulting situation becomes welfare enhancing.

The 3-D representation of total surpluses given the ranges of $0.1 < \gamma < 1.1$ and $0.1 < c_c < 10.1$ and when $\alpha = 12, c_a = 1, c_r = 1$ is shown in Figure 10. According to the figure[7], $TS^{SI} > TS^{FD}$ holds within the given range.

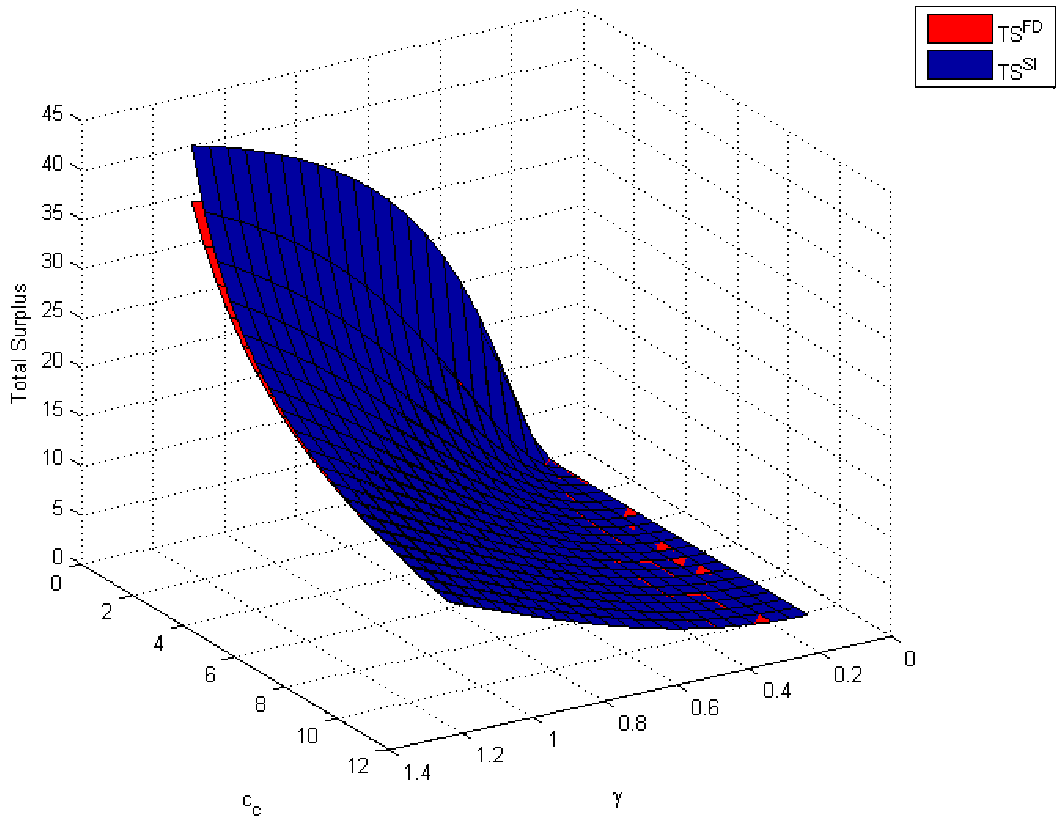

Figure 10: $TS^{SI} > TS^{FD}$

[7] The area where the colors are intertwined is the range where the two total surpluses are close, however the inequality still holds.

CHAPTER 8

CONCLUSION

In this thesis, we modeled a vertical market as applied to the accumulator industry. The waste accumulator market is assumed to consist of three layers. Collectors are in the upstream, which collect waste accumulators from retailers or maintenance services and sell them to recyclers. Recyclers extract lead from waste accumulators and sell lead to accumulator producers. Accumulator producers, which are in the downstream, use lead in order to produce brand new accumulators.

