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Mikulas Stubna

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Abstract

The goal of this Thesis is to analyze a successful decentralization strategy in a supply chain with a monopolistic supplier. Such strategy has been proposed by Arya and Mittendorf (2007). This thesis further identifies key aspects to focus on during the decentralization of a company and it also proposes solutions for different scenarios. Furthermore, consequences of each strategic decision are quantified. The key decision aspects include the trading relationship between newly created divisions of the previously centralized firm, assignment of roles to each division, and assignment of the internal pricing decision rights. These aspects shape interactions in the supply chain and they ultimately affect profits, quantity produced, prices, and profit distribution in the supply chain. The company on the downstream market is in the monopolistic position and the same holds for the supplier firm.

Keywords: supply chain interactions, decentralization, double-marginalization problem, transfer pricing, supplier pricing

Übersicht

Ziel dieser Arbeit ist die Analyse der Dezentralisierungsstrategie in einer Lieferkette mit monopolistischen Lieferanten. Eine solche Strategie wurde von Arya und Mittendorf (2007) vorgeschlagen. Diese Arbeit identifiziert Schlüsselaspekte während der Dezentralisierung einer Firma und schlägt Lösungen für verschiedene Szenarien vor. Darüber hinaus werden die Konsequenzen jeder strategischen Entscheidung quantifiziert. Die wichtigsten Entscheidungsaspekte sind die Handelsbeziehungen zwischen den neu gegründeten Bereichen einer ursprünglich zentralisiert organisierten Firma, die Zuteilung der Rollen zu jedem Bereich und die Vergabe der Rechte für die interne Preisgestaltung. Diese Aspekte beeinflussen die Interaktionen innerhalb der Lieferkette und somit die Profite, die produzierte Menge, die Preise, sowie die Verteilung von Profiten innerhalb der Lieferkette. Der Kunde des nachgelagerten Marktes ist in einer monopolistischen Position und somit auch der Lieferant.

Schlüsselwörter: Wechselwirkungen in der Beschaffungskette, Dezentralisierung, Problem der doppelten Marginalisierung, Transfer-Pricing, Preisfindung für Lieferanten

Content

1. Introduction

Companies make a lot of effort to reach higher profit today or in the future. Typically, managements try to either increase revenues or cut costs or both. There are many ways to do it depending on industry, market, geographic location, company size, product maturity, or portfolio composition just to name a few. Sometimes, it is not easy to grow and even the management has no clear idea how to do it. They hire consultants with the hope that their knowledge and information allow them to come up with a solution they cannot see.

The context in which the company tries to increase profit is always important. If you are a startup you would follow a different strategy path than a well-established corporation. The context in which we will operate throughout this work is the following: a monopoly firm interacts with a supplier who charges significant markup on his products. Even in such small supply chain where are only two players there is a lot of room for making decisions of huge impact on firm's profitability and supply chain profit distribution.

Profitability is naturally the most important economic indicator for any company. A profitable company creates resources for investments, dividend payments to shareholders, creation of new jobs, nowadays increasingly important social responsibility, or we can basically say – growth. These are examples of why the profit is so important in a society in general. For a company itself profitability is an indicator of a long term survival. That is why we will be carefully examining effects of different measures on company profitability. However, there are more indictors under our focus. Specifically, the production output because it indicates how many customers on the market are satisfied. Finally, we will examine how prices and profit distribution change with different measures in place. Overall, this work is a detailed analysis of a successful strategy for a company facing monopolistic supplier.

The underlying idea of this work is decentralization of the downstream company. Management is often willing to split operations of the company into two or more independent divisions. One of the reason could be when a company acquires

another company, management might decide to leave the acquired entity separate, for example because of their high specialization. Another reason for dividing a company could be cheaper production costs or lower tax rate in another country. The letter reason is usually connected with charging specific transfer prices[1] that decrease the overall level of taxes the company has to pay.

Lots of discussions have been going on in Europe regarding companies using such transfer prices. Governments and EU officials fight against this practice. The reason is, perhaps, that they want to maximize the tax collection. Even though we will not focus on the tax aspects of transfer pricing, this is a good real-world example of a supply chain interactions where transfer pricing plays a role.

We will rather focus on what happens if the company is faced with a monopolistic supplier? Supplier charging a premium to his marginal production cost makes the buyer procure less goods then he would have procured if the supplier was selling at his marginal cost. Form the downstream firm perspective this is called a double-marginalization problem. The general knowledge is that the double-marginalization problem is an unwanted inefficiency. If the firm was able to buy at marginal costs, then of course it would produce more and gain higher profit.

Is there any way to make the supplier soften his prices so that firm can procure more of his products? Well, actually, there is. Arya and Mittendorf (2007) have proposed a solution that is sort of a self-sabotage. They suggest to divide the company and introduce additional layer of double-marginalization problem. The second double-marginalization problem comes from the division of the company where one division sells a product to another company's division while charging a markup on these internal goods. Even though the company will produce smaller volume because of more expensive inputs, it turns out that the profit will increase.

However, it is not that simple. There are decision issues that a management has to deal with while doing decentralization. The strategy path for successful decentralization is so specific that even one wrong decision will lead to failure. By

[1] Transfer price is a price of a good or service that is traded within a company, for example between two divisions.

doing wrong choices the company will end up with lower profit then under centralization and in few cases with the profit that equals to centralization. If at least one wrong decision is made the divided company is never more profitable than under centralization. We will take a close look on the choices a company has to make in order to yield benefits of decentralization.

Arya and Mittendorf (2007) have shown that making a company less efficient or weaker, if you will, softens the pricing of the supplier. A self-interested supplier does not lower the price just because his buyer got weaker. We assume that supplier does not make decisions based on altruism, but rather on the economic value. He lowers the price because newly divided company creates a different demand function for the supplier's goods. The supplier facing new demand function chooses such price that maximizes his profit. This price turns out to be lower than under centralization scenario. In the end of a day, lower input price will ensure higher profit for the firm.

The secret behind this success is the following. The root cause is the design of the decentralization. The upstream division now sells intermediate product to the downstream division which assembles the final good. Even though the supplier price is lower, the markup on the internal products forces the downstream division to cut on their production. This creates two effects for the downstream division – the price and the production effect, which are closely connected with the demand function of the end customers. Given the demand function on the final market, the lower output corresponds to a higher price. It turns out that the overall effect for the company is the profit increase.

An important assumption here is that variable production costs of a company cannot increase. These costs translate into the demand function at the input market. If their level does not change, then the supplier is forced to decrease the price, which has a positive effect on the company's bottom line in the end of the day. We can discuss whether or not the assumption is realistic. However, a management who tries to benefit from decentralization should keep it in mind.

The second issue to consider is the relationship between newly created divisions. Horizontal relationship would have no effect. In this case, the two divisions would be just independent entities with no interaction which could potentially affect their outcomes. The vertical relationship between divisions, on the other hand, is necessary. In a vertical relationship the two divisions have to trade. Internal trading is a desired and, in fact, necessary condition for introducing a double-marginalization problem in a firm, and therefore it is possible to soften supplier pricing.

The successful strategy path for decentralization gets even more complicated. The third issue the management has to pay attention to is the assignment of functions to newly created divisions. A common practice is to decentralize a company according to functions the newly created divisions will serve. As an example, let's consider a production division and a sales division. This way of decentralization is exactly what management should avoid. Why? The reason is that this design does not create desired supply chain interactions that eventually lead to profit increase. Divisional functions are so important because they affect the timeline of interactions in the supply chain. We are now coming to probably most important ingredient of the successful decentralization. The management should design such company structure where upstream division has to interact with the supplier at the same stage in time. In another words, decisions of the upstream division and the supplier are made simultaneously. These two decisions then affect the next player in the timeline together. When decisions of the upstream division and the supplier affect the next player down the flow, their decisions are mutually dependent. Furthermore, when these two players interact, they naturally settle for such prices that are mutual best response. It is in fact the mutual best response that softens supplier pricing.

Even still the management can destroy its efforts on its hunt for profitability by making a wrong decision. The fourth issue on which it is necessary to decide is the assignment of transfer pricing power. There are many options how to come up with a transfer pricing policy. For example, the headquarters could have full control of internal pricing, or, any division can have this right in its hands. Price of

the internal good can also be a result of negotiations among divisions. Until now we have considered that it is the upstream division that has transfer pricing in its hands. In fact, if all of the conditions above are fulfilled, the transfer pricing in hands of the upstream division ensures success. It is because the upstream division can create pressure on the supplier if it has power to make a decision about internal price which in the end leads to a mutual best response of these two players. On the other hand, internal pricing under control of the headquarters would not improve situation before decentralization.

If we look at it from a different angle, it is the structure of the transfer price that have dramatic effect on company's profitability. The upstream division would charge certain markup to its variable cost because it shoots to maximize its profit. However, the headquarters would set the internal price at the level of variable cost with an aim to eliminate all inefficiencies in order to maximize profit of the whole firm. As you may have already noticed, the structure of the transfer price is not decided just for the sake of having certain transfer price structure. Rather, the internal price structure is inherently given by the assignment of transfer pricing power to certain entity.

We will define the setup under which we will operate during the thesis in chapter 2. Then we will design a successful decentralization strategy from the profitability point of view in chapter 3. In chapter 4 we will broaden our understanding through graphical interpretation of the successful strategy. Chapter 5 examines how changes in organizational structure affect supply chain outcomes. Similarly, in chapter 6 we will study the effects of transfer pricing decision rights allocation. In chapter 7 we will run a brief experiment with shifting the payment of the supplier price to the downstream division under the "functional" decentralization. Finally, we will summarize the results from different stakeholders' point of view in chapter 8.

2. Set-up

The supply chain set-up is inspired by Arya and Mittendorf (2007) who have proposed the idea that introducing internal frictions can soften supplier pricing. I have made a few changes though. We will not consider competition on the downstream market. The effects of decentralization are more visible under the monopolistic setup. For simplicity, we further assume no competition on the market of external intermediate products. The same holds for an upstream division. There is no competition for internal intermediate products either.

Every player will be self-interested. That in another words means that each player wants to maximize his profit.

The underlying theme of this thesis is decentralization of previously centralized firm. A centralized firm means that the firm is led by one group of managers who make decisions for the whole company. On the other hand, decentralized company is split into two or more independent divisions and the decision rights are shifted from company headquarters to the divisions managements. Just keep in mind that even though the company is decentralized and divisions act like separate entities, there is always company headquarters that can assign competences, set limits, or simply set rules for the divisions.

We will be using terms “firm” and “company”. These terms will refer to the firm on a downstream market. Supplier firm is also a firm; however, we will refer to the supplier firm solely as a “supplier”.

Firms final product quantity is denoted by q. Consumer demand for the final good is represented by the inverse demand function $P = a – q$, where P is the consumer price and “a” is the y- intercept.

The final good is produced from two intermediate products. One intermediate good is produced internally at constant unit (marginal) cost c_i. The other intermediate good is produced by external company (supplier) at constant unit cost c_e, $c_i + c_e < a$. Manufacturing with both in-house production and procurement from external parties reflects the reality of most manufacturing companies and it allows us to incorporate both internal and external frictions.

In-house production and external procurement does not apply only to manufacturing companies of course. In fact, it is the reality of almost every company, no matter whether it is service oriented or product oriented. The level of how much a firm depends on external supplier versus internal operations varies from company to company. In our set-up the production is normalized – one unit is procured internally and one unit externally in order to produce the final good.

The price payed to the supplier for its good will be denoted by p and we will refer to this price as a supplier price. The price payed for internally produced good is called the transfer or internal price and it will be denoted by t.

3. The successful strategy of decentralization

Arya and Mittendorf (2007) came with a very interesting idea. They demonstrate that "*…when the firm relies on externally supplied inputs, it can benefit from often-discussed transfer-pricing problems. Though transfer prices above marginal cost introduce coordination problems, they also introduce a lower willingness to pay to outsiders.*" (Arya, Mittendorf 2007: 552) In another words, decentralization introduces inefficiencies based on coordination problems and internal tensions between divisions. The authors claim that in fact the firm can benefit from these inefficiencies.

Or, if we look at it from slightly different angle, "*relying on self-interested supplier who is charging premium for his products… restricts firm's procurement relative to that of vertically integrated entity.*" (Ibid.) This is called the double-marginalization problem. "*A move toward decentralization of internal production introduces a second friction that also falls under the rubic of double-marginalization: transfer prices above marginal cost for the internal good further increase the cost of production from the standpoint of the procuring (downstream) division and thus further cut into production.*" (Ibid.)

While doing such a thing as introducing a second double-marginalization problem seem to make things even worse, "*it turns out that such a curse can be a blessing in the face of an external supplier.*" (Ibid.)

What is going on in here are two opposing effects. We will show everything in detail in the upcoming sections and we will satisfy ourselves with a brief explanation now:

By introducing additional layer of double-marginalization problem we make procurement of production inputs even more expensive because the downstream division is where the final assembly happens. Limited budget of the downstream division forces her to procure less units of intermediate goods. Because of this, the firm produces and sells less units. Less units sold naturally decrease the profit.

On the other hand, the supplier is trying to maximize his profit. He sees that company is buying lower volume from him at given price level[2]. He also believes it is due to a "weaker" position of the buyer. The original price doesn't maximize his profit anymore, so he is willing to shift the price to such level that makes him as much profitable as possible. The optimal supplier price under the new supply chain setup is in fact lower relatively to the centralized scenario. Lower input price has a positive effect on the company profitability.

Furthermore, the effect of lowering the supplier price outweighs the effect of selling less units and in the end of the day, the company will end up with higher profit relative to centralization.

This is a desired outcome for the company. Since the company has a monopoly power on the end market, it does not have to fear the loss of a market share to a competitor because of selling a smaller volume of the final product. On the other hand, a monopoly firm might expect some tensions from a regulator if he is concerned with smaller consumer surplus.

