Contributions to Game Theory and Management, IX, 7–101

Coordinating Contracts in Cooperative Supply Networks*

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Abstract It is widely accepted that the decentralization process exerts negative influence on the supply chain economic performance relatively to the case of an integrated supply chain in terms of total supply chain profit. In other words, a decentralized supply chain is less efficient than a centralized one, as in a decentralized supply chain each separate member tends to maximize his own benefits and pursue his private objectives, even if it harms the system wide performance. Coordination, in turn, helps to mitigate these negative effects of a decentralized decision-making. Nevertheless, coordination may be hard to achieve if some of the supply chain members are competing with each other, which leads to a new line of research on such systems, referred to as supply networks. Supply chain contract can be an effective coordination mechanism to motivate supply network members to be a part of entire system, in order to improve individual and system wide performance. There are different types of contracts, such as revenue-sharing, quantity-discount and other. The objective of the paper is methodology improvement of contract selection in cooperative supply networks for achieving better supply network economic performance. The research was focused on a two-level standard newsvendor model, which was adapted in order to reflect the situation of competing retailers. The methodology of coordination contracts decision-making was developed by devising a mechanism for contract selection for the case of multi-echelon supply network with two competing retailers enabling coordination at a system-wide level. The proposed model is a novel approach in applying coordination theory at systems with inside competition.

Keywords: Supply Chain Management, Supply Chain Coordination, Coordinating Contract, Supply Network, Bargaining Power in Contract Decision-Making

1. Introduction

In modern economy the most important features determining market competitiveness include product quality, company's flexibility, costs optimization, logistic accuracy, high service level and responsiveness to the ever-changing consumer needs. Companies which are not able to adapt in time to changing market environment should expect serious troubles in their long-term competitiveness. In this regard,

* This work is supported by the Russian Foundation for Basic Research, projects No.16-01-00805A and 14-07-00899A and Saint-Petersburg State University, project No.9.38.245.2014

the concept of supply chain management is becoming more and more important over the years, as it is seen as a strategic factor to balance customer orientation and profitable growth (Procenko, 2006).

According to (Fedotov, 2010), the research in the field of supply chain management is currently at the stage of its conceptual development, characterized by predominance of papers devoted to practical business needs. Main directions of the studies include (Fedotov, 2010):

– Strategic aspects of supply chain management;
– Detailed examination of specific functions;
– Engineering and IT support of supply chain management;
– Contract relationships in supply chains.

Current article is focused on the last of the listed lines of research, namely, contract relationships. Studies in this particular field emerged from the notion of supply chain coordination, introduced by Williamson (1986) as a part of a broader science of supply chain management. Managerial implication here lies in the necessity to improve supply chain economic performance.

In the ideal situation, all the processes throughout the supply chain would be managed by a single company, as, stated by Anupindi and Bassok (1999) , a single decision-maker optimizes the network performance with the union of information and resources available. Such a supply chain is usually referred to as an integrated or a centralized one. Hence, supply chain economic performance is at risk as soon as there are multiple decision-makers, who may have different private information and their own incentives, which are at odds with the supply chain as a whole. Unfortunately, current trends, such as globalization, application of outsourcing activities and spread of information technologies worldwide lead to further fragmentation and decentralization of supply chain operations.

This decentralization process exerts negative influence on the supply chain economic performance relatively to the case of an integrated supply chain in terms of total supply chain profit. In other words, a decentralized supply chain is less efficient than a centralized one, as in a decentralized supply chain each separate member tends to maximize his own benefits and pursue his private objectives, even if it harms the system wide performance. Coordination, in turn, helps to mitigate these negative effects of a decentralized decision-making.

Despite of wide literature devoted to both theoretical and practical analysis of contract coordination mechanisms in a supply chain, as well as their modeling and application, there is a gap in literature in what relates to researches devoted to coordination mechanisms in a different setting of supply chain - supply network - and to modeling the application of those mechanisms on real life cases and examples. Supply network is understood here as a set of three or more organizations directly involved in the upstream and downstream flows of products, services, finances and information from a source to a consumer, provided that two or more of them are direct competitors. In other words, supply network is a set of distinct supply chains connected into a system with existing competition between its members.

Therefore, supply network coordination can be defined as identifying interdependent activities between supply network members and devising mechanisms to manage those interdependencies for improving the supply network economic performance in the best interests of participating members Arishinder, 2011.

Thus, a supply network, as a set of supply chains, is coordinated by a set of supply chain contracts. Here, a supply chain contract stands for a set of rules, rights and obligations regulating relationships between supply chain or network members. Typically, a supply chain contract should capture the three types of flows encountered between the companies, i.e. material, information, and financial flows Hohn, 2010. Moreover, contracts are considered to be one of the most powerful mechanisms to achieve coordination, as they address directly the nature of relationships evolving within the supply system.

The goal of the present research is methodology improvement of contract selection in cooperative supply networks for achieving higher supply network economic performance, where economic performance stands for total supply network profit. The research was focused on a two-level one-period newsvendor model, which was adapted to reflect the situation of competing retailers and applied as a basis to describe the decision-making process in a given supply network. Then, the established framework was used to model the supply network economic performance in market dynamics under the implementation of different supply chain coordinating contracts.

2. Cooperation, Coordination and Collaboration

Following Mentzer et al. (2001), Supply Chain Management can be defined as a systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. Therefore, as noted by Simatupang et al. (2002), the main concern of supply chain management is how to coordinate independent companies to work together as a whole to pursue the common goal of improving individual and overall supply chain economic performance in changing market conditions. This has been a major issue of early economic theory that differentiated between the firm and its hierarchies and price mechanisms as forms of coordination (Williamson, 1986). Following Coase (1937), if separate companies coordinate, it is referred as combination or integration.

In the context of industrial engineering research and in particular SCM research, the related terms cooperation, coordination, and collaboration are often used interchangeably without clearly distinguishing them from each other (Hammer, 2006). At the same moment, some authors Arishinder, 2011 assume that integration, collaboration and cooperation are just the elements of coordination. For the purposes of the current paper, terms cooperation, coordination and collaboration are assumed to be different levels of supply chain integration. Therefore, it is necessary to introduce clear distinction between the related terms.

Cooperation is defined as acting or working together for a shared purpose (Cambridge Dictionaries Online), working or acting together toward a common end or purpose, acquiescing willingly and being compliant (American Heritage Dictionary of the English Language), or as the act of working with someone toward a common goal (Heinle's Newbury House Dictionary). In the context of supply chain management, Quiett (2002) referred to cooperation as little more than toleration of each other. While this view might be a bit drastic, the other definitions imply that cooperation emphasizes mainly the alignment towards a common goal and a shared purpose. Hammer (2006) highlights that the notion of working together in the context of cooperation does not suggest a close operational working relationship, but rather a positive attitude towards each other. Therefore, for the purposes of the current paper cooperation is understood as *an existing willingness to work together towards a shared goal or purpose and openness towards negotiations.*

Coordination, in turn, refers to a more direct, active cooperation. It is defined as the activity of organizing separate things so that they work together (Cambridge Dictionaries Online), the act of making arrangements for a purpose, the harmony of various elements (American Heritage Dictionary of the English Language), and harmonious adjustment or interaction (Heinle's Newbury House Dictionary). Following Moharana et al. (2012), compared to cooperation, coordination indicates an interactive, joint decision making process, where separate entities influence each other's' decisions more directly. Besides horizontal coordination, i.e. coordination within a supply chain tier, and vertical coordination, i.e. coordination across supply chain tiers, for example between supplier and customer, coordination can also be distinguished from mechanism of coordination. According to Williamson (1991), the fundamental mechanisms are markets and hierarchies. Market structures refer mainly to incentive-driven coordination between separate, legally independent companies whereas hierarchical structures indicate either a high unilateral dependency or those companies are not legally independent or equity is shared. Hence, coordination is defined *as a set of incentives and direct actions making companies work together towards a common goal, as well as joint decision-making.*

Collaboration, therefore, can be defined as working together or with someone else for a special purpose (Cambridge Dictionaries Online), or simply as working with someone (American Heritage Dictionary of the English Language) or working together (Heinle's Newbury House Dictionary). Following Stank et al. (1999), whereas coordination is a joint, interactive process that results in joint decisions and activities, collaboration depends on the ability to trust each other, and to appreciate one another's knowledge and emphasizes the building of meaningful relationships. By that, it also indicates a higher degree of joint implementation and can be thought of as a teamwork effort. Then, collaboration can be defined as a *superstructure evolving between separate entities in form of shared vision, culture, mission, etc. that facilitates the processes of working together towards a common goal.*

3. Supply Chain Integration

According to Anupindi and Bassok, 1999, supply chain management deals with the management of material, information, and financial flows in a network consisting of vendors, manufacturers, distributors, and customers. Exchange of flows can be regarded as a routine transaction, occurring between any pair of suppliers and buyers in the system. Ideally, the quantity and pricing decisions in the supply chain would be made by a single decision maker who has all information at hand Hohn, 2010. Such a situation is generally referred to as a fully integrated, or centralized, supply chain. Respectively, a supply chain is called decentralized if the network consists of multiple decision-makers having different information and incentives.