In Turkey, the market structure in accumulator market has changed after the launch of environmental regulation on waste batteries and accumulators, APAK, in 2005, due to the associations formed by the producers in order to follow up the recovery process of waste accumulators. In the new structure, one of the associations, Aküder, started to act as a vertically integrated body. This vertical integration was considered as an anti-competitive act by the Competition Authority, and hence the Authority punished the Aküder members with the claim that vertical integration of Aküder members decreased the welfare of the society. The aim of the thesis is to analyze the impact of vertical integration in such a market, and hence to evaluate the decision by the Competition Authority in the lights of the results.

In order to capture alternative cases, four different market structures are analyzed in the model.

The Successive Monopolies market structure is the basic case where there are monopolies in middle and downstream layers. The Fully Integrated market structure is the result of vertical integration of firms in the Successive Monopolies structure. This integration results in higher levels of production and also increases social welfare. This result is a well-established result in the literature, which refers to the elimination of 'double monopoly markup' (Carlton and Perloff, 2000) or 'double marginalization'(Church and Ware, 2000). In the Successive Monopolies case, the recycler and the accumulator producer both apply monopoly pricing. This means that there arise twice dead-weight losses due to double monopolies. Note that we have assumed the collector to apply marginal cost pricing, and hence there is not a third dead-weight loss in the market, hence no triple-monopoly markup. After integration, there is only one monopoly and hence the dead-weight loss arises only once. The resulting structure is profitable for both firms and consumers.

The third case, the Fully Disintegrated market structure, increases competition horizontally. This structure is better in terms of social welfare than the Successive Monopolies structure. Therefore, it can be concluded that introducing competition to each layer is a good policy for the betterment of the society. The Fully Disintegrated case corresponds to the case that the Competition Authority of Turkey implicitly suggests while fining producers because of hindering competition in the market.

Furthermore, the Fully Disintegrated market structure is better than Fully Integrated structure in terms of social welfare except for a range that corresponds very low collection cost and high extraction rate of lead from a waste accumulator. This result indicates that; if there exists a problem of inefficiency due to 'double marginalization' in the market, introduction of competition will yield better outcomes than the vertical integration of firms. Further note that the second case of Full Integration can be considered as a combination of vertical and horizontal mergers of the third case, where all mergers result in one monopolistic firm in the industry. The results show that such a multi-merger can be welfare enhancing or not depending on the market characteristics, namely the collection cost and lead-extraction rate. There are two forces affecting this outcome. Competition is desirable but increased production will come up with increased marginal cost of collected waste accumulators.

The fourth case, the Semi-Integrated market structure, corresponds to the case that is realized in the Turkish accumulator market after the introduction of the environmental regulation on waste accumulators. As the APAK regulation suggested, the firms formed two associations for the follow-up of the material recovery process and elimination of hazards arising from uncontrolled waste accumulators. The members of one of the associations have started to act collaboratively in their actions as if they were vertically integrated, which corresponds to the integrated side of the Semi-Integrated market structure; however, the firms on the other association remained independent, which corresponds to the non-integrated side. The results show that the integrated side had an incentive to integrate within the assumed range of collection cost and lead-extraction rate as they make higher profits than in the case where they remained independent, as in the one side of the Fully Disintegrated market structure. The non-integrated side complained about the resulting situation, because they were making less profit than in the case where they were competing with rivals that were independent, as in the one side of the Fully Disintegrated market structure.

The resulting structure was considered as welfare diminishing by the Competition Authority, which then decided to punish the firms in the integrated side. The results of the model indicate that the integration by one side is indeed welfare enhancing. The Semi-Integrated case, which is the realized case in Turkey, is better in terms of social welfare than the Fully Disintegrated case, which is promoted by the Competition Authority. Therefore, the results in this thesis falsify the decision of the Competition Authority.

The result that shows vertical integration by successive monopolies increases consumer benefit and social welfare is a re-demonstration of the well-established result in the literature. However, there are contrary studies on the impact of vertical integration when there is imperfect competition. The results in this thesis are supporting the result obtained by Hamilton and Mqasqas (1996), in which vertical integration increases social welfare; and Chen (2001) and Salinger (1988), in which the consumers benefit out of integration. But, they are contradicting to the results obtained by Ordover, Saloner and Salop (1990), in which consumers' surplus as well as social welfare decrease after vertical integration.

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