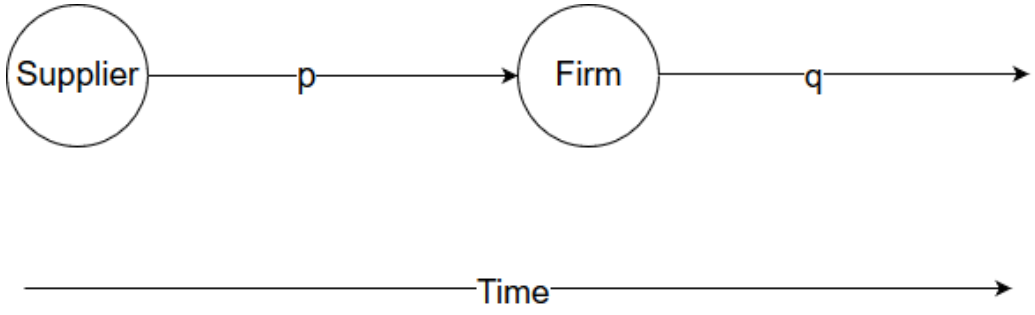
Arya and Mittendorf don't want us to approach this issue so narrowly. "*This is not to say that firms decentralize with the sole intention of cutting input prices. Rather, the broader point here is that decentralization can have far-reaching effects: it not only alters the internal operations and competitive posture of a firm, but it can also influence the behavior of other constituents (in this case, suppliers).*" (Ibid.)

We will proceed with actual model in order to demonstrate what we have been discussing above. We will start with a centralized company relying on an external supplier and we will continue with examining what effects brings the decentralization of the downstream player.

[2] Supplier price under centralization.

3.1 Centralization

Diagram 1: Supply Chain Timeline with the Centralized Firm



On the Diagram 1 you can see the timeline of the supply chain interactions. First, supplier determines the per unit supplier price p for the intermediate goods he produces. Then the firm procures inputs from the supplier and also produces intermediate product in-house. The firm assembles the final product from internal and external product, using one unit from each. The firm then sells a specific number of units on the retail market. The price of the final good is dictated by consumer demand P = a – q. At this point firm profit is realized and customer demand satisfied.

Problems like these are usually solved by the backward induction[3]. The process of backward induction is solving the problem backward in time. That means that we don't start solving the problem of the player who makes the first move, but we start solving the problem of a player who moves the last. After solving the problem of the last player, we continue with the problem of a player who is positioned as the first before the last on the timeline. We already know what is optimal solution for the last player and we will take the solution of the last player into consideration when solving his problem. This procedure continues until we solve the problem of the first player.

[3] *„Backward induction is an iterative process for solving finite extensive form or sequential games. First, one determines the optimal strategy of the player who makes the last move of the game. Then, the optimal action of the next-to-last moving player is determined taking the last player's action as given. The process continues in this way backwards in time until all players' actions have been determined."* (The Game Theory.net 2005)

But this is just half of the story of the backward induction. The optimal solutions are expressed in many unknowns at this state. For example, if we look at our scenario with a centralized company, we start with its optimization problem. The result of this optimization problem is dependent on the supplier price p which we do not know yet. However, we can fix this issue quite easily. Since we have solved optimization problems of all players, we can now go in opposite direction in time and plug for the unknown variables. That is plugging in the solution of the first player into the solution of the second player, then plugging this solution into the solution of the third player, and so on until we reach the last player. This way we will substitute for all of the unknown variables and obtain optimal solutions of each player in final numbers.

If we look at path of solving a problem by backward induction, the starting point is the player who makes the last move. We solve optimization problems in the opposite direction of the timeline until we reach the first player. At this point we turn around and go in the direction of the timeline while plugging in for the unknown variables in each player's solution until we reach the last player.

Let's go back to the supply chain with a supplier and centralized firm sketched on the Diagram 1. Each player's goal is to maximize his profit. In the metrics that we use the profit simply equals to total revenue minus total cost. The revenue and cost functions will be obviously different for each player because the drivers of these two variables differ for each player.

In general, the revenue is the number of units sold multiplied by the price that customer pays for one unit. Recall, the price of the final good is determined by the inverse demand function $P = a - q$. Multiply the price of the final good by the number of units sold and you will know firm's revenue. How does the cost of the firm look like? We know that in order to produce one unit of final good the firm has to buy one piece of intermediate good from the supplier and it has to produce one piece of internal good itself. Then the firm has to put these two inputs together. So production cost of one unit of final good is the price for the external good and internal per unit cost of production, that is $(p + c_i)$. If we multiply this term by the number of units produced, we will know the total cost of the firm.

Since we already know how revenue and cost function of the firm look like, it is easy to determine the profit function. The profit function of the firm is noted in Table 1 in a profit maximization form.

Recall, the firm is in the monopoly position on its market. We know from the monopoly theory that a monopoly firm maximizes profit by producing certain (profit maximizing) quantity. Price is then inherently given by the demand function. We will describe monopoly profit maximization in detail in the upcoming chapter. Anyway, the centralized firm maximizes profit by choosing the optimal quantity q. This is done by taking the first order condition of the firm's profit function with respect to quantity. The optimal production quantity of the firm is then $q = ½ * (a – p – c_i)$. Note, that the firm still does not know how much exactly to produce, because the supplier price p remains unknown.

The supplier can observe the profit maximizing quantity of the firm and he will take it into consideration while solving his own optimization problem. How? The supplier is a monopoly firm as well and that means that he searches for optimal quantity that maximizes his profit. However, he cannot decide on his profit maximizing quantity directly because it is given by the buyer – the firm ($q = ½ * (a – p – c_i)$). But the supplier can influence this quantity because he has a power to set the per unit price p for his products. He does it by taking the first order condition of his profit function. Supplier's profit function is driven by the supplier price on the revenue side, and by the cost of production on the cost side, see Table 1. From the first order condition the supplier determines the price for his good noted in the Table 1.

Since the firm now knows the price of the externally produced production input, it can determine the output by substituting for p in its optimal production quantity. So finally we can conclude that the centralized firm will produce $q = ¼ * (a – c_e – c_i)$ units of the final product.

The firm will procure the above stated quantity of the external good from the supplier and therefore supplier profit will be realized. Then the firm will proceed

and assemble the final product and sell it to end customers. At this point the firm realizes its profit. Both, the supplier and firm profits are stated in Table 1.

Table 1: Outcomes of the Supply Chain with the Centralized Firm

	Firm	Supplier
Profit maximization problem	$Max_q\ q*(a - q) - q*(p + c_i)$	$Max_p\ q*(p - c_e)$
Optimal quantity/price	$q = ¼ * (a - c_e - c_i)$	$p = ½ * (a + c_e - c_i)$
Profit	$1/16 * (a - c_e - c_i)^2$	$1/8 * (a - c_e - c_i)^2$
Profit distribution ratio	1	2

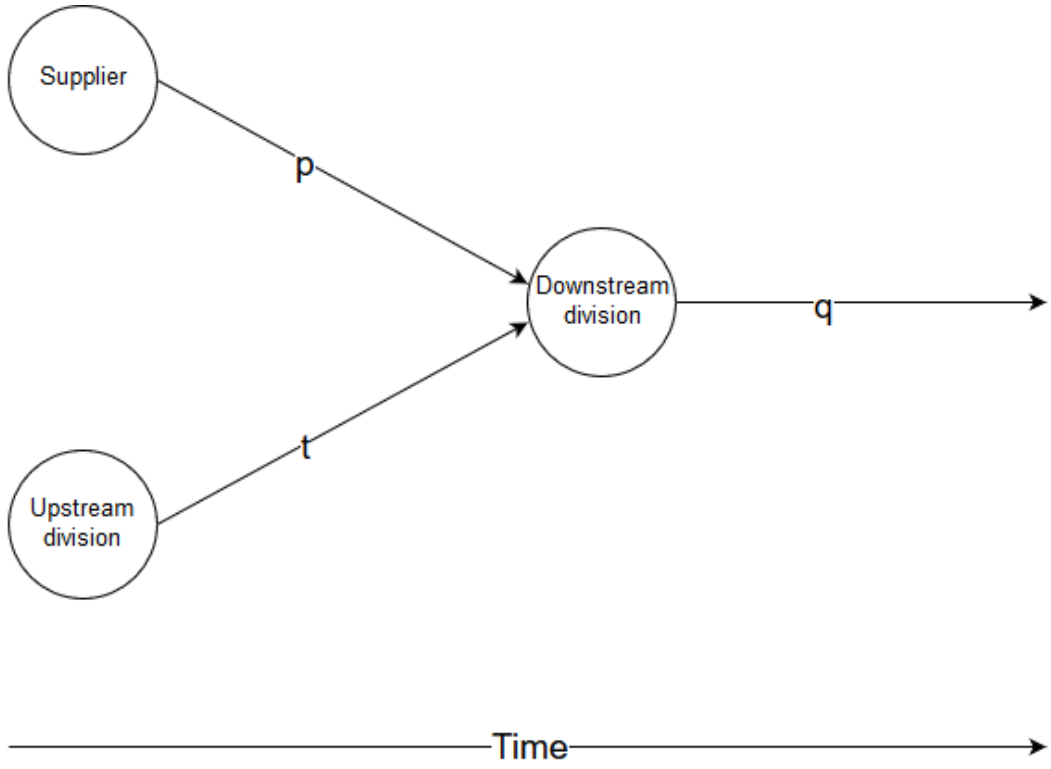
We can observe that the supplier earns twice as much as the firm. Apparently, if there are two companies, each with monopoly power, that vertically interact with each other, the advantage lies on the upstream company. So even though the firm brings a value added to end customers, its profit is substantially smaller relative to its supplier whose only customer is the firm. Interestingly, one might expect that it will be the frim that brigs value added who will have higher profit than the firm selling for example row materials. We will show how to improve the outcome of the firm in the next section.

3.2 Decentralization

Arya and Mittendorf (2007) suggest a way how to soften supplier pricing of the overcharging monopoly supplier. The suggestion is to decentralize a company. Decentralized company is weaker because decentralization adds another layer of internal frictions. This makes the company less efficient and therefore it cannot produce as much as before. However, the company with a new structure will create a completely new demand function for the external production input. It turns out that the supplier will have to set lower price relative to the centralized case. Furthermore, this price effect is so strong that it makes the company more profitable than under centralized setup. It is also very important how the company is decentralized as we will see in upcoming chapters.

Supply Chain Timeline with the Decentralized Firm

Diagram 2: Supply Chain Timeline with the Decentralized Firm



In the diagram 3 we can see the timeline of the supply chain with a decentralized company. First players to move are the supplier and the upstream division. The supplier and the upstream division set the per unit supplier price and per unit transfer price of their intermediate product, respectively. Both prices are set simultaneously. The downstream division then procures the intermediate

products from both upstream players and assembles them together. The downstream division makes a decision how much units of the final product to produce (q), and sells them on the end market.

The structure of the decentralization where the downstream division does the assembly of the final product allows for the mutual interaction between the upstream division and the supplier. Because the final product is produced from exactly one unit from each input material the downstream division will procure the same amount of units from both the supplier and the upstream division. This fact forces the upstream players to settle for such prices that result in equal output of their productions. In another words, prices that are set by the supplier and the upstream division are mutual best responses.

Again, we use the backward induction to solve the outcomes in the current supply chain. Because we operate in a different supply chain, entities will have slightly different profit functions. We start with the entity that makes the last move and that is the downstream division.

The cost term of its profit function (t + p) reflects simultaneous procurement of intermediate inputs from the upstream division and the supplier. Multiply the cost term from above by the output and you will know the total cost of the downstream division. The demand for the final good remains unchanged and it is determined by the inverse demand function P = a – q. Multiply this price by the quantity sold and you get total revenue. Now it is easy to create profit function, which you can find in Table 2 already in its optimization form.

Recall from the centralized setup that since the downstream division has monopoly power on the end market, it maximizes its profit by producing specific profit maximizing output q. Again, the management of the downstream division takes the first order condition in order to determine this output, which is q = ½ * (a – p – t). The management will know the exact quantity once the supplier and transfer prices are known.

At the previous stage in time there are two players making a decision – the upstream division and the supplier. It does not matter whose problem we start

solving first, but keep in mind that decisions of both players will be mutually dependent.

The upstream division's production cost is c_i and its revenue is driven by the transfer price t. You can easily determine the profit formula from this information and it is stated in the Table 2 in optimization form. Similarly, to the centralized setup, the upstream division cannot decide on its optimal output directly, because it is dependent on decisions of the downstream division as well as the supplier. Rather, the upstream division maximizes its profit through setting optimal transfer price which in turn influences decisions of the supplier and the downstream division. The first order condition of the profit formula yields the optimal transfer price: $t = ½ * (a – p + c_i)$. Note, that the optimal transfer price depends on the supplier price.

The supplier's cost remains c_e and the revenue will be determined by the supplier price p. You can see suppliers profit formula in Table 2 in its optimization form. After taking the first order condition of the supplier profit formula with respect to supplier price, we receive $p = ½ * (a – t + c_e)$. You can see that the optimal supplier price depends on the value of the transfer price.

As we have already mentioned several times, the level of transfer price and supplier price are mutual best responses of the upstream division and the supplier, respectively. The optimal transfer and supplier price formulas above create a system of two equations of two unknowns. The final values of these prices are stated in the Table 2.

Having the transfer and supplier prices determined we can go back to the downstream division's problem. We substitute the values of the above mentioned prices into the optimal output expression. The optimal production volume of the downstream division is summarized in Table 2.

Finally, when the optimal quantity is known, the upstream division and supplier know how much to sell to their buyer. At this point they realize their profits. The downstream division will then assemble final products and sell them on the retail

market. Its profit is realized at this point. Profit of each player is summarized in the Table 2.