Following Anupindi and Bassok, 1999, a single decision-maker optimizes the network with the union of information that otherwise various decision-makers have. Hence, supply chain performance is at risk as soon as there are multiple decision-makers in the network who may have different private information and incentives.

For instance, as it was highlighted by Corbett et al. (2004), decision-makers are often reluctant to share private information regarding cost and demand, which may lead to suboptimal supply chain decisions and economic performance.

This was first described in literature by Spengler (1950) as a problem of double marginalization. It can be shown that when operating independently, supplier and buyer will produce less than a vertically integrated monopolist, because they receive less than the total contribution margin at any given quantity. This clearly is a case, where locally optimal decisions of supplier and buyer do not optimize the global supply chain problem, or, in other words, the decentralized supply chain is inefficient, since the total expected profit of the decentralized supply chain is lower than the total expected profit of the fully integrated supply chain Hohn, 2010. Thus, the centralized, fully integrated system can be taken as a benchmark situation, while integration itself can be viewed as a tool for a decentralized supply chain to achieve or approach the economic performance of a centralized chain in terms of total profit.

For the research purposes cooperation, coordination and collaboration are assumed to be stages of supply chain integration process. Notable, that in SCM research, integration usually enhances two elements: interaction and collaboration. Both elements were introduced as separate philosophies and combined as integration. Following Hammer (2006), the interaction philosophy emphasizes exchange of information, while the collaboration philosophy highlights strategic alignment through a shared vision, collective goals, and joint rewards, along with an informal structure of managing relationships. Mentzer and Kahn (1996) stated that integration, therefore, is viewed as comprising interaction and collaboration activities.

Thus, dividing supply chain integration into distinct levels means recognition of specific stages in inter-firm relationships development, ranging from decentralized decision-making with poor interactions and no shared vision, goals or rewards to fully centralized decision-making with a single decision-maker having all available information and one unified goal and vision. It is necessary to note that, for the research purposes, moving along these stages towards increased supply chain integration is assumed to improve overall supply chain performance. Hence, the hierarchy of supply chain integration levels can be presented as follows (Fig. 1).

Fig. 1: Levels of supply chain integration

In the suggested framework, it is expected that all firms when establishing relationships in the supply chain start with decentralized decision-making. Following Jarillo (1998), cooperation is a little step further from decentralized decision-making, when the participants of the supply chain adapt their behaviors to that of other partners and create informal links between companies. Therefore, cooperation is an acknowledgement of the common goal and willingness to pursue supply chain profit maximization function instead of individual profit maximization functions by members of the supply chain.

While cooperation refers to creating informal links, coordination and collaboration are both aimed at devising formal mechanisms to manage supply chain interdependencies (Arishinder, 2011). In terms of coordinating intensity, collaboration can be seen as more intensive than coordination because most of the time it subsumes all characteristics of coordination as well. Therefore, in a hierarchy of different levels of integration, collaboration would be positioned above coordination. In his research Hammer (2006) agrees that, in the context of SCM, coordination aims at achieving global optimization within a defined supply chain network. Meanwhile collaboration aims to exploit hidden potential and consequently expand the optimization potential, i.e. shifting the efficient performance frontier upwards.

This view is also supported by Shaw (2000), who has differentiated between three types of coordination in terms of level of involvement, in ascending order: simple information exchange, formulated information sharing, and modeled collaboration. Simple information exchange is quite straightforward as it refers to information exchange without additional interpretation or rules. In formulated information sharing, such policies as restocking policies are shared together with operational information. In modeled collaboration, operational models are also shared, together with capabilities, factory load, inventories, and orders (Shaw, 2000). The importance of information exchange was confirmed by Swaminathen et al. (2003), who highlighted that information sharing is of central importance for coordination, as it allows for coordinated forecasts and forecasts based on richer information. Extending this idea, Sahin and Robinson (2002) have stated that a lack of coordination occurs when decision makers have incomplete information or incentives, which are not compatible with system-wide objectives.

This understanding can be directly linked to the three levels of collaboration that Quiett (2002) has identified, which are data exchange, cooperative collaboration and cognitive collaboration. These views, however, indicate a more extensive information sharing scheme on the highest level instead of a close, teamwork-like working relationship (Hammer, 2006).

As opposed to that, in a Deloitte study (Koudal, 2003) conducted in 2003, collaboration has been characterized by internal and external teamwork in the context of manufacturing companies, i.e. with customers and suppliers. As differentiating factors, strong cross-functional teams, stronger commitments to these teams, design for quality, and design for manufacturability techniques have been identified. Necessary elements were cited to be joint-working with suppliers and customers on production planning, inventory management, replenishment, forecasting, and demand planning.

An understanding in line with this interpretation of collaboration is provided by Liedtka (1996), who has defined collaboration as a process of decision making among interdependent parties, which involves joint ownership of decisions and collective responsibility for outcomes. Liedtka (1996) has emphasized the cross-functional teamwork aspect of collaboration with a clear focus on processes instead of functions. Because processes rarely stop at company boundaries, this includes external organizations as well. Therefore, the term partnership is also used to include external collaboration. Success factors identified in Liedtka's study (1996) are quite independent from legal forms of partnerships. The components of successful partnering comprise a partnering mindset, a partnering skillset, and a supporting organizational architecture.

Barratth (2004) has identified yet another, however closely related, set of elements that define collaboration. These are cross-functional activities, process alignment, joint decision making, and supply chain metrics. The elements that support a collaborative culture are trust, mutuality, information exchange, openness, and communication, which, in turn, is necessary for successful collaboration. It is important to note, that a rather close proximity to team working exists. As Christopher (2005) remarked, the closer the relationship between buyer and supplier the more likely it is that the expertise of both parties can be applied to mutual benefit. Consequently, higher levels of internal and external collaboration are expected to improve performances in the areas of collaboration (Stank, 2001).

Therefore, summarizing different approaches presented in literature, cooperation is referred to as willingness to participate in supply chain performance improvement, coordination encompasses joint decision-making, process alignment, information exchange and other active steps for supply chain performance improvement, while collaboration is a superstructure in form of creating a unite supply chain culture, mindset and architecture. Thus, in order to proceed to the next stage a given supply chain should fully embrace characteristics of the previous step(s). For example, in order to start working on activities to achieve coordination, a given supply chain should be already cooperative and embrace the characteristics of this stage.

Spekman et al., 1998 have drawn a similar conclusion. In their view, cooperation refers to rudimentary information exchange with little interaction and is seen as a necessary but not sufficient condition for managing business relationships. The next level would then be coordination. Just-in-time (JIT) and electronic data interchange (EDI) linkages can reflect such coordinated relationships. Again, though companies cooperate and coordinate, they still might not behave as true partners. According to (Spekman et al., 1998) in order to achieve collaboration, a level of trust and commitment beyond the one found in cooperation and coordination is required. Thus, supply chain partners may cooperate and coordinate, but still not collaborate.

4. Supply Network

Up to this point, the paper was focused on the relationships in a traditional supply chain, no matter what level of complexity was assumed. Notably, while increasing supply chain complexity, Mentzer et al. (2001) were only talking about the number of tiers a supply chain might have. Nevertheless, apart from the number of tiers, supply chain complexity may be increased further by the number of firms at a given tier as shown in Figure 2. According to Mentzer et al. (2001), Figures 2a and 2b are both representations of a direct supply chain, although it is clear that the supply chain 2b is more complex in both functional and managerial terms.

While direct supply chain in the Figure 2b consists of a supplier, an organization and three distinct customers, it can be argued that this is just a unite representation of three distinct supply chains. Nevertheless, following Mentzer et al. (2001), supply chain members are defined by their involvement in the upstream and downstream flows of products, services, finances and (or) information from an initial source to a consumer. Thus, supply chain in the Figure 2b is defined as a single supply chain if it serves one unique flow of products, services, finances and information from the ultimate supplier to the ultimate customer. Notably, the term unique flow here refers to the non-competitive nature of inter-firm relationships within the supply chain.

Absence of rivalry is of vital importance when it comes to supply chain management as it reassures that all the members of the given supply chain would have

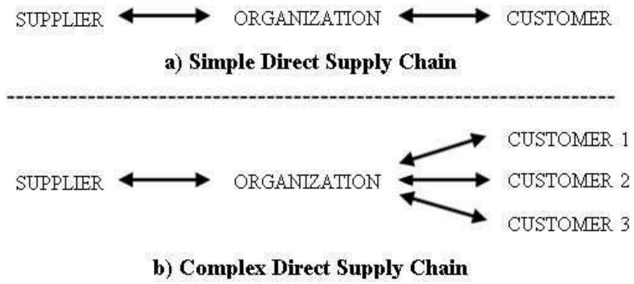

Fig. 2: Levels of direct supply chain complexity

incentives for mutual performance improvement, which, in terms of SCM, means working together to achieve coordination. A traditional example of such a supply chain is automotive industry, with one car assembler and multiple dealers, which are not owned by the manufacturer, but do not compete with each other as they either cover different segments and (or) regions (Fig. 3a).

At the same time, if companies within one supply chain tier compete with each other, it may be assumed that they are all serving different flows of products, services, finances and information and, therefore, are members of different supply chains. However, in a situation when all these flows go alongside the supply chain from one unite source to the same end consumer, despite the fact of existing competition, it can be argued that this system is close to supply chain in terms of management and optimization. In the case of automotive industry that would mean that one car assembler sells its cars through multiple dealers, who are competing with each other in the open market using both price and quantity (Fig. 3b).

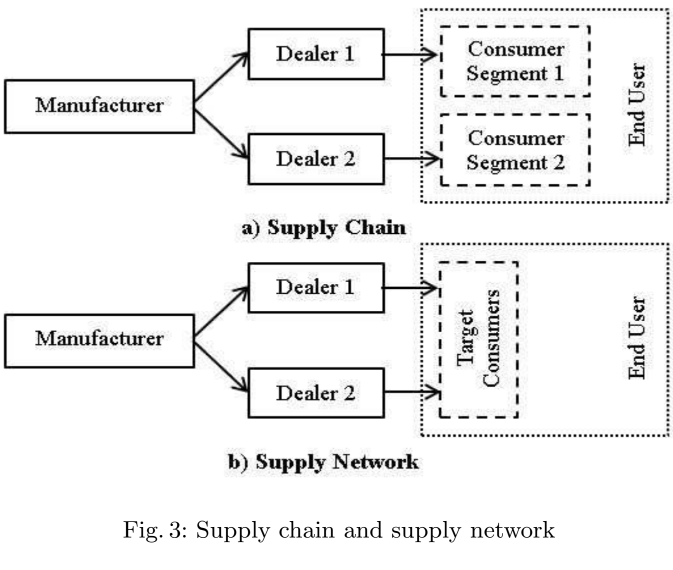

Fig. 3: Supply chain and supply network

The concept of supply chain assumes Mentzer et al. (2001), that all supply chain members are interconnected one after another, comprising a single line of relationships. Introducing competition inside one of the supply chain tiers means that these relationships no longer form a direct line, but rather a system of interconnected companies.

Therefore, for the research purposes, such system would be called supply network and defined as *a set of three or more organizations directly involved in the upstream and downstream flows of products, services, finances and (or) information from a source to a consumer provided that two or more of them are direct competitors*. In other words, supply network is a set of distinct supply chains connected into a system with existing competition at one or more of its tiers. Consequently, the main concern of supply network management is coordination of independent companies in order to improve the economic performance of the individual companies and the supply network as a whole.

Bryant, 1980 appears to be the first published paper to address the supply network setting, including into a supply chain a competitive oligopoly model with stochastic demands, which arise from a finite customer population. Another such model is Deneckere, Marvel and Peck (1997), addressing a market with a continuum of identical retailers offering a completely homogenous product. Most directly related to the current research are papers of Birge et al. (1998) Carr et al. (1999) and van Mieghem and Dada (1999), who consider the special case of the supply network model with two competing retailers.

5. Cooperative Supply Network

Birge et al. (1998) have shown that pricing and capacity decisions, those directly influencing economic performance, are affected greatly by the actual parameters that the decision makers can control as well as whether decision makers are optimizing system-wide or individual channel profits. This raises a question of integration in a supply network as opposed to that of its individual channels, e.g. separate supply chains.

As supply network is a system comprised of individual supply chains united by an integrated flow of products, services, finances and information, it can be claimed that supply network as a phenomenon shares some characteristics with a supply chain, level of integration being one of those.

Therefore, in terms of integration supply network follows the same steps as supply chain (Fig. 1), from being completely decentralized to fully integrated. Nevertheless, due to competition between its members, full integration here refers to achieving the same economic performance as if it was managed under a single decision-maker. Thus, in terms of supply network, cooperation is referred to as *willingness to participate in supply network performance improvement*, when its members understand that they can achieve better results and they are ready to invest in that. Coordination embraces any *activities aimed at supply network performance improvement*, while collaboration is *a superstructure in form of creating a unite culture, mindset and architecture*. Similarly to a supply chain, in order to proceed to the next stage, a given supply network should fully embrace characteristics of the previous step(s).

Hence, the process of coordination can be only initiated in a cooperative supply network, meaning that all its members are open towards negotiations and ready to invest in system-wide performance improvement.

6. Coordinating Contracts

Although contracts have been studied in law, economics, and marketing disciplines, their study in SCM takes a rather different approach. Following Tsay, 1999, what distinguishes SCM contract analysis may be its focus on operational details, requiring more explicit modeling of material flows and complicating factors such as uncertainty in the supply or demand of products, forecasting and the possibility of revising those forecasts, constrained production capacity, and penalties for overtime and expediting.

By viewing a supply chain as nexus-of-contracts (Wang and Sarkis, 2013), meaning a group of rational agents interacting with each other according to pre-specified set of rules, an improved supply chain management is achieved by designing appropriate contracts coordinating the agents' decisions. Typically, a supply chain contract should capture the three types of flows encountered between the members of supply chain, i.e. material, information, and financial flows Hohn, 2010. Nevertheless, to date there is no commonly accepted classification of the rules, parameters and dimensions fixed in those supply chain contracts.

One of the first classifications of supply chain contracts was suggested by Anupindi and Bassok (1999) and consisted of eight parameters: horizon length, pricing, periodicity of ordering, quantity commitment, flexibility, delivery commitment, quality and information sharing. In contrast, Tsay, 1999 classified supply chain contracts by eight contract clauses, including specification of decision rights, pricing, minimum purchase commitments, quantity flexibility, buy-back or returns policies, allocation rules, lead time, and quality.

Those two classifications were synthesized and developed further by Hohn, 2010. Integrated framework comprised eleven dimensions: specifications of decision rights, pricing, minimum purchase commitments, quantity-flexibility, buy-back or return policies, allocation rules, lead time, quality, horizon length, periodicity of ordering and information sharing.

Notably, supply chain contracts are not always required to be legal. Several papers in the literature consider contracts among independent agents that are divisions of the same company and a higher level manager can verify the execution of lateral promises (Lee and Whang 1999, Zhang 2006). Nevertheless, the process of contract design should explicitly point out the verifying ability of the enforcing agent. Two approaches to verification are presented in literature: direct and indirect. In direct verification, the conditions regarding the fulfillment of contract terms can be observed. In indirect verification, studied by Hezarkhani and Kubiak, 2010, the conditions may be only inferred. For example, in case of direct verification a retailer can observe and count the number of products received from a supplier, while indirect verifications require self-enforcing, e.g. manufacturer can verify that if the market selling price is greater than the total production cost and salvage value, the retailer would satisfy market demand as much as it can.

If the contract parameters are well defined, contract enforces coordination in the supply chain. First studies devoted to supply chain contracts and their coordination capabilities appeared in the scientific literature in 1980s. However, only in 1990s the systemic integrated research of this mechanism emerged, which summarized fragmented findings of previous papers and build on that. The earliest overviews focused on coordinating contracts included papers of Wang and Sarkis, 2013, Tsay, 1999, Cachon, 2003 and Lariviere, 2001.

Among the recent papers in this field it is necessary to mention an extensive overview of different types of contracts by Cachon, 2003 and his joint study with Lariviere (Cachon and Lariviere, 2005) on the interchangeability of contracts of different types. Most recent research includes subsequent comprehensive reviews of the topic by Hohn, 2010, Govindan and Popiuc, 2011 and Arishinder, 2011.