Table 2: Outcomes of the Supply Chain with the Decentralized Firm

<table>
<tr><th></th><th>Downstream division</th><th>Upstream division</th><th>Supplier</th></tr>
<tr><td>Profit maximization problem</td><td>$Max_q\ q*(a - q) - q*(t + p)$</td><td>$Max_t\ q*(t - c_i)$</td><td>$Max_p\ q*(p - c_e)$</td></tr>
<tr><td>Optimal quantity/transfer/supplier price</td><td>$1/6 * (a - c_e - c_i)$</td><td>$1/3 * (a - c_e + 2c_i)$</td><td>$1/3 * (a + 2c_e - c_i)$</td></tr>
<tr><td rowspan="2">Profit</td><td>$1/36 * (a - c_e - c_i)^2$</td><td>$1/18 * (a - c_e - c_i)^2$</td><td rowspan="2">$1/18 * (a - c_e - c_i)^2$</td></tr>
<tr><td colspan="2">$1/12 * (a - c_e - c_i)^2$</td></tr>
<tr><td rowspan="2">Profit distribution ratio</td><td>1</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">3</td><td>2</td></tr>
</table>

After bringing inefficiencies by splitting the company into two divisions, the supplier price has decreased – see Table 3. For verification refer to Appendix where you can find proof by contradiction. So weakening the company by decentralization has its benefit – lower input price from the supplier.

But what about quantity produced? By looking at the comparison in Table 3 we can see that the output decreased by 33.3%. In another words, the company lost 33.3% of its customers after decentralization. It is due to higher price of the final good as you can see also in Table 3.

What happened at the final market is that the firm has increased prices and sells lower volume of final goods. This phenomenon has beneficial effect on the firm's profitability – it has increased by slightly more than 33.3% or by one third if you will. The rate of the increase in profitability is extraordinary. If this rate would have

been quite smaller, for example in single digits, maybe the company management would not bother to decentralize the firm because of a big work load connected with the decentralization. But the growth rate of 33.3% makes a decision to decentralize worthwhile for every company. Bigger the company is in terms of profit, more benefit it would have form decentralization.

Furthermore, the profit distribution in the supply chain changes in favor of the firm after the decentralization as you can see in Table 3. Note that supplier's profit decreased dramatically by 44.4%. Since supplier's cost is stable, the decrease has to be caused on the revenue side. In fact, there are two reasons for that. Namely, the supplier price after decentralization has dropped and the quantity sold to the downstream division has decreased relative to what has been sold to centralized firm. It is interesting to notice how much was the supplier overcharging its buyer. After the 44.4% decrease in profitability, he even still remains profitable.

Table 3: Outcome Comparison of the Supply Chains with the Centralized vs. Decentralized Firm

	Centralization	Decentralization
Supplier price	½ * $(a + c_e - c_i)$	1/3 * $(a + 2c_e - c_i)$
Quantity	¼ * $(a - c_e - c_i)$	1/6 * $(a - c_e - c_i)$
Price of the final good[4]	a - ¼ * $(a - c_e - c_i)$	a - 1/6 * $(a - c_e - c_i)$
Firm profit	1/16 * $(a - c_e - c_i)^2$	1/12 * $(a - c_e - c_i)^2$
Supplier profit	1/8 * $(a - c_e - c_i)^2$	1/18 * $(a - c_e - c_i)^2$
Profit distribution (firm/supplier)	1/2	3/2

Let's now go back and examine the success of the company in raising its profitability. We have described the revenue part of the profit function when we were talking about the 33.3% decrease of production volume on one hand, and the increase of price on the final market on the other. The price effect is so strong that it offsets the volume effect with net profit increase of 33.3%.

[4] Recall, P = a – q.

However, interesting things happen on the cost part of the profit function. Or, I should rather say that they don't happen. Let's take a closer look.

The supplier's marginal production cost is c_e. The production cost of the upstream division's is c_i. But what is the manufacturing cost of the downstream division? It has to put the two components together in order to make the final product. As you could see in the downstream division profit function below, there are no production costs whatsoever. Only costs the downstream division incurs are the costs of procurement – namely the transfer price and the supplier price.

$Max_q\ q*(a - q) - q*(t + p)$

In order to get full picture of the cost structure of the whole company, let's take a look also on the profit function of the upstream division:

$Max_t\ q*(t - c_i)$

One might argue that the transfer price represents a new cost for the firm. However, the transfer price is cost in face of the downstream division on one hand, but it is the revenue driver of the upstream division on the other. The transfer price therefore cancels itself out in the profit function of the whole firm. So we should view the transfer price rather as an inefficiency. Specifically, the markup as a component of the transfer price is the cause of inefficiencies because it decreases the final output. The transfer price at variable cost would not influence production decision as we will see in the following chapters.

What is more important to observe in the firm's cost structure is the cost of manufacturing c_i. It remains at the same level! This is counterintuitive because we would expect an increase of production cost after decentralization, especially when both divisions are engaged in production. We would specifically expect that the downstream division will incur production costs since it assembles final product. This is not the case and it leads to a very important assumption about the increase in company's profitability by the decentralization – the costs of the whole company cannot increase!

There are several ways to interpret application of this assumption in the proposed supply chain.

One interpretation is that the downstream division's problem $Max_q\ q*(a - q) – q*(t + p)$ suggests that the cost of production of this division is zero. By looking at the cost term $q*(t + p)$ of the downstream division, we observe that the only costs of the downstream division are the procurement costs, hence the cost of putting procured parts together is zero.

The second interpretation of the above mentioned assumption could be that in fact the final assembly costs something. Therefore, the marginal production cost c_i incorporate the cost of production of the intermediate good as well as the final assembly. Then, production cost c_i should have been split into two parts after decentralization. However, since we assume that the company cost remains the same after decentralization, it is not necessary to split the cost among divisions from purely technical point of view.

The last interpretation I could think of lies in the transfer price structure. The transfer price is constructed in such way that it includes all the production costs except the procurement costs. In another words, the upstream division pays for all manufacturing cost. The only cost the downstream division takes into consideration are the procurement costs.

No matter which interpretation sounds more or less likely, we should keep in mind the underlying assumption. To conclude, the results of Arya and Mittendorf (2007) hold only if the company remains as efficient under decentralization as it was under centralized set-up.

We can try to think of an example where this assumption can work. Let's suppose that decentralization happens sort of pro forma. That means that both divisions stay in the same building as they were. Also, no people are hired to newly created entities in order to keep costs unchanged. If new positions are created by decentralization, the current headcount has to handle them. That means that some people will have additional function relative to centralization but without increased wages. These arguments indicate that decentralization without a cost

increase is quite unlikely. However, I would not do a forgone conclusion like this because near future might prove me wrong. According to the Boston Consulting Group the rise of forces such as new technology, automation, big data and analytics, agility and innovation or access to information and ideas will change the way how will organizations work. (Bhalla, Dyrchs, Strack, 2017) No one says, that the company cannot fully redesign its operations while doing decentralization.

We also have to be aware of one important aspect in the supply chain interactions, and that is observability. The firm somehow has to make sure that the supplier knows and believes that the company is divided into two divisions. He has to have a credible information about the transfer price. Simply, he can observe and believe that the firm is not just pretending the weakness. He has to believe that this is the new status quo. Then, of course, he is willing to lower the price because by doing that he increases his profit.

We will now turn to graphics to get even better understanding of the interactions in the supply chain.

4. The successful strategy of decentralization - graphically

The decision making process of different players is best captured graphically. We are going to go through decision making process of each player under both supply chain setups – with the centralized and with the decentralized company.

According to Mankiw "Rational people often make decisions by comparing marginal benefits to marginal costs." (Mankiw 5e: 6) If we translate it into the language of company's management, it means that decisions are made based on analysis of marginal revenue and marginal cost. We know from basic microeconomic theory that firm maximizes its profit when marginal revenues equal to marginal cost (MR = MC). If the revenue from selling additional unit of product would be higher than the cost of selling this unit, then we would produce and sell this unit because we are making a profit. We would do this exactly until MR = MC. Or, in another words, until zero profit is made. It is because if the cost of selling marginal unit is higher than revenue we would generate; we would write down a loss. So producing such quantity that MR = MC is optimal because it maximizes company profit.

A monopoly firm is not a price taker. It has a market power to determine the price. So how does a monopoly firm maximize its profit since it knows that it wants to produce such quantity that MR = MC, and that it has the market power to set the price?

Well, a monopoly firm would start with a marginal analysis in order to determine the optimal quantity to be produced. The firm then looks at its demand function to see the price level corresponding to demanded quantity as you can see in the Graph 1. This analysis shows why the firm maximizes its profit through quantity and not through price.

Profit is then given by the quantity times the markup. Markup on the graph is the distance between the marginal cost – marginal revenue intersection and the demand curve. Profit is represented by the shaded area in the Graph 1.

We will solve the supply chain problems again by the backward induction but this time using graphics and marginal analysis rather than optimization problems. We will begin with a supply chain with a centralized company and then we will move towards decentralized setup.

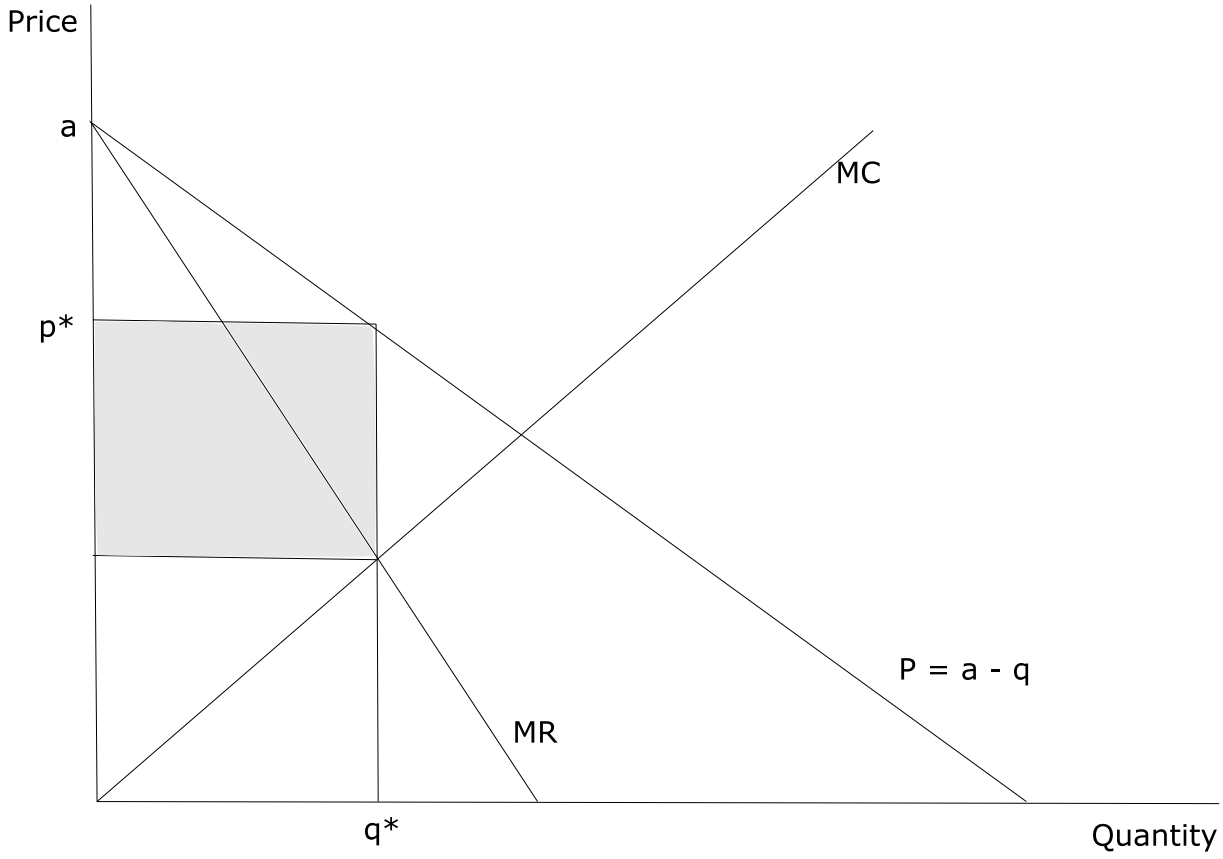
4.1 Centralization

You can see the supply chain timeline with a centralized company in Diagram 1. Since we are solving the problem by the backward induction we have to start with the downstream firm. We cannot start with marginal analysis right away because we only know marginal cost[5] ($p + c_i$), but the marginal revenues are unknown for us.

You can see the inverse demand function P for the final product plotted in the Graph 1. The marginal revenue can be easily derived from the inverse demand function. We simply derivate the total revenue with respect to quantity in order to get the marginal value:

$MR = \partial TR / \partial q$.

Graph 1: Profit Maximization of the Centralized Firm



[5] Marginal cost is the same as the variable cost for every player. Fixed costs are not decision relevant.

From the firm's profit function marked in Table 1 we can see that the total revenue is TR = q * (a – q). After the derivation with respect to q we get the marginal revenue[6] being MR = a – 2q.

We have determined both the marginal revenue and marginal cost. Now it is easy to find their intersection. The production volume corresponding to the intersection of marginal revenue and marginal cost is $q = ½ (a – p – c_i)$. Notice that the production volume is dependent on the level of the supplier price p.

Prolong the line between the optimal quantity on the horizontal axes and the intersection of marginal cost and marginal revenue until it reaches the demand curve. As we have already mentioned, the distance between the intersection of marginal cost – marginal revenue and the demand function is the markup. Multiply the markup by the optimal quantity and you will get the profit. However, the supplier price remains undetermined. So before the firm can make the final decision about its production volume it has to know the price for goods from the supplier.

Since the supplier has a monopoly power on his market as well, he faces a similar optimization problem as his buyer. However, there are few differences in calculations compared to the downstream firm. The inverse demand function for the supplier's goods is not explicitly given. However, the supplier knows what is the optimal quantity demanded by the downstream firm ($q = ½ (a – p – c_i)$) and he knows that this value is affected by his pricing decision. So the supplier has to find such price that maximizes his profit.

[6] Why is the marginal revenue curve below the inverse demand curve? We know that TR = p * q. The increase in q has two effects – production effect and price effect. Production effect means that more units sold increase revenue. The price effect suggests that lower price decrease revenue and thus, these effects oppose each other.
In order to increase production a monopolist has to decrease price of all units he is selling. So MR < p. Furthermore, you can notice that the marginal revenue curve is twice as steep as the inverse demand function. This implies that if the inverse demand function intersects the horizontal axis at point k, the marginal revenue curve intersects this axis at k/2.

Even though the supplier maximizes his profit through price, he would start with the marginal analysis just as any monopoly company would do. As we mentioned above, the supplier does not know the inverse demand function for his goods. But since he knows the optimal production volume of his buyer, he can easily derive the inverse demand function from it as you can see below.

$q = ½ (a – p – c_i) \rightarrow \mathbf{p = a – 2q – c_i}$

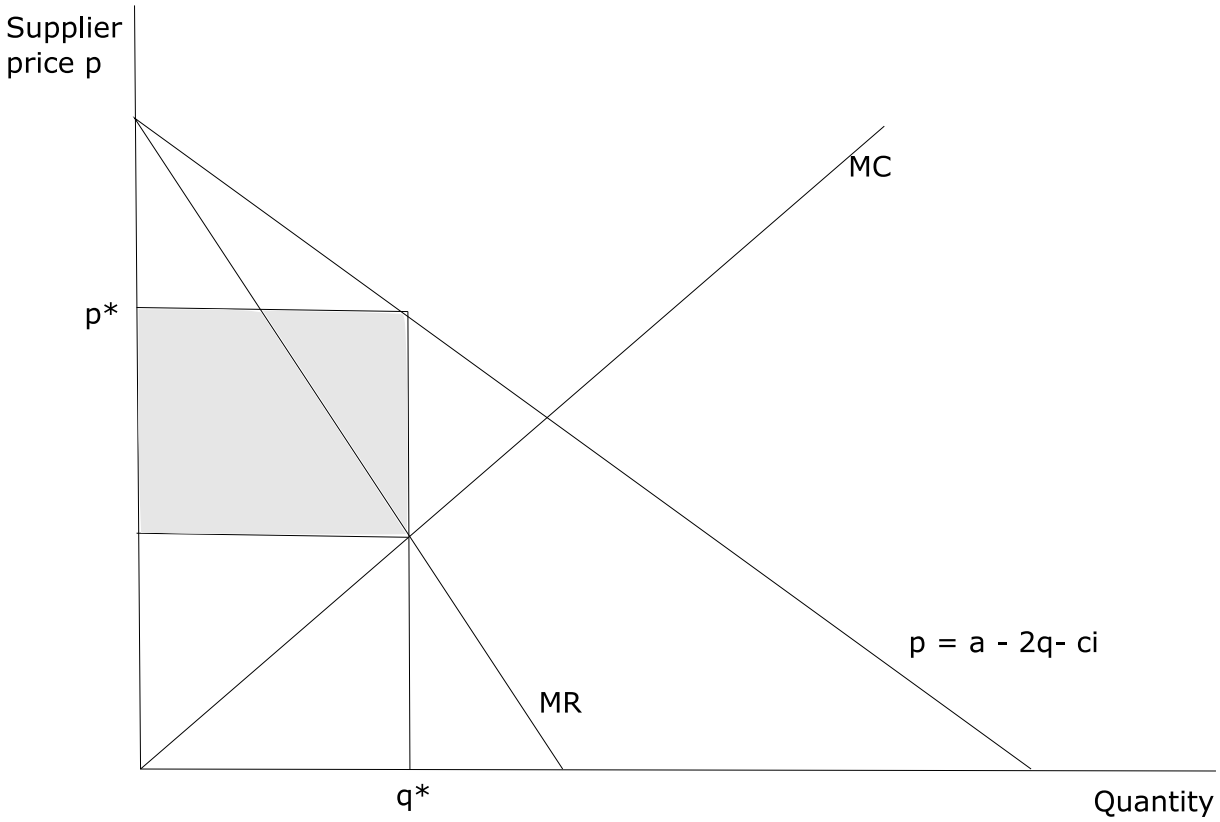
Now the supplier can proceed with marginal analysis; refer to the Graph 2. He calculates the profit maximizing output and finds the optimal price[7].

The downstream firm now knows the information about the supplier price and finally can determine its output and profit. The results are summarized in Table 1.

This is the basic mechanics of the supply chain interactions with a centralized firm shown on monopoly graphics. It is now clearer how monopolies do their profit optimization. We will proceed to the scenario with the decentralized firm.

[7] For the optimal supplier price see Table 1.

Graph 2: Profit Maximization of the Supplier, Supply Chain with Centralized Firm



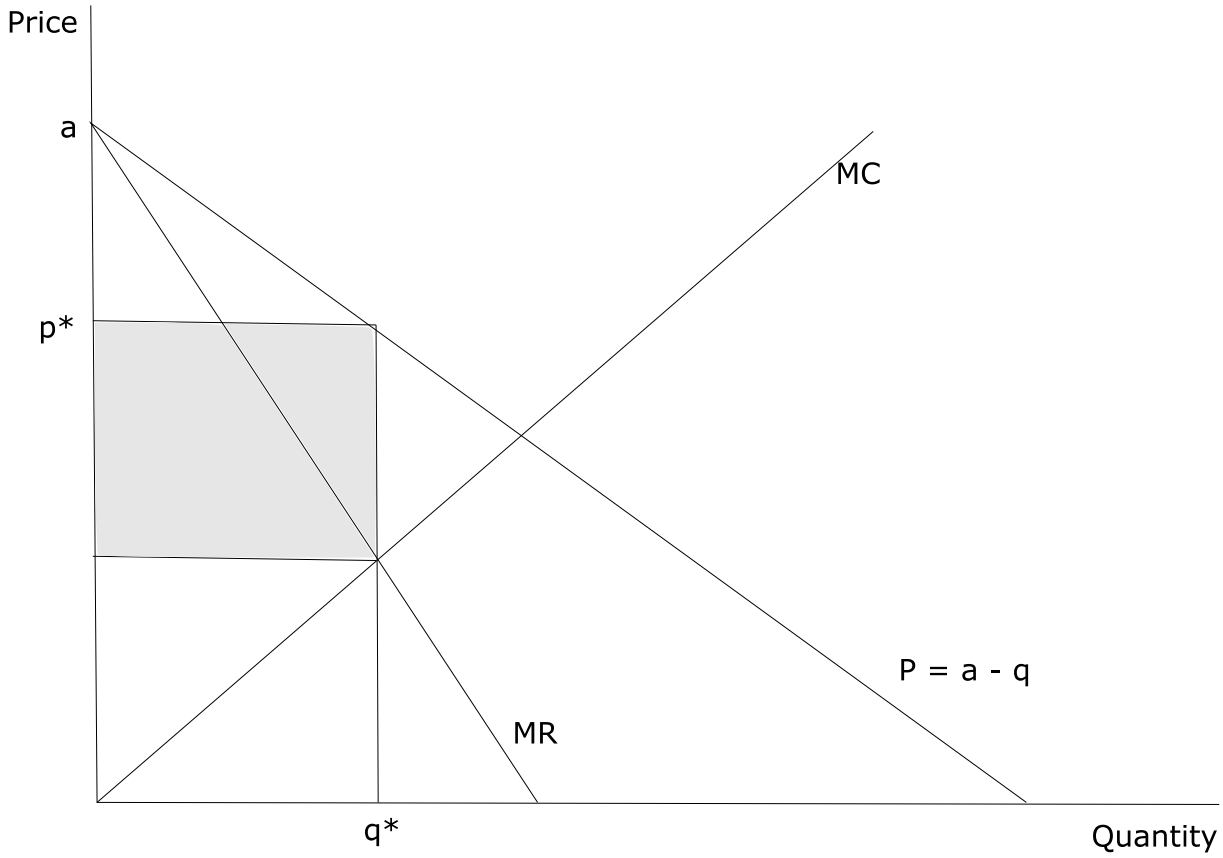
4.2 Decentralization

The timeline of the supply chain with a decentralized firm is indicated in the Diagram 3. Recall, that all players have monopoly power on their market. This suggest that each player will be maximizing its profit in the way as we have done above.

We start with the downstream division. The demand for final products remains unchanged and therefore the same holds for the marginal revenue. Production costs of the whole company stay the same as well. However, the firm is now divided, and as we have mentioned earlier, the downstream division has no manufacturing costs. The only cost the downstream division faces are procurement costs of intermediate goods (p + t). In fact, the procurement costs are already marginal costs, because in order to produce an additional unit of the final good, the firm has to procure additional unit from both intermediate products.

From this point on, the marginal analysis follows as usually arriving at the optimal production volume in terms of the transfer price and the supplier price ($q = ½ (a – t – p)$).

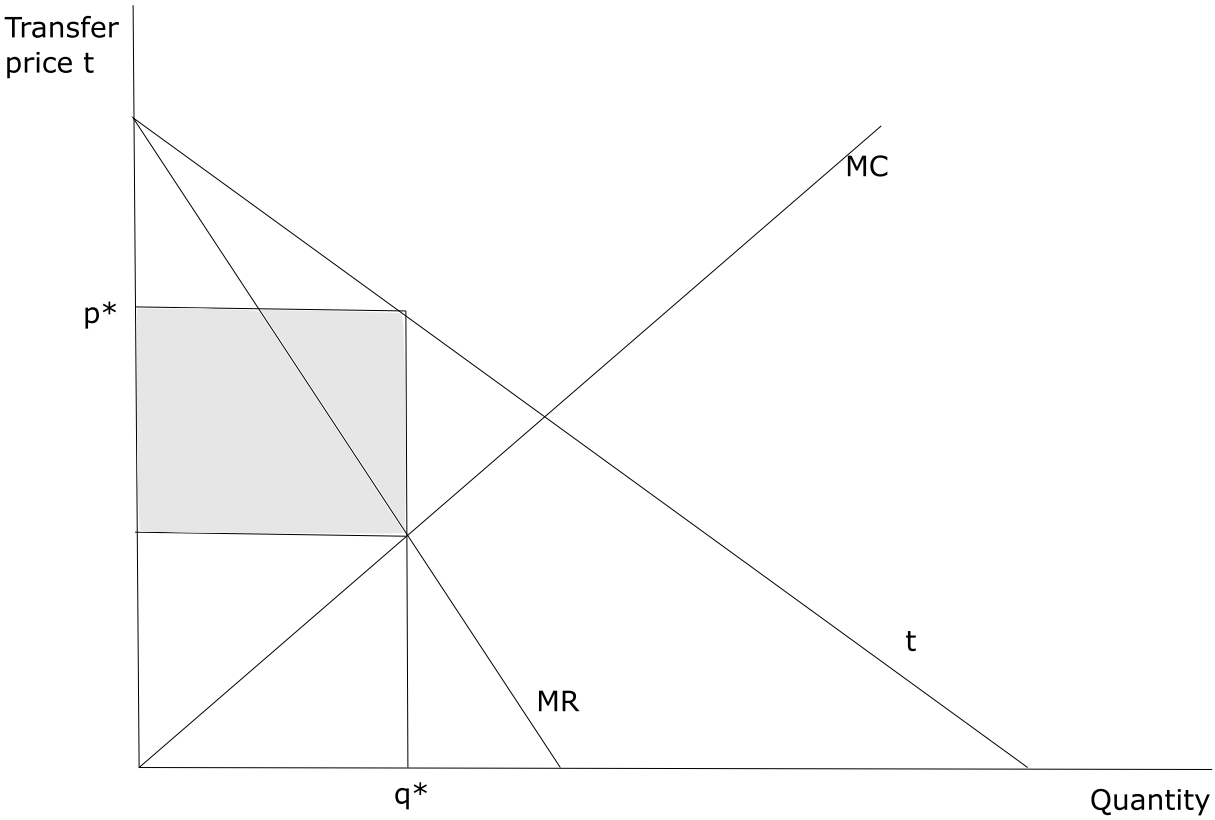
Graph 3: Profit Maximization of the Downstream Division, Supply Chain with the Decntralized Firm



According to the backward induction process, we go back one stage in time. At this time stage there are two players making a move simultaneously. Let's start with the upstream division.

The upstream division derives its inverse demand function from the production output of its downstream division while bearing in mind the decision of the supplier. After doing the marginal analysis, the upstream division sets its price at t = ½ * (a – p + c_i).