6.1. Coordinating Contract Definition

Following Tsay, 1999, from the point of view of supply chain coordination, a contract can be defined as *a coordination mechanism that provides incentives to all of its members so that the decentralized supply chain behaves nearly or exactly the same as the integrated one.*

This definition emphasizes the capability of supply chain contracts to integrate a supply chain in terms of centralizing decision making in a way and turning supply chain processes into optimal for the whole channel. However, not every coordinating contract can be actually implemented, which happens due to acceptability rules.

6.2. Acceptability Rules

The notion of acceptability rules implied in supply chain contracts was described by Hezarkhani and Kubiak, 2010. According to their research, two approaches towards formulating the acceptability conditions exist in literature. The first approach supposes that, in order to be acceptable, the contract should lead to the each member's utility being above a certain acceptable level. This level can take the form of reservation profit, opportunity costs, outside options or status quo utilities, i.e. an agent should not be in worse situation with a new contract than it was with the existing one.

This approach was followed by Gan et al., 2004, who defined coordinating contract as a contract which the agents of a supply chain agree upon, while the optimizing decisions of the agents under the contract should satisfy each agent's reservation payoff (minimum acceptable utilities) constraint and lead to Pareto-optimal decisions and Pareto-optimal sharing rule. This definition formulates the acceptability condition according to the first approach stated earlier, as satisfaction of minimum acceptable utilities. Nevertheless, it has a sufficient drawback as it does not indicate how one contract should be preferred over the others in case of multiple contracts with Pareto-optimal sharing rules which satisfy the agent's minimum acceptable utilities.

The second approach implies that the contract should not only guarantee some minimum acceptable level of utility to all the members, but also allocate extra benefits from the contract to its members in some fair manner. The notion of fairness here provides that the profit is allocated among members proportionally to their investments, i.e. share of costs (Hezarkhani and Kubiak, 2010).

This approach was adopted by Cachon, 2003, who stated that there are three conditions that a supply chain contract should meet in order to be coordinating:

1. With a coordinating contract, the set of supply chain optimum decisions should be a pure Nash equilibrium;

2. Coordinating contract should divide the supply chain profits arbitrarily among agents;
3. Coordinating contract should be worth adopting.

The first condition implies that no member should have an incentive to deviate from the set of optimal actions. Ideally, the described equilibrium should be unique, with cooperation being the most profitable alternative for all members. Gan et al., 2004. Finally, the third condition articulates that coordinating contracts with highest efficiency may not be the best option for the supply chain, as sometimes non-coordinating contracts with high efficiency ratio can be preferred by the supply chain members.

Despite the different interpretations of the acceptability condition of a coordinating contract by Cachon, 2003 and Gan et al., 2004, the fundamental notion in both definitions is similar. That is, with the coordinating contract, agents' optimum decisions must be the same as the supply chain's optimum decisions, and the contract should divide the resultant payoffs among the supply chain members so that all agents are satisfied and, as the result, they would accept the contract (Hezarkhani and Kubiak, 2010).

Therefore, two variations of the concept of coordinating contract were formulated by Hezarkhani and Kubiak, 2010:

* *Weak Coordination*: If a contract could achieve the equivalence of agents' optimal decisions (pure Nash equilibrium) and the supply chain's optimal solution, and at the same time it satisfies the minimum acceptable utilities for all agents, then the contract is weakly coordinating.
* *Strong Coordination*: If a contract could achieve the equivalence of agents' optimal individual decisions (pure Nash equilibrium) and the supply chain's optimal solution, and at the same time it could divide the total supply chain payoff in any manner among the agents, then the contract is strongly coordinating.

The relationship between the two definitions is that if a weakly coordinating contract is also flexible, then it is strongly coordinating as well.

7. Coordination in Supply Network

A typical model that is used for analyzing supply chain coordination with contracts is a newsvendor model - a standard one-period one-product one-echelon (i.e. consisting of two firms, a supplier and a buyer) setting for modeling order quantity decisions under stochastic demand, presented in Figure 4 below.

In this framework the supplier (manufacturer) produces one type of product at a constant cost c and sells it to the buyer (dealer) at a wholesale price $w(Q)$ per unit. In turn, the buyer resells this product to the market at a retail price r. In the newsvendor model, the action to coordinate the supply chain is the buyer's order quantity Q, as, while facing stochastic demand, the buyer must determine an order quantity Q before the start of the selling season. Cachon, 2003 emphasizes that a contract is said to coordinate the supply chain if the set of supply chain optimal actions is Nash equilibrium, i.e. no firm has a profitable unilateral deviation from the set of supply chain optimal actions.

This model is a building block for a large stream of the research modeling and scientific literature on supply chain contracts. According to Khouja, 1999, the traditional newsvendor setting lies in the basis of the majority of other more complex

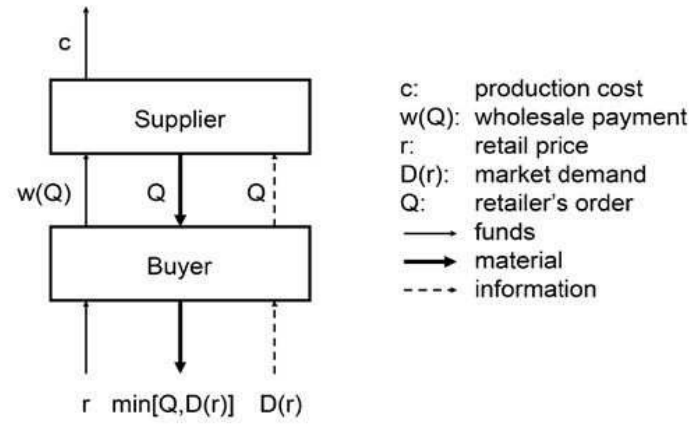

Fig. 4: Basic one-period one-product supply chain model (Hohn, 2010)

models developed for more complicated configurations of parameters. Thus, the described newsvendor model will be used for current research purposes as a basis for supply network model, presented in Figure 5 and discussed further.

This is a one-period one-product topology with one upstream firm that supplies two downstream firms. In this framework manufacturer produces one type of product at a constant cost c and sells it to the dealers at wholesale prices $w1$ and $w2$ per unit of good. In turn, dealers resell this product to the open market at a retail prices $p1$ and $p2$ accordingly. Product is homogeneous and neither of the dealers has any technical advancements, i.e. they have the same marginal costs. Thus, they compete with each other in the open market with demand function defined as $D(p1, p2)$. Full summary of parameters used in the model is described below.

Table 1: Parameters for Supply Network Model

C:	production cost
$w_1(Q_1)$:	wholesale payment of the 1st dealer
$w_2(Q_2)$:	wholesale payment of the 2d dealer
Q_1:	1st dealer's order
Q_2:	2d dealer's order
p_1:	1st dealer's retail price
p_2:	2d dealer's retail price
$D(p_1, p_2)$:	Market demand
q_1:	1st dealer's sales
q_2:	2d dealer's sales
$\rightarrow$:	Financial flows
$\longrightarrow$:	Material flows
- ➝ :	Information flows

For the purposes of the current research, it is assumed that the dealers compete under the rules of Bertrand competition model, which examines interdependencies between rivals' decisions in terms of pricing. According to this model, there are two firms, selling homogeneous goods with the same marginal costs, which have to take

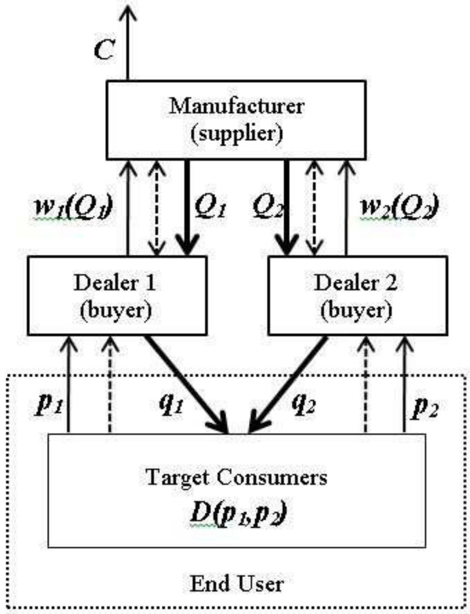

Fig. 5: Supply network model

simultaneous decisions on setting a retail price based on their assumptions on the expected price of their rival. Then the market determines the quantities bought from each firm dependent on the prices they have previously set.