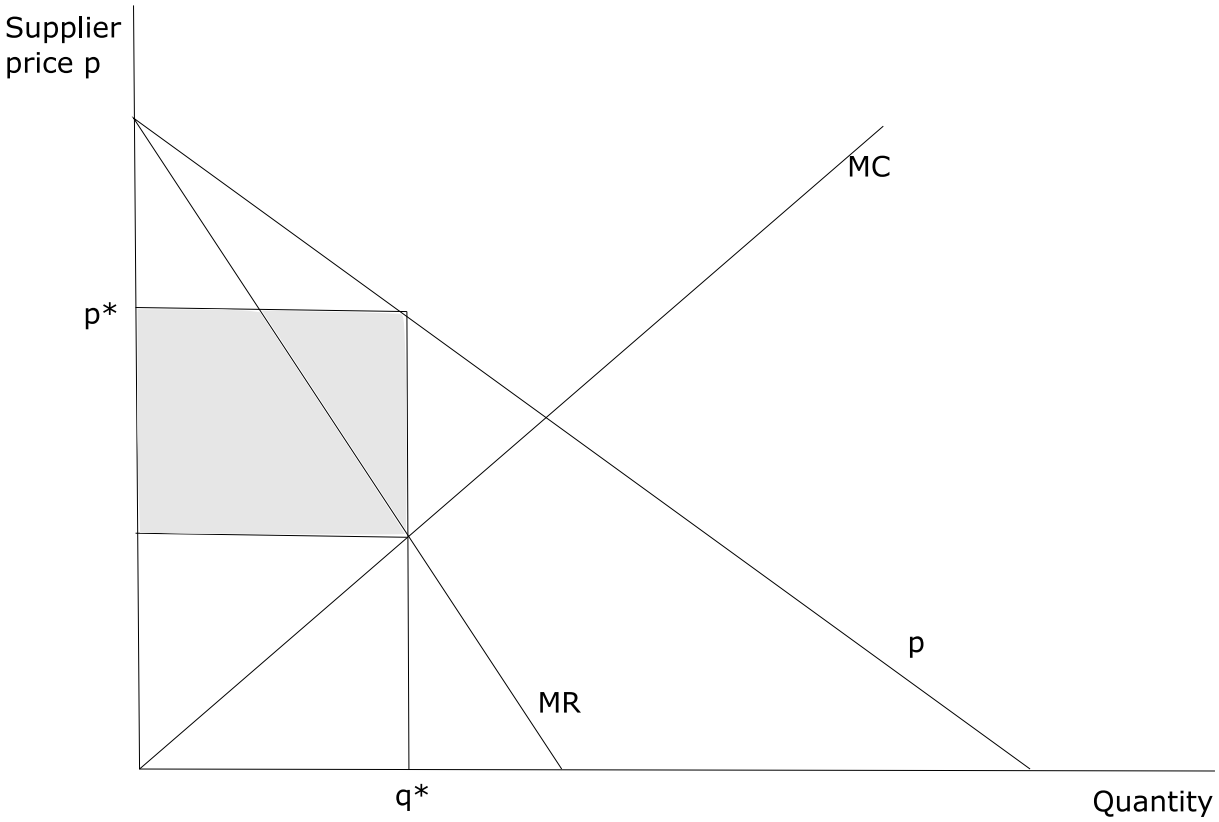
Graph 4: Profit Maximization of the Upstream Division, Supply Chain with the Decentralized Firm



Finally, let's get the last piece of the puzzle and that is the supplier price p. After the marginal analysis the supplier comes up with and optimal price $p = ½ * (a – t + c_e)$.

Table 1 summarizes the outcomes of the supply chain with a decentralized firm.

Graph 5: Profit Maximization of the Supplier, Supply Chain with the Decentralized Firm



You can see that we have arrived at exactly the same quantities, transfer prices, and supplier prices in both versions of maximization problems. Marginal analysis brought another perspective on maximization problems and we have also verified or results by doing this analysis.

This graphical analysis illustrates why the supplier lowers his price. It is because the new company structure (decentralization) and its coordination problems create a new demand function for the supplier goods as you could see in the Graph 2 and in the Graph 5. The supplier only maximizes his profit given the market conditions.

5. Changing of organizational structure

The results of Arya and Mittendorf (2007) are interesting because the general economic knowledge is that you do not want to face a double marginalization problem. It brings inefficiencies. More double marginalization problems a company faces, more inefficiencies it has to deal with. Therefore, a management should focus on reducing double marginalization problems as much as possible. More efficient firms are more profitable, right? Well, in general we would think so. However, according to Arya and Mittendorf (2007) it is actually beneficial for company's profitability to be faced not with one, but two double-marginalization problems. Hence, the supplier and the upstream division are two entities both creating a double marginalization problem for a firm since they charge markup on top of their variable costs. And interestingly, while inefficiencies were increasing with decentralization, the profit of the firm has risen at the same time.

I would like to challenge this paradox and I would like to examine under which conditions it holds. It is important to do this analysis because some real world companies out there might decide to yield benefits of decentralization. The management of this firm has to be careful because if certain conditions are not met, then decentralization of this company will lead to reduction in profitability relative to the centralized setup. The production volume will be also depressed which will lead to customer dissatisfaction. Even though we still talk about a monopolistic firm, no manager would like to be held responsible for such a failure.

Just splitting a company does not guarantee a successful increase in profitability. First of all, we have already discussed one crucial assumption – company's variable cost cannot increase with decentralization. In most cases, this condition is quite improbable to meet, however, not completely unrealistic for certain firms mainly due to the way they operate and the number of arising technologies they can benefit from.

The second important issue in yielding benefits of decentralization is the structure of the newly decentralized company. In another words, how management decentralize matters. The roles, competencies, and functions of newly created divisions have dramatic effect on the outcomes. There are multiple options how

to approach decentralization with regards to company structure. Some approaches lead to failure while other become part of the success.

A necessary, but not sufficient condition for successful decentralization is that the newly created entities have to be in vertical relationship so that trade will be going on between them. Otherwise, the divisions would only be independent departments with limited mutual interactions that do not create desired frictions. Or, specifically, a second layer of double-marginalization problem will not be introduced. Yet still, even if entities are in vertical relationship, the success is not guaranteed. The important condition for the success of decentralization is to make such a design of a decentralized firm where the mechanism of mutual best response between the supplier and one of the company's division is introduced.

In the previously proposed supply chain set up the decentralized firm was split into two divisions. Both of these divisions were manufacturing divisions where one of the division was producing intermediate good. The intermediate good was a production input for the division which was producing the final product. Perhaps, a more common practice is that companies are divided according to functions they serve, for example a production division and a sales division. The production division's role is to do all manufacturing work while the sales division's role is to buy the product from the upstream production division and sell it to the end customer with certain markup. How would the interactions look like in the supply chain with such company structure?

Well, in fact, the new design of the company structure changes the nature of interactions among different players. This change in nature of interactions affects the supply chain timeline. While previously every player was engaged in manufacturing, currently there are only two players doing manufacturing job – the supplier and the upstream division. The downstream division only buys and sells. In fact, the game becomes sequential (see Diagram 3). Here is why.

The upstream division is the only production division in the company and that makes her to take on new roles. It still has to produce the internal intermediate good. However, since it is responsible for all manufacturing, there is more job to

do. Namely, the final assembly. In order to make the final product, the upstream division has to procure external input from the supplier, which is another new function that the upstream division has to tackle. Furthermore, the final product has to be sold to a selling division based on a new transfer pricing mechanism. The new transfer pricing mechanism has to reflect the nature of the divisions.

So, by assigning the above mentioned roles to newly created divisions we are changing the timeline of the supply chain from (partially) simultaneous to sequential. It turns out that such company structure leads to decrease in profitability and customer satisfaction. We will quantify these results in the upcoming chapter.

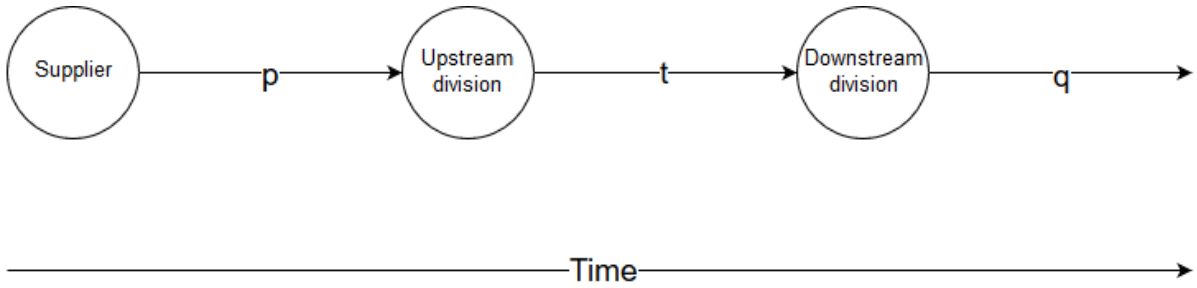
The third important aspect affecting the success of decentralization is the assignment of decision making power of the transfer price. Obviously, the transfer price structure will differ based on who has the power to determine it[8]. Under the company structure where all players are engaged in manufacturing, it is better if the upstream division has the power to set the transfer price. On the other hand, under the company structure with the production and sales divisions it is more beneficial for the whole company if the transfer price is set by company headquarters. We will quantify this phenomenon in the upcoming chapters.

Until now we have been discussing what has a crucial effect on the success of decentralization. However, there are issues which do not affect it. For example, if we take the company structure where one division is a production division and the other is a sales division, it does not matter if the payment of the supplier price is shifted to the downstream division. It might sound obvious, but I have decided to verify it in order to check whether there are some interesting questions arising by doing this. Let's now go back to the new company structure.

[8] Transfer price could also be negotiated among divisions.

5.1 New company structure

Diagram 3: Supply Chain Timeline with the decentralized firm with a new firm structure



The company is now decentralized into two divisions according to functions they serve. The upstream division is in charge of manufacturing and the downstream division's role is sales of final products. As we have already mentioned, such decentralization setup makes the supply chain timeline sequential – refer to the Diagram 4.

The flow in the supply chain starts with the supplier. He has a market power to determine the price for the goods he sells. The only customer of these goods is the upstream division of the firm. She uses them as an input for her own production. Further, the upstream division produces her own internal product. She combines it with the purchased product from the supplier and assembles them together. This way the final product is born. The sales (downstream) division buys the final product and sells it to the end customer. At this point, consumers are satisfied and the downstream division realizes her profit.

Because we are solving this supply chain problem by the backward induction, we start with the downstream division. The revenue driver for her is the price, which remains $P = a - q$. In terms of costs, the downstream division has to only pay for the final good from the upstream division. The per unit price for the final product is the transfer price t. The profit function of the downstream division is noted in the Table 4 in its optimization form.

The downstream division has monopoly power and it can determine its optimal production volume either through marginal analysis (MR = MC) or through the first order condition of the profit function. Either way, the downstream division's

optimal output is determined as q = ½ (a - t). As you can see, the optimal production volume depends on the price level of goods bought from the upstream division.

Going one step up the steam, there is the upstream division. She will of course use the information about the optimal quantity set by its downstream sister. The upstream division's revenue is driven by the transfer price which has to be determined in such a way that her profit is maximized. The cost term of the profit function is driven by two factors. The first factor is the own production cost related to manufacturing of the internal and final products. The second factor driving the cost is the price of the external input. The profit function is noted in the Table 4 in its optimization form.

The upstream division is in monopoly position as well. However, in order to maximize its profit, it has to determine the optimal transfer price, which directly influences the output produced. The first order condition of the upstream division's profit function yields the level of the transfer price: $t = ½ (a + p + c_i)$. So the transfer price depends on the level of the supplier price p.

The last player who is positioned one step up the stream from the upstream division is of course the supplier. While he is optimizing his profit, he is taking into account the information he can observe from both entities that are down the stream from him. He knows that he has power in his hands to affect not only his profit, but also the profits of both of the divisions. It is because the supplier price influences the upstream division who is setting the transfer price and therefore also the downstream division is affected by this decision.

The revenue driver for the supplier is the price he charges for his product and cost driver is simply the production cost of this product. The final profit function is marked in the Table 4 in its optimization form.

The supplier derives the optimal price for his goods from the first order condition of his profit function. For the optimal supplier price refer to the Table 4.

Since the supplier price is finally known we will go back down the stream and we will first determine the optimal transfer price for the final products upstream

division manufactures. Once the transfer price is determined, we will move one step down the stream and finally set the optimal volume the downstream division would like to sell to its customers. The supplier and the transfer price, optimal output, and profit of each player is summarized in the Table 4.

Table 4: Outcomes of the Supply with Decentralized Firm with a New Firm Structure

<table>
<tr><th></th><th>Downstream division</th><th>Upstream division</th><th>Supplier</th></tr>
<tr><td>Profit maximization problem</td><td>Maxq $q^*(a - q) - q^*t$</td><td>Maxt $q^*(t - p - c_i)$</td><td>Maxp $q^*(p - c_e)$</td></tr>
<tr><td>Optimal quantity/transfer/supplier price</td><td>$1/8\ (a - c_e - c_i)$</td><td>$¼\ (3a + c_e + c_i)$</td><td>$½\ (a + c_e - c_i)$</td></tr>
<tr><td rowspan="2">Profit</td><td>$1/64\ (a - c_e - c_i)^2$</td><td>$1/32\ (a - c_e - c_i)^2$</td><td rowspan="2">$1/16\ (a - c_e - c_i)^2$</td></tr>
<tr><td colspan="2">$3/64\ (a - c_e - c_i)^2$</td></tr>
<tr><td rowspan="2">Profit distribution ratio</td><td>1</td><td>2</td><td>4</td></tr>
<tr><td colspan="2">3</td><td>4</td></tr>
</table>

Let's now examine what can we observe by comparison to the company with the original structure.

We would logically think that the transfer price should increase with the new company structure. It is because under the new company structure the upstream division takes on new roles and responsibilities, thereby increasing her cost. Specifically, the upstream division takes on the procuring and final assembly role. It has to be reflected in the higher transfer price. And, in fact, this statement holds. For the proof by contradiction refer to the Appendix.

Table 5: Outcome Comparison Between Supply Chains with Different Company Structures

	Original firm structure	New firm structure
Transfer price t	$1/3\ (a - c_e + 2c_i)$	$¼\ (3a + c_e + c_i)$
Supplier price p	$1/3\ (a + 2c_e - c_i)$	$½\ (a + c_e - c_i)$
Optimal quantity	$1/6 * (a - c_e - c_i)$	$1/8\ (a - c_e - c_i)$
Downstream div. profit	$1/36 * (a - c_e - c_i)^2$	$1/64\ (a - c_e - c_i)^2$
Upstream div. profit	$1/18 * (a - c_e - c_i)^2$	$1/32\ (a - c_e - c_i)^2$
Company profit	$1/12 * (a - c_e - c_i)^2$	$3/64\ (a - c_e - c_i)^2$
Supplier profit	$1/18 * (a - c_e - c_i)^2$	$1/16\ (a - c_e - c_i)^2$
Profit distribution (D:U:S)	(1:2:2)	(1:2:4)
Profit distribution (F:S)	(3:2)	(3:4)

The supplier price is higher under the supply chain with the sequential timeline. For the proof by contradiction refer to the Appendix.