Thus, assuming that dealers compete on prices, the quantity Q_i ordered by a dealer i from manufacturer can be described by the demand function $q_i(p_1, p_2)$ (1).

$$Q_i(p_1, p_2) = \theta k_i - \delta_i p_i + \gamma(p_j - p_i), \qquad i = 1, 2, i \neq j \tag{1}$$

Q_i stands for the order quantity of a dealer i at a given period of time under the conditions of price competition with dealer j, with p_i being retail price of dealer i. θ represents the potential size of the market, where k_i is market share of the dealer i, provided that $k_1 + k_2 = 1$. δ_i and γ are parameters of the demand function.

In the stated model (1) it is assumed that there are two types of customers forming the market: switching customers and marginal customers. Switching customers will always buy the good at a cheapest possible price. Marginal customers will only buy the good if its price is lower than a certain minimum price. Therefore, parameter γ describes the behavior of switching customers and stands for demand leakage, while parameter δ_i characterizes marginal customers, who can be attracted by lowering the price. Total demand can be defined as follows (2).

$$D(p_1, p_2) = \sum_{i=1}^{2} q_i = \theta - \sum_{i=1}^{2} \delta_i p_i \tag{2}$$

Following the assumptions of Bertrand competition model, both dealers have the same marginal costs c, nevertheless manufacturer's operating expenses to fulfill their orders are different and equal to s_1 and s_2 per unit of good accordingly.

Relationships between the members of a supply network can be formalized by a two-tier hierarchical game leader – competing followers, where manufacturer sets contract parameters, while dealers compete on prices in the next round after the choice is made. Taking into consideration assumptions and specifications of the developed supply network model, this would be a non-zero sum game under conditions of perfect information.

In order to formalize the discussion, let us introduce a game:

$$\Gamma =< N, \{X_i\}_{i \in N}, \{\pi_i\}_{i \in N} > \tag{3}$$

where $N = \{S, B_1, B_2\}$ is a set of players, with S being a supplier (manufacturer) and B_i being buyer i (dealer), X_i is a set of strategies available for a player i, π_i is a payoff function of a player i defined by the profit function of a given company. To make it clearer, let us define the manufacture's payoff as π_m.

Each of the discussed contract types is formalized into a separate game, where the goal of the first-tier player is to choose a dependent contract parameter according to the definition of the coordinating contract and, therefore, define the transfer payment. Meanwhile, the chosen parameter is a function of the dealers' retail prices, e.g. a function of followers' strategies.

The set of manufacturer's strategies (player S) in a game number k, where k is correspondent to a specific contract type, will look as follows:

$$X_1^k = \{T^k = (T_1^k(p_1, p_2), T_2^k(p_1, p_2))\}, k = 1, 2, 3, 4 \tag{4}$$

where $T_i^k(p_1, p_2) \in C^2(p_1, p_2)$ is a function of dealer's i transfer payment (player B_i) in a contract k, which is a double continuously differentiable function on p_1,p_2. Each dealer has his own transfer payment function. Notably, manufacturer determines the formulas for these functions, while dealers, in their turn, use given functions to solve the competition problem on the second stage of the game. Therefore, manufacturer's strategy is a choice of vector comprised of transfer payment functions for a distinct contract type. These functions are chosen according to the rule determined by a definition of a coordinating contract. The vector T^k, in turn, stands for the chosen contract.

The dealer i strategy (for each contract type k, e.g. in any given game) is a choice of the retail price p_i under the rules of Bertrand competition model. The order quantities $Q_i(p_1, p_2)$ are uniquely defined by the demand function (5):

$$X_2 = \{p_1\}_{p_1 \geq 0}, X_3 = \{p_2\}_{p_2 \geq 0}. \tag{5}$$

Let us consider the set of deales' payoffs, which are equivalent to their profit functions. $\pi_i(p_1, p_2)$ is a function of dealer i profit and equals to (6, 7):

$$\pi_1(p_1, p_2, T_1^k) = Q_1(p_1, p_2)(p_1 - c) - T_1^k(p_1, p_2), \tag{6}$$

$$\pi_2(p_1, p_2, T_2^k) = Q_2(p_1, p_2)(p_2 - c) - T_2^k(p_1, p_2) \tag{7}$$

for $Q_2(p_1, p_2)$ being defined by (1), $Q_i p_i$ being dealer i profit, cQ_i being total dealer's expenses on purchase, storage and sales of Q_i units of good and T_i being a transfer payment from dealer i to manufacturer according to the terms of contract $T^k(p_1, p_2)$. The manufacturer's profit function is a sum of two local profit functions in simple supply chains manufacturer - dealer(8):

$$\pi_m(p_1, p_2, T_1^k, T_2^k) = \pi_{m1} + \pi_{m2}. \tag{8}$$

The local profit functions equal to (9) and (10) accordingly, where $s_i Q_i(p1, p2)$ are operational costs to fulfill the order of a dealer i.

$$\pi_{m1}(p_1, p_2, T_1^k) = T_1^k(p_1, p_2) - s_1 Q_1(p_1, p_2), \tag{9}$$

$$\pi_{m2}(p_1, p_2, T_2^k) = T_2^k(p_1, p_2) - s_2 Q_2(p_1, p_2). \tag{10}$$

The total supply network profit can be concurrently divided into two streams: $P(p1, p2) = P_1(p1, p2) + P_2(p1, p2)$, where P_1 and P_2 are local supply chain profit functions resulting from interaction between manufacturer and an associated dealer.

$$P(p_1, p_2) = Q_1(p_1, p_2)(p_1 - c - s_1) + Q_2(p_1, p_2)(p_2 - c - s_2), \tag{11}$$

$$P_1(p_1, p_2) = \pi_1(p_1, p_2) + \pi_{m1}(p_1, p_2) = Q_1(p_1, p_2)(p_1 - c - s_1), \tag{12}$$

$$P_2(p_1, p_2) = \pi_2(p_1, p_2) + \pi_{m2}(p_1, p_2) = Q_2(p_1, p_2)(p_2 - c - s_2). \tag{13}$$

Let us assume the direct manufacturer's payoff function equals to the total supply network profit function P. Then, the main goal of the manufacturer is coordination of supply network as a whole or coordination of the two affiliated supply chains separately, if supply network coordination is impossible. Therefore, the main concern of the manufacturer is choice of such contract parameters that the maximum supply network profit is achieved. For the research purposes, that sort of contract is called coordinating.

Thus, contract $T^k(p_1, p_2)$ is called *strongly coordinating* if it meets the conditions (14):

$$\begin{cases} \arg\max\limits_{p_1} \; P(p_1, p_2) = \arg\max\limits_{p_1} \; \pi_1(p_1, p_2), \\ \arg\max\limits_{p_2} \; P(p_1, p_2) = \arg\max\limits_{p_2} \; \pi_2(p_1, p_2). \end{cases} \tag{14}$$

Following the conditions for coordinating contract, an optimal solution of the dealer's market competition problem optimal prices p_1^*, p_2^*, should also be an optimal solution for the supply network coordination problem, as in this point the maximum of the supply network profit function (11) should be attained. This is achieved through manufacturer's choice of the dependent parameter of the contract and, respectively, the transfer payment function, compliant with (14). Therefore, we have defined the rule for manufacturer's strategy choice by introducing the optimality principle, which is supply network profit maximization.

Notably, in some situations with specific contract types the optimal solution to supply network coordination problem cannot be found analytically. For this cases the optimization criteria is lowered, allowing maximization of the profit function separately for each supply chain constituting the network. Therefore, contract $T^k(p_1, p_2)$ is assumed to be weakly coordinating if it meets the conditions (15).

$$\begin{cases} \arg\max\limits_{p_1} \; P_1(p_1, p_2) = \arg\max\limits_{p_1} \; \pi_1(p_1, p_2), \\ \arg\max\limits_{p_2} \; P_2(p_1, p_2) = \arg\max\limits_{p_2} \; \pi_2(p_1, p_2). \end{cases} \tag{15}$$

By introducing conditions (14) and (15), we introduce the rule for manufacturer's optimal strategy choice, which states that manufacturer will always choose such contract parameters that guarantee supply network profit maximization. In other words, while dealers pursue to maximize their individual profits, manufacturer integrates the supply network in order to maximize the profit of the whole system. Thus, supply network is fully coordinated if it meets the conditions (16) and the problem of the game is to find corresponding strategies of all the players, so that these conditions are met.

$$\begin{cases} \arg\max\limits_{p_1} \; P(p_1,p_2) = \arg\max\limits_{p_1} \; \pi_1(p_1,p_2), \\ \arg\max\limits_{p_2} \; P(p_1,p_2) = \arg\max\limits_{p_2} \; \pi_2(p_1,p_2), \\ \max\limits_{p_1} \; \pi_1(p_1,p_2,T_1^*), \\ \max\limits_{p_2} \; \pi_2(p_1,p_2,T_2^*). \end{cases} \tag{16}$$

Consequently, supply network is weakly coordinated if it only meets lowered optimization criteria (17).

$$\begin{cases} \arg\max\limits_{p_1} \; P_1(p_1,p_2) = \arg\max\limits_{p_1} \; \pi_1(p_1,p_2), \\ \arg\max\limits_{p_2} \; P_2(p_1,p_2) = \arg\max\limits_{p_2} \; \pi_2(p_1,p_2), \\ \max\limits_{p_1} \; \pi_1(p_1,p_2,T_1^*), \\ \max\limits_{p_2} \; \pi_2(p_1,p_2,T_2^*). \end{cases} \tag{17}$$

8. Contract Decision-Making

Based on the choice of the contract parameters, there are several types of coordinating contracts recognized in literature that can be applied in a newsvendor setting. These are revenue-sharing, buy-back, price-discount, quantity-flexibility, sales-rebate, two-part tariff and quantity discount contracts. Studies of Cachon, 2003, Hohn, 2010, and Arishinder, 2011 synthesize the main findings and give summarizing reviews on the existing supply chain contract topologies. Behzad et al. (2010), in turn, provides a detailed overview of coordinating contract in literature and presents the state of art research in this field. According to his study, two broad classes of coordination contracts can be identified in literature: quantity dependent contracts and price dependent contracts.

As the supply network model, presented in the previous section, is based on the model of Bertrand price competition, the scope of this paper is restricted to the price dependent contracts, including wholesale, buy-back, price-discount, revenue-sharing, sales-rebate, quantity-discount and two-part tariff contracts.

Namely, four contracts chosen for the modeling and analysis are wholesale, revenue-sharing, quantity-discount and two-part tariff contracts, which are described later in this chapter. Each contract has dependent and independent variables, which determine how the profit is distributed between manufacturer and dealers. The decision on the independent variables is taken as a result of negotiations between the agents (manufacturer and dealer), strictly after the retail prices were set by the dealer and the dependent contract variables were chosen by the manufacturer. In a general case, dealer i has to pay a transfer payment T^k (18) to the manufacturer, where k refers to the specific contract type.

$$T_i^k(p), i = \{1, 2\} \tag{18}$$

where $p = (p_1, p_2)$ is a price vector.

8.1. Wholesale Contract

Under a wholesale contract a dealer buys goods in quantity Q_i from the manufacturer at a wholesale price per unit w_i and then resells them at a retail price p. Therefore, the transfer payment looks as follows (19):

$$T_i^1(p) = w_i(p)q_i(p), \qquad i = \{1, 2\}. \tag{19}$$

This type of contract only has one dependent variable, chosen by manufacturer, and no independent variables to be negotiated later. Wholesale contract is the least flexible type of contract among all chosen for the analysis, as the supply chain profit is distributed uniquely between manufacturer and dealer. Consequently, manufacturer's (20) and dealers' (21) profit functions can be formalized as follows:

$$\pi_{mi}(p, T_i^1) = Q_i(p)(w_i(p) - s_i), \tag{20}$$

$$\pi_i(p, T_i^1) = Q_i(p)(p_i - c - w_i(p)). \tag{21}$$

This type of contract is the most commonly observed in practice, as it is the simplest to set out and to administer, so it is usually assumed as a basic model for supply chain contract studies with all other types of contracts being derived from it.

8.2. Revenue-Sharing Contract

Under a revenue-sharing contract a dealer buys goods in quantity Q_i from the manufacturer at a wholesale price per unit w_i plus pays a percentage of his revenue. Notably, the supply chain revenue is assumed to include salvage revenue as well. In the end of the selling season dealer receives ϕ share of the revenue, while manufacturer receives the remaining part $(1 - \phi)$. Both parameters are specified before the order quantity Q_i is decided by the dealer. The transfer payment with this type of contract is equal to (22).

$$T_i^2(p) = (1 - \phi_i)Q_i(p)p_i + w_i(p)Q_i(p). \tag{22}$$

Therefore, manufacturer's (23) and dealers' (24) profit functions look as follows:

$$\pi_{mi}(p, T_i^2) = Q_i(p)((1 - \phi_i)p_i + w_i(p) - s_i), \tag{23}$$

$$\pi_i(p, T_i^2) = Q_i(p)(\phi_i p_i - c - w_i(p)). \tag{24}$$

Notably, profits of the separate supply chains and supply network as a whole will be the same for all the studied contracts (11), (12), (13), as the finite function is not dependent on the specific contract parameters due to the fact that transfer payment T is shortcut in the process of mathematical computations.

Revenue-sharing contract is one of the most widely applied in practice, as it has clear interpretation and explicit formulas for ϕ and w, which enforce the coordination in one-echelon supply chains under the rules of Cournot competition model. Moreover, this type of contract allows flexible allocation of profit between manufacturer and dealer, which is highly valued.

8.3. Quantity-Discount Contract

Under a quantity-discount contract a dealer buys goods in quantity Q_i from the manufacturer paying the wholesale price per unit $w_i(Q)$, which decreases with the increase of Q_i. In other words, this means that the discount is dependent on the quantity ordered. In general case transfer payment for this type of contract can be presented as $T(Q) = w(Q)Q$. Nevertheless, in case of two competing dealers quantity-discount contract becomes more complex, where transfer payment may be expressed by the following correlations (25).

$$T_i^3(p) = \begin{cases} w_i(p)Q_i(p) - \frac{1}{2}v_iQ_i^2(p), & \text{if } Q_i(p) \leq \overline{Q_i}(p) = \dfrac{w_i(p) - s_i}{v_i}, \\ T(\overline{Q_i}(p)) + s_i(Q_i(p) - \overline{Q_i}(p)), & \text{otherwise}, \end{cases} \tag{25}$$

where s_i are manufacturer's operating costs to produce and deliver a unit of good for dealer i, $w_i(p)$ is a wholesale price per unit for dealer i, v_i represents a discount (independent parameter) obtained by dealer i, compliant with the following criteria (Cachon and Kok, 2010): $v_i \in [0, \bar{v})$ $\bar{v} = min(\frac{2\delta_1}{\delta_0}, \frac{2\delta_2}{\delta_0})$, where

$$\delta_0 = \delta_1\delta_2 + \gamma(\delta_1 + \delta_2). \tag{26}$$

Notably, that this contract allows flexible allocation of profit between manufacturer and dealer and is included in the multitude (19) with $?_i = 0$. Profit functions of manufacturer (27) and dealers (28) in each case are as follows:

$$\begin{cases} \pi_i(p, T_i^3) = Q_i(p)(p_i - c) - w_i(p)Q_i(p) + \frac{1}{2}v_iQ_i^2(p), & \text{if } Q_i(p) \leq \overline{Q_i}(p), \\ \pi_{mi}(p, T_i^3) = w_i(p)Q_i(p) - \frac{1}{2}v_iQ_i^2(p) - s_iQ_i(p), \end{cases} \tag{27}$$

$$\begin{cases} \pi_i(p, T_i^3) = Q_i(p)(p_i - c) - T(\overline{Q_i}(p)) - s_i(Q_i(p) - \overline{Q_i}(p)), & \text{if } Q_i(p) > \overline{Q_i}(p), \\ \pi_{si}(p, T_i^3) = T(\overline{Q_i}(p)) - s_i\overline{Q_i}(p). \end{cases} \tag{28}$$

8.4. Two-Part Tariff Contract

Two-part tariff is actually a particular case of the wholesale price contract. Manufacturer sells the produced goods in quantity Q_i to the dealer at a wholesale price w_i and charges and additional fee equal to F_i. While the wholesale price is chosen by manufacturer, the parameter F is independent (negotiated) and should be paid at the end of the selling season disregarding the actual dealer's profit. Thus, transfer payment may be formalized as follows:

$$T_i^4(p) = F_i + w_i(p)Q_i(p). \tag{29}$$

Therefore, profit functions of manufacturer (30) and dealers (31) can be presented as follows:

$$\pi_{mi}(T_i^4) = Q_i(p)(w_i(p) - s_i) + F_i, \tag{30}$$

$$\pi_i(p, T_i^4) = Q_i(p)(p_i - c - w_i(p)) - F_i. \tag{31}$$

9. Optimization Results for Quantitative Modeling

Let us formulate the general rule for solving the game in terms of finding the appropriate players' strategies. As manufacturer is a leading player, he would have to analyze the current situation, taking into consideration competition between dealers and their next move, and based on this knowledge take a decision on dependent contract parameters to choose. The resulting parameters should ensure strong or weak coordination of the supply network, provided retail prices and order quantities chosen by the dealers.