Why is the supplier price higher under the "functional" decentralization structure? Well, as you might have already guessed, the main difference between the two company structures is that there is a mechanism of a mutual best response in place in the original structure. The new company structure does not have this mechanism and thus, no additional pressure is made on the supplier. The important takeaway is that the only successful decentralization design for a company facing an overcharging supplier is a design that introduces a mutual best response mechanism between the supplier and one of the company's division.

Logically, when the supplier price is higher, the upstream division with its limited budget cannot procure as much goods from the supplier as under the original company structure. Therefore, less units of the final goods can be produced and sold to the downstream division. From the downstream division's point of view, the higher supplier price and higher transfer price makes purchase of goods from the upstream division costly leading to smaller orders. To be more specific, the company output is 25% smaller relative to the scenario with the original decentralization structure.

Profit of the whole firm is dramatically lower relatively to the decentralized company with the original structure, specifically 43.75%, which is decrease by almost a half. This number highlights even more how careful a company should by before deciding to yield benefits of decentralization. Interesting point is also a proportion between upstream and downstream division causing this decrease. It turns out that both divisions' profit decreases in the same pace, namely 43.75%.

Furthermore, the decentralization done in a wrong way can strengthen the overcharging supplier even further. His profitability would be 12.5% higher relative to the supply chain structure with a mutual best response mechanism.

To wrap up, the profit distribution has shifted back in favor of the supplier. The profit distribution ratio of the supply chain with a "functional" company structure is 3:4 in favor of the supplier compared to the ratio 3:2 of the supply chain with the original company structure.

Also the profit of the whole supply chain has decreased dramatically – by 21.25%. So even though the supplier is better off if the company is decentralized according to functions, the company itself is in such a bed condition that the decrease of the whole supply chain profit is more than a fifth relative to original decentralization structure. The firm and the end customers are losers of this new supply setup.

6. Transfer price decided by the headquarters

Until now we assumed that the upstream division has the power to decide on the transfer price. Naturally, the upstream division sets such transfer price that maximizes her profit. She maximizes her profit by charging a markup above its variable cost. In another words, if the transfer pricing decision power lies in hands of the upstream division, the structure of the transfer price will be cost plus[9].

Who should be the one in charge of transfer pricing policy? The immediate answer what usually comes to mind that it should be the headquarters. Headquarters have the incentive to look at the overall firm profitability while if the power is in hands of certain division, its management look after its own interest.

However, even though the logic above holds in most cases, it turns out that if the upstream division of a company is engaged in the mutual best response mechanism with an overcharging supplier, then the company is more profitable if it gives the transfer pricing decision power to the upstream division. In fact, if the upstream division would not be in charge of transfer pricing policy, then it could not be engaged in an interaction with the supplier resulting in the mutual best response. The value of the transfer price and the value of the supplier price are actually mutual responses of the upstream division and the supplier, respectively, since these two players make a decision at the same stage in time.

On the other hand, in most other scenarios a decentralized firm would be better off if the transfer pricing decision power lies in hands of the headquarters. When headquarters sets the price, it lowers the markup on the cost of goods produced by the upstream division. What happens in our analysis is that the headquarters actually reduces the markup to zero. Then the transfer price structure is variable cost. This allows the downstream division to purchase more goods from the upstream division, which potentially leads to higher profit.

What you could notice regarding the transfer price is that nobody decides on its structure only for the sake of having a specific transfer price structure. The

[9] Cost plus means that the structure of the transfer price is the variable cost plus markup. PWC defines it as following: “Cost plus method: A method of pricing based on the costs incurred plus a percentage of those costs.” (PWC 2014: 8)

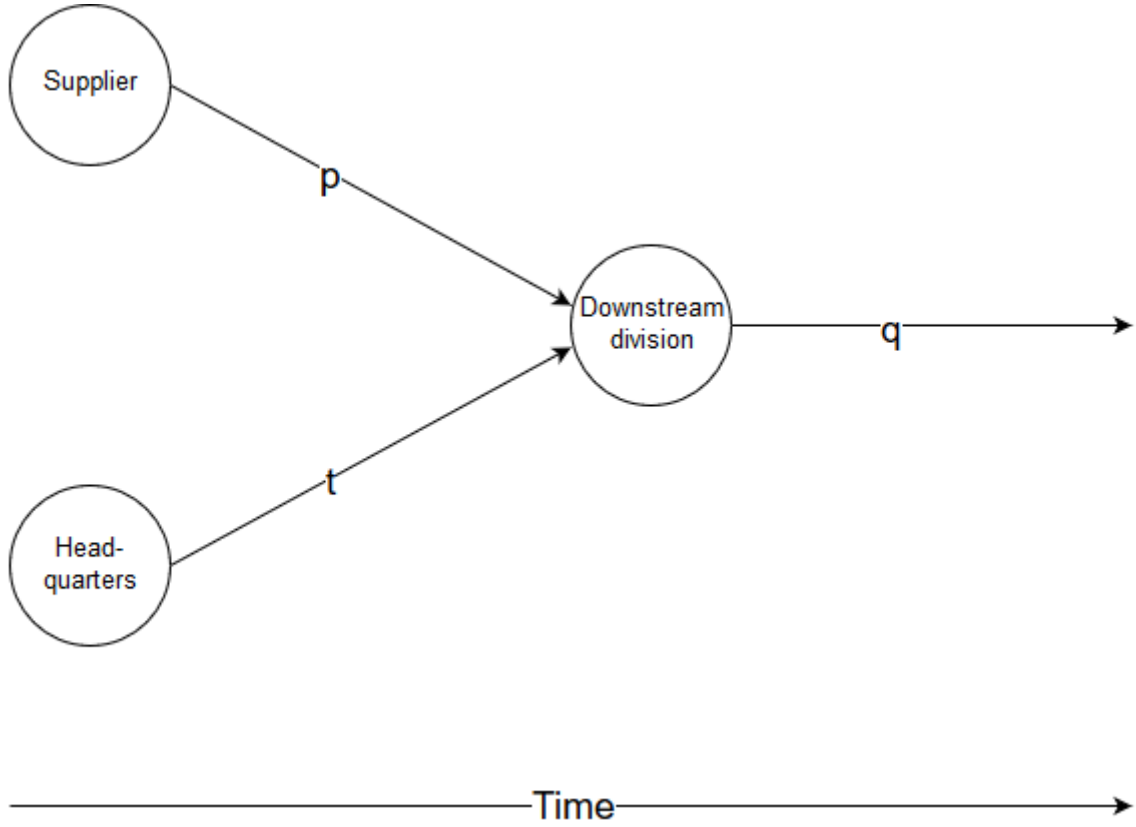
structure of the transfer price is given inherently by the profit maximization incentives of different players. Namely, for the benefit of the upstream division it was the best to charge a profit maximizing markup. On the other hand, headquarters were concerned with the benefit of the whole firm, and for this reason the variable cost is the profit maximizing transfer price structure.

We will now proceed with quantifying the effects of shifting the transfer pricing decision power from the upstream division to headquarters under both company decentralization designs. We start with the original design where both company divisions are production divisions. Then we move towards a decentralization design with one manufacturing division and one sales division

6.1 Transfer pricing power – headquarters – original decentralization design

The timeline of the supply chain is plotted in the Diagram 5. You can notice a new player sketched in the Diagram 5 – the headquarters who is setting the transfer price. The upstream division does not have any power to influence processes in the supply chain. The transfer price is given to them – the variable cost.

Diagram 4: Supply Chain Timeline with the Original Decentralization Design, Transfer pricing decided by the Headquarters



The supply chain flow starts with the supplier and the upstream division. These players are making a move at the same stage in time. The supplier decides on the price of his goods p while the headquarters set the transfer price t, which both divisions have to accept. Then the downstream division procures production inputs from the above mentioned entities so that she can do the final assembly. Based on the supplier and transfer prices, the downstream division makes a decision about the optimal output q. At this point in time the downstream division profit is realized and customer demand is satisfied.

As usually, we will solve this problem by the backward induction. The player at the last time stage is the downstream division. Nothing changes for him regarding his optimization approach. Of course, the levels of procurement prices will be different, but the principle remains. The revenue of the downstream division is driven by the price on the final market, namely $P = a - q$. The divisional cost will be driven by the prices of upstream intermediate goods: $(t + p)$. The profit function of the downstream division is noted in Table 6 in its optimization form.

The optimal production volume of the downstream division is of course dependent on the supplier price and the upstream division price. In order to find out the optimal output, the management of the downstream division has to take the first order condition of its profit function with respect to quantity. The solution is then $q = ½ (a - p - t)$.

If we go one step back in time we see two players that have to make a move simultaneously. As we have already discusses above, the upstream division does not make any decision in this supply chain set up. It is the headquarters who has to determine the transfer price with a goal to optimize company profit; and the supplier setting the price for his product.

We start with the headquarters. Since its goal is different than the goal of the upstream division, the profit function of the headquarters will be different. Recall, the upstream division was only concerned with her own divisional profit, while the headquarters makes sure that the company as whole makes the highest profit.

The headquarters' goal is company profit maximization, what we can interpret as a sum of profits of the both divisions. Technically, it is the sum of profit functions of both divisions. So there will be two revenue drivers in the company profit function, one for each division. The first revenue driver is naturally the price at which company sells on the final market: $P = a - q$. The other revenue driver is the revenue driver of the upstream division, which is the transfer price t. Similarly, on the cost side of the company profit function will be two cost drivers. One will be procurement cost of the downstream division, namely the supplier price and the transfer price. The other cost driver will be the manufacturing cost of producing

the internal intermediate product. The company headquarters profit function is marked in Table 6 in its optimization form.

The headquarters takes the first order condition of its profit function with respect to the transfer price. It turns out that the optimal transfer price for the company is the variable cost, $t = c_i$. This implies that the profit of the upstream division will be zero, since there is no markup from which she can make a profit. But before we make conclusions, let's look at the supplier.

The supplier still does his job as usual. His revenues are driven through the supplier price and cost is driven by his variable production cost. His profit function is noted in the Table 6 in its optimization form. For the optimal supplier price also refer to the Table 6.

We can now go back and determine the optimal production volume of the downstream division. Once this number is finalized, profits can be calculated as well. All of the results are summarized in Table 6.

Table 6: Outcomes of the Supply Chain with the Firm with Original Structure, Transfer Pricing Decided by Headquarters

	Downstream division	Headquarters	Supplier
Profit maximization problem	$Max_q\ q*(a - q) - q*(t + p)$	$Max_t\ q*(a - q) - q*(t + p) + q*(t - c_i)$	$Max p\ q*(p - c_e)$
Optimal quantity/transfer/supplier price	¼ $(a - c_e - c_i)$	c_i	½ $(a + c_e - c_i)$
Profit	1/16 $(a - c_e - c_i)^2$	1/16 $(a - c_e - c_i)^2$	1/8 $(a - c_e - c_i)^2$
Profit distribution ratio	1		2
	1		2

Table 7: Outcome Comparison between Transfer Pricing Assignments in a Supply Chain with a Decentralized Firm with Original Firm Structure

	Upstream division	Headquarters	Centralization
Transfer price t	$1/3\ (a - c_e + 2c_i)$	c_i	-
Supplier price p	$1/3\ (a + 2c_e - c_i)$	$½\ (a + c_e - c_i)$	$½\ (a + c_e - c_i)$
Optimal quantity	$1/6 * (a - c_e - c_i)$	$¼\ (a - c_e - c_i)$	$¼\ (a - c_e - c_i)$
Downstream div. profit	$1/36 * (a - c_e - c_i)^2$	$1/16\ (a - c_e - c_i)^2$	-
Upstream div. profit	$1/18 * (a - c_e - c_i)^2$	0	-
Company profit	$1/12 * (a - c_e - c_i)^2$	$1/16\ (a - c_e - c_i)^2$	$1/16\ (a - c_e - c_i)^2$
Supplier profit	$1/18 * (a - c_e - c_i)^2$	$1/8\ (a - c_e - c_i)^2$	$1/8\ (a - c_e - c_i)^2$
Profit distribution (D:U:S)	(1:2:2)	(1:0:2)	-
Profit distribution (F:S)	(3:2)	(1:2)	(1:2)

By looking at the comparison of the same company with two different transfer pricing decision assignments in the Table 7 we can see that it really matters who has the decision right. This simple shift changes literally everything.

As we have already mentioned, the transfer price declined to the variable cost of the upstream division which leads to no profit for this entity.

The supplier price is greater under the scenario when the headquarters is in charge of transfer pricing.[10] Furthermore, transfer pricing in hands of headquarters makes the supplier to charge the exact same price as under centralized company design.

[10] For proof refer to appendix.

The optimal production volume has increased as we shifted the transfer pricing control to the Headquarters. Actually, it is at the same level as under the centralized setup of the company. This makes perfect sense because, since there is no markup charged on the internal good, only the variable cost, the cost structure is exactly the same as under centralization.

Consequently, since the production cost and the supplier price under headquarters pricing are exactly the same as under centralization, the company profit is also the same as you can see in the Table 7.

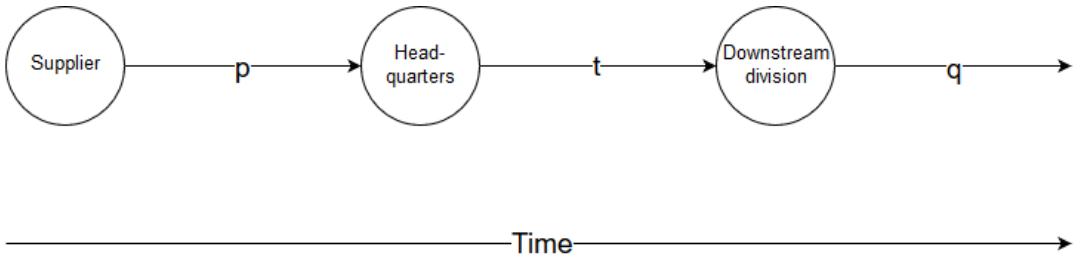
The supply chain profit distribution shifts back in favor of the supplier. Not surprisingly, the profit distribution ration between the company and the supplier is the same as under centralization: (1:2).

To wrap up, shifting of the transfer pricing decision rights to the headquarters not only changes every price, profit, or production volume, it also brings the supply chain outcomes to the exact same levels as under the supply chain with centralized company design.

6.2 Transfer pricing power – headquarters – new decentralization design

The timeline of the supply chain with a decentralized company according to functions with a transfer pricing power at headquarters is plotted on the Diagram 6. The upstream division does not make any decision about the price for the products she makes. It is the headquarters who now determines the transfer price which both divisions have to accept.

Diagram 5: Supply Chain Timeline with the New Decentralization Design, Transfer pricing decided by the Headquarters



The flow in the supply chain starts again with the supplier, who chooses a price p for his product. Then the headquarters with knowledge of this information sets the transfer price. The upstream division then buys external production input form the supplier, produces one intermediate product internally, and finally assembles the final product. Last, the downstream division buys these final products for the per unit transfer price t and sells them with a markup to end customers. At this point, downstream division's profit is realized and customer demand satisfied.

Once again, the problem of this supply chain is solved by the backward induction. The downstream division is the player who moves as last in the timeline. His revenue is driven by the price at the end market: $P = a - q$. His cost is driven by the price t that the upstream division charges for her goods. The downstream division's profit function is noted in the Table 8 in its optimization form.

The management of the downstream division has to take the first order condition with respect to price in order to get the optimal volume. The optimal output is of course dependent on the level of the transfer price: $q = ½ (a - t)$.

Going one stage back in time we come across the headquarters who is producing the final product and selling to the downstream division. However, she has no decision making power in the design of this supply chain. It is the role of the headquarters to set the transfer price.

The headquarters takes into account the information about optimal production volume from the downstream division. The interest of the headquarters is to maximize the profit of the whole company. In another words, it has to maximize the profit of both divisions. This is reflected in its profit function as a sum of the profit function of both divisions. The revenue driver of the company profit is of course the price of its product on the final market: $P = a – q$. The revenue driver of the upstream division is the transfer price, however, it is the cost driver for the downstream division as well. So the only cost driver of the firm is its variable production cost c_i and the cost of procurement of the external good p. The company's profit function is marked in the Table 8 in its optimization form.

The headquarters takes the first order condition in order to determine the optimal transfer price t, which of course is affected of yet unknown supplier price: $t = p + c_i$.

The headquarters has decided to set the transfer price at the variable cost of the firm. Recall, this is the same result as under supply chain with the original decentralization company design with transfer pricing power at headquarters.

The supplier takes the information above into consideration while making his decision about the price of his goods. His revenue and cost drivers are unchanged and his profit function is noted in the Table 8 in its optimization form. He takes the first order condition of the profit function in order to determine the optimal price, which you can see in the Table 8.

We can now go back and determine the optimal transfer price and consequently the optimal production volume. All of the outcomes are noted in the Table 8.

Table 8: Outcomes of the Supply Chain with the Firm with New Structure, Transfer Pricing Decided by Headquarters

	Downstream division	Headquarters	Supplier
Profit maximization problem	Max_q $q^*(a - q) - q^*t$	Max_t $q^*(a - q) - q^*t + q^*(t - p - c_i)$	Max_p $q^*(p - c_e)$
Optimal quantity/transfer/supplier price	¼ $(a - c_e - c_i)$	½ $(a + c_e + c_i)$	½ $(a + c_e - c_i)$
Profit	$1/16\ (a - c_e - c_i)^2$	$1/16\ (a - c_e - c_i)^2$	$1/8\ (a - c_e - c_i)^2$
Profit distribution ratio	1		2
	1		2

Table 9: Outcome Comparison between Transfer Pricing Assignments in a Supply Chain with a Decentralized Firm with New Firm Structure

	Upstream division	Headquarters	Centralization
Transfer price t	¼ (3a + c_e + c_i)	½ (a + c_e + c_i)	-
Supplier price p	½ (a + c_e – c_i)	½ (a + c_e – c_i)	½ (a + c_e – c_i)
Optimal quantity	1/8 (a – c_e – c_i)	¼ (a – c_e – c_i)	¼ (a – c_e – c_i)
Downstream div. profit	1/64 (a – c_e – c_i)^2	1/16 (a – c_e – c_i)^2	-
Upstream div. profit	1/32 (a – c_e – c_i)^2	0	-
Company profit	3/64 (a – c_e – c_i)^2	1/16 (a – c_e – c_i)^2	1/16 (a – c_e – c_i)^2
Supplier profit	1/16 (a – c_e – c_i)^2	1/8 (a – c_e – c_i)^2	1/8 (a – c_e – c_i)^2
Profit distribution (D:U:S)	(1:2:4)	(1:0:2)	-
Profit distribution (F:S)	(3:4)	(1:2)	(1:2)

Under the decentralization design with a manufacturing division and a sales division, the transfer price gets cheaper when the transfer pricing power is shifted from the upstream division into the hands of headquarters[11]. Furthermore, we can observe that the structure of the transfer price changes from cost plus to the variable cost. It is because the goal of the headquarters is to maximize overall company profit. Therefore, the headquarters do not put a markup above production cost because it creates an inefficiency within the firm. No markup on top of the variable costs of course leads to no profit for the upstream division.

Shifting of the pricing power decision rights have no effect on the supplier price. It remains the same no matter who is determining the transfer price in this

[11] For proof refer to Appendix.

“functional” decentralization design. So clearly, the introduction of second marginalization itself will not help the company to profit more.

Cheaper transfer price has a dramatic effect on the number of final goods produced. The production volume doubles as transfer pricing rights are shifted to the headquarters. Consequently, since the supplier per unit price and cost remain unchanged, the profit of the supplier doubles as well.

The downstream division benefits from low transfer price and consequent high production volume. Her profit increases dramatically. Perhaps, because of such a high profit the headquarters could compensate the upstream division by an ex post transfer of financial from the downstream division.

In the end of the day the profit distribution ration shifts back in favor of the supplier. Under the allocation of the transfer pricing power to headquarters, the supplier makes twice as much profit as the company. Overall supply chain profit has increased by 71.43%. The policy maker would be happy with such a result because of higher tax income. Furthermore, twice as much customers are satisfied relative to transfer pricing power at the upstream division. So the policy maker would have high incentive to put transfer pricing power into the hands of headquarters.

Another very interesting observation is that there are the exact same results in the original and new design of company decentralization when transfer pricing power lies in hands of the headquarters. In another words, we can make a conclusion that when the headquarters have the transfer pricing decision rights on their side, it does not matter how does the structure of a decentralized company look like. The transfer price structure will be variable cost and the company will yield the exact same profit. The profit will not only be the same over all, but the divisions would be earning the exact same amount as well.

7. Changing the transfer price structure – shifting the payment of the supplier price to downstream division

In the search for interesting results I decided to experiment with trading relations between the upstream and downstream division. The idea is to examine what would happen if the payment of the supplier price is not part of the transfer price, but the downstream division pays the supplier price separately. Or, in another words, the payment of the supplier price is shifted to the downstream division. Obviously, this experiment has to be done in the new decentralization design where the upstream division does manufacturing while the downstream division is a sales division. It would not be possible to run this experiment in the original decentralization where both company divisions are engaged in manufacturing – the upstream division producing the internal intermediate good and the downstream division doing the final assembly because the supply chain timeline would not be simultaneous any more.

It turns out that this measure would have no effect. The upstream division has to procure intermediate goods from the supplier in order to produce the final product. Then naturally, the price for supplier good is included in the transfer price along with the production cost and markup. If we want to make the downstream division pay for the supplier goods separately, the upstream division would be sending two invoices to the downstream division instead of one. On one invoice there would be the variable production cost plus the markup while on the other invoice there would be just cost of procuring. So what was previously on the one invoice would be split into two invoices and thus, such measure has no effect on company profitability nor on the quantity produced.

We are going to verify the effect of shifting the payment of the supplier price to the downstream division on the outcomes in the supply chain with the "functional" decentralization design. As usually, we will solve this problem by the backward induction. The timeline of the supply chain is plotted on the Diagram 5.

The downstream division is the player at the end of the timeline thus we start with his problem. His revenue driver remains the consumer price $P = a - q$. The cost driver is now of course the transfer price and the cost of procurement, $(t + p)$. The

profit function of the downstream division is marked in the Table 10 in its optimization form. In order to determine the optimal quantity, we take the first order condition of the profit function with respect to quantity, ending up with $q = ½ (a – p – t)$.

The upstream division's revenue driver is naturally the transfer price t. The cost term of its profit function is only the variable production cost c_i since the payment of the supplier price is shifted to the downstream division. The upstream division's profit function is noted in the Table 10 in its optimization form. After taking the first order condition with respect to quantity, we obtain the optimal transfer price being $t = ½ (a – p + c_i)$.

Finally, the supplier problem is the same as usual and it is marked in the Table 10 in its optimization form. The optimal price for the supplier goods is derived from the first order condition of the supplier's profit function and marked in the Table 10.

We will now go back and determine the optimal transfer price as well as profit of each player. All of the outcomes are marked in the Table 10.

Table 10: Outcome of the Supply Chain with a Firm with New Firm Structure, Supplier Price Payed by the Downstream Division

	Downstream division	Upstream division	Supplier
Profit maximization problem	Max_q $q^*(a - q) - q^*(t + p)$	Max_t $q^*(t - c_i)$	Maxp $q^*(p - c_e)$
Optimal quantity/transfer/supplier price	1/8 $(a - c_e - c_i)$	¼ $(a - c_e + 3c_i)$	½ $(a + c_e - c_i)$
Profit	1/64 $(a - c_e - c_i)^2$	1/32 $(a - c_e - c_i)^2$	1/16 $(a - c_e - c_i)^2$
	3/64 $(a - c_e - c_i)^2$		
Profit distribution ratio	1	2	4
	3		4

Table 11: Outcome Comparison of the Supply Chain with a Decentralized Firm with the New Firm Structure, Payment of the Supplier Price by the Upstream vs. Downstream Division

	Upstream division	Downstream division
Transfer price t	¼ $(3a + c_e + c_i)$	¼ $(a - c_e + 3c_i)$
Supplier price p	½ $(a + c_e - c_i)$	½ $(a + c_e - c_i)$
Optimal quantity	1/8 $(a - c_e - c_i)$	1/8 $(a - c_e - c_i)$
Downstream div. profit	1/64 $(a - c_e - c_i)^2$	1/64 $(a - c_e - c_i)^2$
Upstream div. profit	1/32 $(a - c_e - c_i)^2$	1/32 $(a - c_e - c_i)^2$
Company profit	3/64 $(a - c_e - c_i)^2$	3/64 $(a - c_e - c_i)^2$
Supplier profit	1/16 $(a - c_e - c_i)^2$	1/16 $(a - c_e - c_i)^2$
Profit distribution (D:U:S)	(1:2:4)	(1:2:4)
Profit distribution (F:S)	(3:4)	(3:4)

By looking at the Table 11 we can observe that the shift of the payment of external procurement to the downstream division changes the transfer price. In fact, the

transfer price is now smaller by the level of the supplier price[12]. However, this is the only change that happens in the supply chain. We have already discussed why this happens. From technical point of view, what happens is only adding p term in the downstream division's problem and subtracting this term from the upstream division's optimization problem. Again, if we look at it logically, it should not matter who in a company pays for the procured goods and this should not affect the outcomes in the supply chain. And yes, indeed, that is what we observed. However, I was not sure, if shifting of the payment of the supplier price would not affect the interactions. Therefore, I have diced to verify it.

[12] To verify it take the transfer price from the Table 11 and subtract the supplier price from it. You will see that
¼ (3a + c_e + c_i) - ½ (a + c_e – c_i) = ¼ (a – c_e + 3c_i)

8. Summary

There are many ways how to look at the effects and results we have just seen. We will sum up our observations from different angles now. We will first look from the perspective of the business owner of the firm. Then we would examine how a policy maker would perceive the problem. Finally, we will consider how would a holding that owns a firm in every layer of the supply chain approach this problem. As a business owner or a manager of the company you have a lot of power in your hands to influence the outcome of your company under our setup. Ultimately, you can decide on company structure – centralization or decentralization, roles of the divisions, and assignment of transfer pricing power as we have mentioned above. These were the three most important aspects affecting the final outcome. You will be most likely limited in each of these aspects by legislation and other issues, but for simplicity we have assumed that you are completely free in decisions regarding these three aspects. Because of this, it does not matter what is your starting position. You can always end up in the best possible situation (the highest profit) if you make right decisions. You are of course limited by internal and external production costs, however, you can influence the cost of procurement. So there are lots of things in your hands.