9.1. Optimal parameters for the wholesale contract

After the manufacturer's first move, on the second stage of the game each dealer would maximize his profit function, using the first-order conditions, provided that the profit function is strictly concave:

$$\frac{\partial \pi_i}{\partial p_i} = 0.$$

Therefore, manufacturer has to choose contract parameters in such a way, that condition (32) is fulfilled (if weaker criterion of optimality is chosen):

$$\frac{\partial P_i}{\partial p_i} = \frac{\partial \pi_i}{\partial p_i}. \tag{32}$$

If this condition is fulfilled in the point $p_i = p_i^*$ (e.g. optimal dealer's price under competition) the supply chain profit would also hit its maximum, as manufacturer's and dealer's profit functions would match due to specific choice of contract parameters. If both functions are strictly concave on the price of the dealer i, there is no need to check the second-order conditions to demonstrate that point of extremum is a maximum.

Therefore, let us illustrate that both profit functions are strictly concave on the price p_i:

$$\pi_i(p) = Q_i(p)(p_i - c - w_i(p)) = (\theta k_i - \delta_i p_i + \gamma(p_j - p_i))(p_i - c - w_i(p)),$$

$$\frac{\partial \pi_i}{\partial p_i} = (\theta k_i - \delta_i p_i + \gamma(p_j - p_i))(1 - \frac{\partial w_i}{\partial p_i}) - (\delta_i + \gamma)(p_i - c - w_i),$$

$$\frac{\partial^2 \pi_i}{\partial p_i^2} = -2(\delta_i + \gamma)(1 - \frac{\partial w_i}{\partial p_i}) - \frac{\partial^2 w_i}{\partial p_i^2}(\theta k_i - \delta_i p_i + \gamma(p_j - p_i)) < 0.$$

If these conditions are met on the function $w_i(p)$, the dealers' profit functions are strictly concave on p_i. Correspondingly:

$$P_i = Q_i(p)(p_i - c - s_i),$$
$$\frac{\partial^2 P_i}{\partial p_i^2} = -2(\delta_i + \gamma) < 0.$$

The conditions for expressing contract parameter w_i from (32) for each of the supply chains can be formalized as follows:

$$\theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i + \gamma)(p_i - c - w_i) = \theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i + \gamma)(p_i - c - s_i),$$
$$w_i = s_i.$$

This leads to a conclusion, that the wholesale contract does not coordinate a supply chain due to the fact that the first-order condition is fulfilled only when the wholesale price is equal to the manufacturer's operational costs, meaning that manufacturer would get a zero profit. Taking into consideration, that this is the simplest type of coordinating contracts, the first criterion of optimality was used. In other words, the chosen contract parameters for each dealer should maximize the total supply network profit function P independently on p_1 and p_2:

$$\frac{\partial \pi_i}{\partial p_i} = \frac{\partial P}{\partial p_i}, \tag{33}$$
$$\theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i + \gamma)(p_i - c - w_i) =$$
$$= \theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i + \gamma)(p_i - c - s_i) + \gamma(p_j - c - s_j),$$
$$(\delta_i + \gamma)(w_i - s_i) = \gamma(p_j - c - s_j),$$
$$w_i(p) = s_i + \frac{\gamma}{\delta_i + \gamma}(p_j - c - s_j). \tag{34}$$

Now the optimal wholesale price is higher than manufacturer's operational costs, providing the positive profit for the manufacturer and ensuring coordination in a supply network. Moreover, in this case w_i does not depend on the price p_i, which means that

$$\frac{\partial w_i}{\partial p_i} = 0, \frac{\partial^2 w_i}{\partial p_i^2} = 0,$$
$$\frac{\partial^2 \pi_i}{\partial p_i^2} = -2(\delta_i + \gamma) < 0.$$

Notably, total supply network profit function P is also strictly concave on p_i:

$$\frac{\partial^2 P}{\partial p_i^2} = -2(\delta_i + \gamma) < 0.$$

In order to solve the problem of competition, knowing the manufacturer's choice on $w_i(p)$, let us insert $w_i(p)$ into the dealer's i profit function (21):

$$\pi_i = (\theta k_i - \delta_i p_i + \gamma(p_j - p_i))(p_i - c - s_i - \frac{\gamma}{\delta_i + \gamma}(p_j - c - s_j)).$$

While choosing the optimal retail price p_i^*, the dealer i would maximize his profit function, thus, applying the first-order condition:

$$\frac{\partial \pi_i}{\partial p_i} = 0 \tag{35}$$

$$\Rightarrow \frac{\partial \pi}{\partial p_i} = \theta k_i + (\delta_i + \gamma)(c + s_i - 2pi) + (2p_j - c - s_j) = 0.$$

As there are two dealers in the model, their reaction functions (describing the reaction of a dealer on the price set by his competitor), can be derived from the first-order conditions (35) and formalized as follows:

$$\begin{cases} p_1 = \frac{1}{2}(\frac{\theta k_1}{\delta_1 + \gamma} + c + s_1 + \frac{\gamma}{\delta_1 + \gamma}(2p_2 - c - s_2)), \\ p_2 = \frac{1}{2}(\frac{\theta k_2}{\delta_2 + \gamma} + c + s_2 + \frac{\gamma}{\delta_2 + \gamma}(2p_1 - c - s_1)). \end{cases} \tag{36}$$

Then, the optimal competitive prices are derived by expressing p_1 in terms of p_2:

$$p_1 = \frac{1}{2}(\frac{\theta k_1}{\delta_1 + \gamma} + c + s_1 +$$

$$+ \frac{\gamma}{\delta_1 + \gamma}((\frac{\theta k_2}{\delta_2 + \gamma} + c + s_2 + \frac{\gamma}{\delta_2 + \gamma}(2p_1 - c - s_1) - c - s_2)),$$

$$p_1 = \frac{1}{2}(\frac{\theta k_1}{\delta_1 + \gamma} + c + s_1 + \frac{\gamma}{(\delta_1 + \gamma)(\delta_2 + \gamma)}(\theta k_2 + \gamma(2p_1 - c - s_1)).$$

If we denote δ_0 as $\delta_1 \delta_2 + \gamma(\delta_1 + \delta_2)$, then:

$$p_1 \left(1 - \frac{\gamma^2}{(\delta_1 + \gamma)(\delta_2 + \gamma)}\right) =$$

$$\frac{1}{2}\left(\frac{\theta k_1}{\delta_1 + \gamma} + c + s_1 + \frac{\gamma}{(\delta_1 + \gamma)(\delta_2 + \gamma)}(\theta k_2 - \gamma(c + s_1))\right),$$

$$p_1 = \frac{(\delta_1 + \gamma)(\delta_2 + \gamma)}{2\delta_0}) \left(\frac{\theta k_1}{\delta_1 + \gamma} + c + s_1 + \frac{\gamma}{(\delta_1 + \gamma)(\delta_2 + \gamma)}(\theta k_2 - \gamma(c + s_1))\right),$$

$$\begin{cases} p_1^* = \frac{\theta(\gamma + k_1 \delta_2)}{2\delta_0} + \frac{1}{2}(c + s_1), \\ p_2^* = \frac{\theta(\gamma + k_2 \delta_1)}{2\delta_0} + \frac{1}{2}(c + s_2). \end{cases} \tag{37}$$

After expressing optimal retail prices (37) in context of market competition, we can consequently determine the optimal order quantities $Q_i^* = Q_i(p_1^*, p_2^*)$.

After all the players choose their strategies, we can evaluate the expected values of manufacturer's, dealers', supply chains and total supply network profit functions based on (8), (11), (20), (21).