Ultimately, there are four issues that a monopolistic company facing an overcharging supplier needs to have in check in order to increase its profitability by decentralization. First of all, the production cost of the whole firm cannot increase after decentralization. Second, the decentralization has to be done is such a way that the relationship between newly created divisions is vertical – they have to trade. Third, the roles of the divisions matter. Such roles have to be assigned to each division that allow for simultaneous interaction between the supplier and the upstream division. The fourth issue to take into account is the assignment of the internal pricing rights. In most cases it is optimal if the headquarters decide on the transfer price, however, if the three conditions above are fulfilled, internal pricing rights have to be in hands of the upstream division. The reason is that the transfer price structure is inherently given by the player who has the power to decide on this price. Because the upstream division would charge a markup above marginal

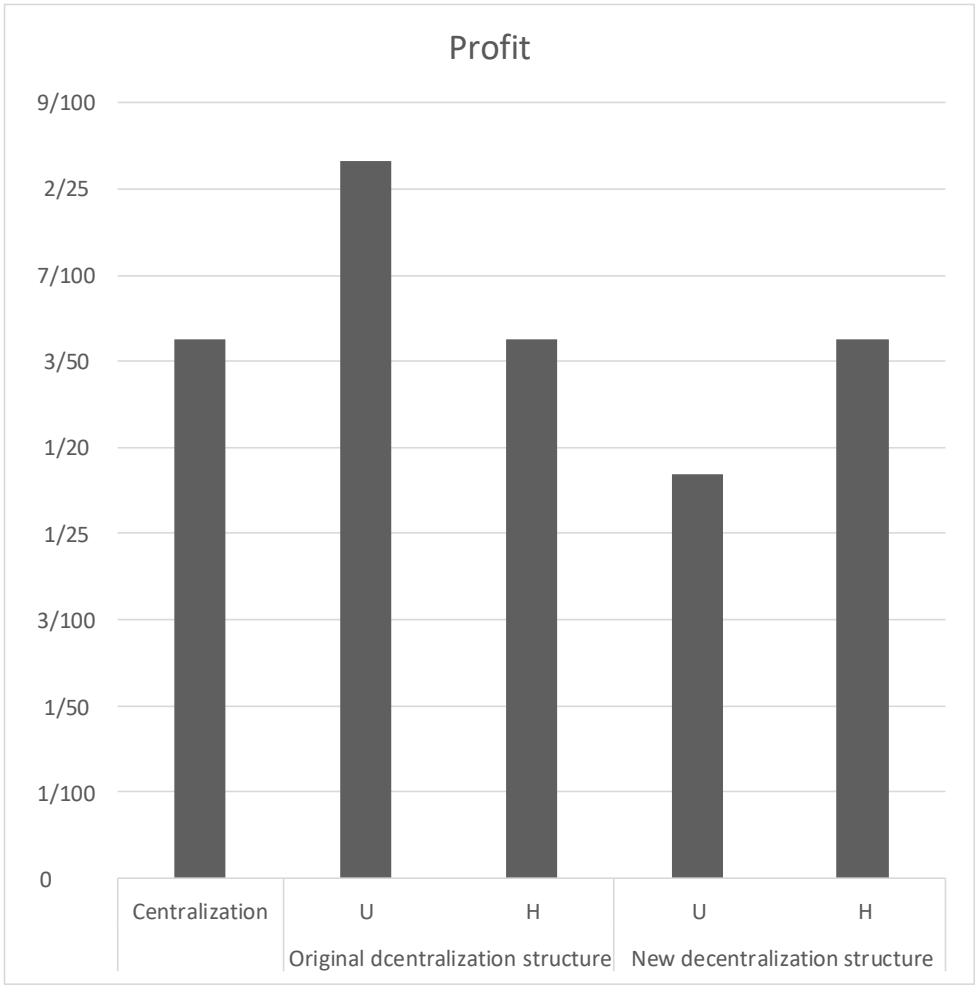
costs (cost plus), it introduces desired second double-marginalization problem to a company. In combination with simultaneous procurement, the supplier lowers his price. The end result for the company is the profitability increase.

According to the Graph 12, the best possible profit you can achieve is under decentralization with original company structure (where both divisions are production divisions and where the supplier and transfer prices are chosen simultaneously) as proposed by Araya and Mittendorf (2007). The transfer price has to be decided by the upstream division.

The worst situation where you can be as a manager under our setup is when you have your company decentralized according to functions – sales and production divisions; and the transfer pricing power is given to the upstream division. The easiest, most effective, actionable, and short term solution that you can make is to assign the transfer pricing power to headquarters in order to gain higher profit. You will, of course, be challenged by the resistance of the management of the upstream division since you will be taking all their profit away. However, you should still do it and perhaps fix unfair profit division by ex post money transfer to the upstream division. Changing divisions functions would require more effort, but the firm would yield yet higher profit. In this case, the transfer pricing power has to be shifted back to the upstream division.

Basically, you can improve your situation by focusing on transfer pricing power and company structure in almost every situation you are facing (of course, except the best situation).

Graph 6: Profit Comparison of Different Scenarios



From the policy makers point of view, you want to make sure that as many customers are satisfied as possible. In another words, you want to make sure that company produces as much goods as possible and therefore satisfying as many customers as possible. Let's say you operate in markets where monopolies were created naturally and there are no barriers to enter the market to other competitors. Counterintuitively, you get the best result when the company is centralized, or, under another scenario with the same result is decentralized company with production and sales divisions and transfer pricing power in hands of headquarters. So, as a policy maker your goal would be to create such rules that would lead either to centralization of the company or above mentioned decentralization setup.

Let's consider the case when there is such business owner who owns a company in each level of the supply chain. As an example we can take the former minister of finance in the Czech Republic. His conglomerate holding Agrofert Group is the biggest player in agriculture in the Czech Republic and Slovakia. There are more than 250 companies that belong to this holding. To illustrate this vertical ownership, I will just name a few levels of the supply chain – fertilizer production, farms, meat products, milk products, bakeries. (Agrofert website) The only missing part in the holding is the retail chain. However, this might be a question of time. Majority of business growth of this holding comes from acquisitions and I think Agrofert is waiting for the right buying opportunity of a retail chain.

If you are a CEO of the holding that owns a company in each level of the supply chain, then of course your goal will be to maximize the sum of profits of all your companies (total supply chain profit). Our monopolistic setup in each level might be unrealistic in modern societies, but perhaps it is not so unreal in some other countries.

In our analysis, the best outcome for such manager are scenarios when the company is centralized or when the company is decentralized according to functions – production and sales divisions; and when the transfer pricing power is in his hands – in the headquarters. The worst scenario for the CEO is the "functional" decentralization with transfer pricing power in hands of the upstream division. So again, it is easy to improve the outcome just by assigning the transfer pricing power to headquarters.

If a company is centralized and its production cost would increase with decentralization, then there is no reason for such company to decentralize. The best possible outcome it could get is the same as under centralization, so decentralization does not make any sense.

The profit distribution between the supplier and the company never gets fair. These two players are unable to get the same share of supply chain profit under any possible scenario. However, under the original decentralization structure a

certain level of fairness was reached. It is because the outcome of the interaction between the supplier and the upstream division is the mutual best response.

To conclude, a company decentralization is a complex and complicated procedure. We focused only on those aspects that are relevant for our model. However, there are even more aspects that are important to company decentralization and that we did not cover.

Table 12: Summary of the Results

	Orginal timeline		New timeline				
	Centralization	Decentralization	Decentralization				Centralization
			t power… U		t power … headquarters		
			p payed by D	p payed by U	p payed by U	p payed by D	
quantity	1/4 (·)	1/6 (·)	1/8 (·)	1/8 (·)	1/4 (·)	1/4 (·)	1/4 (·)
transfer price	-	1/3 * (a – ce + 2ci)	1/4 * (a – c_e +3 c_i)	1/4 * (a – c_e +3 c_i)	1/2 * (a + ce - ci)	ci	-
supplier price	1/2 * (a + ce - ci)	1/3 * (a + 2ce - ci)	1/2 * (a + ce - ci)	1/2 * (a + ce - ci)	1/2 * (a + ce - ci)	1/2 * (a + ce - ci)	1/2 * (a + ce - ci)
downstream division profit	-	1/36 $(\cdot)^2$	1/64 $(\cdot)^2$	1/64 $(\cdot)^2$	1/16 $(\cdot)^2$	1/16 $(\cdot)^2$	-
upstream division profit	-	1/18 $(\cdot)^2$	1/32 $(\cdot)^2$	1/32 $(\cdot)^2$	0	0	-
firm profit	1/16 $(\cdot)^2$	1/12 $(\cdot)^2$	3/64 $(\cdot)^2$	3/64 $(\cdot)^2$	1/16 $(\cdot)^2$	1/16 $(\cdot)^2$	1/16 $(\cdot)^2$
supplier profit	1/8 $(\cdot)^2$	1/18 $(\cdot)^2$	1/16 $(\cdot)^2$	1/16 $(\cdot)^2$	1/8 $(\cdot)^2$	1/8 $(\cdot)^2$	1/8 $(\cdot)^2$
supply chain profit	3/16 $(\cdot)^2$	5/36 $(\cdot)^2$	7/64 $(\cdot)^2$	7/64 $(\cdot)^2$	3/16 $(\cdot)^2$	3/16 $(\cdot)^2$	3/16 $(\cdot)^2$
ratio D:U:S	-	1:2:2	1:2:4	1:2:4	1:0:2	1:0:2	-
ratio F:S	1:2	3:2	3:4	3:4	1:2	1:2	1:2

9. Appendix

3.2 Decentralization

The supplier price has decreased after splitting centralized company according to Araya and Mittendorf model of decentralization.

Proof by contradiction:

Let's suppose that the opposite would be true, that is the supplier price increases after decentralization. Mathematically:

$½ (a + c_e - c_i) < 1/3 (a + 2c_e – c_i)$

By solving this inequality, we arrive at

$a < c_e + c_i$.

But we know that $a > c_e + c_i$ must hold. This condition is not satisfied and therefore the assumption is wrong. Hence, the supplier price has decreased after decentralization.

5.1 New company structure

Transfer price in the new company structure is higher than the transfer price in the original company structure.

Proof by contradiction:

Let's suppose that the opposite would be true, that is the transfer price in the new company structure is lower than the transfer price in the original company structure. Mathematically:

$1/3 (a – c_e + 2c_i) > ¼ (3a + c_e + c_i)$

By solving this inequality, we will arrive at

$a < c_i – 7/5\ c_e$.

But we know that $a > c_e + c_i$ must hold. This condition is not satisfied and therefore the assumption is wrong. Hence, the transfer price in the new company structure is higher than in the original structure.

5.1 New company structure

Supplier price in the new company structure is higher than the supplier price in the original company structure.

Proof by contradiction:

Suppose that the opposite is true, that is the supplier price in the new company structure is lower than the supplier price in the original company structure. Mathematically:

$1/3\ (a + 2c_e - c_i) > ½\ (a + c_e - c_i)$

By solving this inequality, we arrive at

$a < c_e + c_i$.

However, we know that the condition $a > c_e + c_i$ must hold. The condition is not satisfied and therefore the assumption is wrong. Hence, the supplier price in the new company structure is higher than the supplier price in the original company structure.

6.1 Transfer pricing power – headquarters – original decentralization design

The supplier price is higher if headquarters sets the transfer price in original company structure (structure proposed by Araya and Mitendorf 2007).

Proof by contradiction:

Suppose that the opposite is true, that is the supplier price is higher when the upstream division sets the transfer price compared to the scenario when the transfer pricing is in hands of the headquarters. Mathematically:

$1/3\ (a + 2\ c_e - c_i) > ½\ (a + c_e - c_i)$

By solving this inequality, we arrive at

$a < c_e + c_i$.

However, we know that the condition $a > c_e + c_i$ must hold. The condition is not satisfied and therefore the assumption is wrong. Therefore, the supplier price is higher when headquarters is in charge of transfer pricing in the original firm structure as compared to scenario when the upstream division sets the transfer price.

6.2 Transfer pricing power – headquarters – new decentralization design

Transfer price in the new company structure is lower when headquarters sets the transfer price as compared to the upstream division setting the transfer price.

Proof by contradiction:

Let's suppose that the opposite would be true. Mathematically:

$1/4\ (3a + c_e + c_i) < ½\ (a + c_e + c_i)$

By solving this inequality, we will arrive at

$a < c_e + c_i$.

But we know that $a > c_e + c_i$ must hold. This condition is not satisfied and therefore the assumption is wrong. Hence, the transfer price in the new company structure is lower when headquarters sets the transfer price as compared to the upstream division setting the transfer price.

10. References

Agrofert website. In *About Agrofert*, WWW: https://www.agrofert.cz/en/about-agrofert

Alles, M.; Datar, S. 1998. Strategic Transfer Pricing. In *Management Science* 44: 451-461

Arya, A.; Mittendorf B. 2007. Interacting Supply Chain Distortions: The Pricing of Internal and External Procurement. In *The Accounting Review, Vol. 82, No. 3 (May 2007)*

Bhalla, V.; Dyrchs, S.; Strack, R. 2017. Twelve Forces That Will Radically Change How Organizations Work. In The *New* New way of Working Series, The Boston Consulting Group, WWW: https://www.bcg.com/publications/2017/people-organization-strategy-twelve-forces-radically-change-organizations-work.aspx

Fershtman, C.; Jud, K. 1987. Equilibrium Incentives in Oligopoly. In *American Economic Review* 77: 924-940

Goex, R. 2000. Strategic Transfer Pricing, Absorption Costing, and Observability. In *Management Accounting Research* 11: 327-348

Hughes, J.; Kao, J. 1998. Cross-subsidization, Cost-allocation, and Tacit Coordiation. In *Review of Accounting Studies* 2: 265-293

Inkscape.Ink. Version 0.92.1 –x64.1 [computer software] (downloaded on April 20, 2017)

Mankiw, M. Principles of Microeconomics. Fifth edition. South-Western Cengage Learning. ISBN-13: 978-0-324-59132-3

Narayanan, V.; Smith, M. 2000. Impact of Competition and Taxes on Responsibility Center Organization and Transfer Prices. In *Contemporary Accounting Research* 17: 491-529

PWC. International Transfer Pricing 2013/14. WWW: http://www.pwc.com/internationaltp

Sappington, D. and D.Weisman (2005), 'Self-sabotage'. Journal of Regulatory Economics 27, 155–175.

The Game Theory .net. 2005. Backward Induction WWW: http://www.gametheory.net/dictionary/BackwardInduction.html

Wolfram Research, Inc., Mathematica, Version 11 [computer software], Champaign, IL (2017)

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