9.2. Optimal parameters for the revenue-sharing contract

This contract has a more complicated structure, than the one discussed above. Thus, if the first-order conditions (33) are used to find optimal parameters (e.g. strong criterion of optimality), there will be no explicit solution to the game. Therefore, weak criterion of optimality is applied. Parameter ϕ defines specific shares in which revenue is divided between manufacturer and dealer in the supply chain i (Cachon and Lariviere, 2005):

$$\pi_i = \phi P_i.$$

In order to find contract parameters, let us assume that the correlation between the parameters is valid for the model with two dealers, meaning that each dealer receives a share of total supply network profit correspondent to his profit generated in a supply chain:

$$\pi_i = \phi_i P_i. \tag{38}$$

Consequently:

$$\frac{\partial \pi_i}{\partial p_i} = \phi_i \frac{\partial P_i}{\partial p_i}.$$

Possibility of coordination is predetermined by the contract type and the first-order condition results from (38). Hence, while choosing optimal retail price under competition, a dealer, as well, maximizes his local supply chain profit. Let us illustrate that under the revenue-sharing contract dealers' profit functions are strictly concave on the price pi:

$$\pi_i(p) = Q_i(p)(\phi_i p_i - c - w_i(p)) = (\theta k_i - \delta_i p_i + \gamma(p_j - p_i))(\phi_i p_i - c - w_i),$$

$$\frac{\partial \pi_i}{\partial p_i} = (\theta k_i - \delta_i p_i + \gamma(p_j - p_i))(\phi_i - \frac{\partial w_i}{\partial p_i}) - (\delta_i + \gamma)(\phi_i p_i - c - w_i),$$

$$\frac{\partial^2 \pi_i}{\partial p_i^2} = -2(\delta_i + \gamma)(\phi_i - \frac{\partial w_i}{\partial p_i}) - \frac{\partial^2 w_i}{\partial p_i^2}(\theta k_i - \delta_i p_i + \gamma(p_j - p_i)) < 0.$$

Let us express $w_i(\phi_i)$ out of (38), when the coordination in supply chains is attained (Cachon and Lariviere, 2005):

$$Q_i(p)(\phi_i p_i - c - w_i) = \phi_i Q_i(p)(p_i - c - s_i),$$

$$Q_i(p)(c + w_i) = \phi_i Q_i(p)(c + s_i),$$

$$w_i = \phi_i(s_i + c) - c. \tag{39}$$

This formula allows us to find relevant w_i, which maximizes profit in the local supply network and, therefore, ensures coordination, dependent on the ϕ_i, resulting from negotiations between parties. Nevertheless, w_i is not dependent on prices. Thus, dealers' profit functions are strictly concave:

$$\frac{\partial^2 \pi_i}{\partial p_i^2} = -2\phi_i(\delta_i + \gamma) < 0.$$

In order to solve the problem of competition, knowing contract conditions, let us insert w_i into the dealer's i profit function (24):

$$\pi_i = Q_i(p)(\phi_i p_i - c - w_i) = (\theta k_i - \delta_i p_i + \gamma(p_j - p_i))(\phi_i p_i - c - \phi_i(s_i + c) + c).$$

Consequently, first-order conditions are expressed as follows:

$$\frac{\partial \pi_i}{\partial p_i} = -(\delta_i + \gamma)(\phi_i p_i - \phi_i(s_i + c)) + \phi_i(\theta k_i - \delta_i p_i + \gamma(p_j - p_i)) = 0.$$

Then, the reaction functions can be formalized as:

$$-2\phi_i p_i(\delta_i + \gamma) + \phi_i((\delta_i + \gamma)(s_i + c) + \theta k_i + \gamma p_j) = 0,$$

$$\begin{cases} p_1 = \frac{1}{2}(s_1 + c + \frac{\theta k_1 + \gamma p_2}{\delta_1 + \gamma}), \\ p_2 = \frac{1}{2}(s_2 + c + \frac{\theta k_2 + \gamma p_1}{\delta_2 + \gamma}). \end{cases} \tag{40}$$

Finally, let us express optimal retail prices:

$$p_1 = \frac{1}{2}(s_1 + c + \frac{\theta k_1 + \frac{\gamma}{2}(s_2 + c + \frac{\theta k_2 + \gamma p_1}{\delta_2 + \gamma})}{\delta_1 + \gamma}),$$

$$(2p_1 - s_1 - c)(\delta_1 + \gamma) = \theta k_1 + \frac{\gamma}{2}(s_2 + c) + \frac{\gamma(\theta k_2 + \gamma p_1)}{2(\delta_2 + \gamma)},$$

$$p_1(4\delta_0 + 3\gamma^2) = 2(s_1 + c)(\delta_0 + \gamma^2) + 2\theta k_1(\delta_2 + \gamma) + \gamma(s_2 + c)(\delta_2 + \gamma) + \gamma\theta k_2,$$

$$\begin{cases} p_1^* = \frac{2(s_1 + c)(\delta_0 + \gamma^2) + \gamma\theta + \theta k_1(2\delta_2 + \gamma) + \gamma(s_2 + c)(\delta_2 + \gamma)}{4\delta_0 + 3\gamma^2}, \\ p_2^* = \frac{2(s_2 + c)(\delta_0 + \gamma^2) + \gamma\theta + \theta k_2(2\delta_1 + \gamma) + \gamma(s_1 + c)(\delta_1 + \gamma)}{4\delta_0 + 3\gamma^2}. \end{cases} \tag{41}$$

With the expression of optimal retail prices (41), we can find out optimal order quantities and the expected values of all the profit functions.

9.3. Optimal parameters for the quantity-discount contract

In this case formula for transfer payment calculation is divided into two parts, dependent on the order quantity, which should be reflected in the analysis. For the research purposes, weak criterion of optimality is used.

Let us consider the first situation:

$$T_i^3(p) = w_i(p)Q_i(p) - \frac{1}{2}v_i Q_i^2(p), \quad Q_i(p) \le \overline{Q_i}(p) = \frac{w_i(p) - s_i}{v_i}. \tag{42}$$

Assume that $Q_i(p) \le \overline{Q_i}(p)$. In this case, let us define dealer's profit function and show that it is strictly concave on p_i, then evaluate the dependent parameter w_i, wherein the coordination in local supply chains is attained.

$$\pi_i(p) = Q_i(p_i - c - w_i(p) + \frac{1}{2}v_i Q_i),$$

$$\frac{\partial \pi_i}{\partial p_i} = (\delta_i + \gamma)(c + w_i(p) - p_i) + Q_i(p)(1 - \frac{\partial w_i}{\partial p_i} - v_i(\delta_i + \gamma)),$$

$$\frac{\partial^2 \pi_i}{\partial p_i^2} = (\delta_i + \gamma)(2\frac{\partial w_i}{\partial p_i} - 2 - v_i(\delta_i + \gamma)) - Q_i \frac{\partial^2 w_i}{\partial p_i^2} < 0.$$

If $w_i(p)$ is chosen according to the conditions above, dealers' profit functions are strictly concave.

Let us state the first-order conditions:

$$\frac{\partial \pi_i}{\partial p_i} = \frac{\partial P_i}{\partial p_i},$$

$$(\delta_i + \gamma)(c + w_i - p_i) + Q_i(1 - v_i(\delta_i + \gamma)) = -(\delta_i + \gamma)(p_i - c - s_i) + Q_i,$$

$$w_i(p) = v_i Q_i(p) + s_i, \tag{43}$$

which is equivalent to $Q_i = \dfrac{w_i - s_i}{v_i}$, meaning that in this case coordination is achieved only on the threshold value of the interval for Q_i. Let us show the fulfillment of conditions for $w_i(p)$, which ensure that dealers' profit functions are strictly concave:

$$\frac{\partial w_i}{\partial p_i} = -v_i(\delta_i + \gamma),$$

$$\frac{\partial^2 w_i}{\partial p_i^2} = 0,$$

$$\frac{\partial^2 \pi_i}{\partial p_i^2} = -(\delta_i + \gamma)(2 + v_i(\delta_i + \gamma)) < 0.$$

In order to solve the problem of competition and find optimal retail prices, under condition that transfer payment equals to (42), let us instead of $w_i(p)$ insert into the dealer's i profit function (27) its value according to (43):

$$\pi_i = Q_i(p_i - c - v_i Q_i - s_i + \frac{1}{2}v_i Q_i) = Q_i(p_i - c - s_i - \frac{1}{2}v_i Q_i),$$

$$\frac{\partial \pi_i}{\partial p_i} = -(\delta_i + \gamma)(p_i - c - s_i - \frac{1}{2}v_i Q_i) + Q_i(1 + \frac{1}{2}v_i(\delta_i + \gamma)) = 0.$$

Then, the reaction functions can be formalized as:

$$\begin{cases} p_1 = \dfrac{(c + s_1)(\delta_1 + \gamma) + (\theta k_1 + \gamma p_2)(1 + v_1(\delta_1 + \gamma))}{(2 + v_1(\delta_1 + \gamma))(\delta_1 + \gamma)}, \\ p_2 = \dfrac{(c + s_2)(\delta_2 + \gamma) + (\theta k_2 + \gamma p_1)(1 + v_2(\delta_2 + \gamma))}{(2 + v_2(\delta_2 + \gamma))(\delta_2 + \gamma)}. \end{cases} \tag{44}$$

Finally, let us express optimal retail prices:

$$p_1 = \frac{(c+s_1)(\delta_1+\gamma)}{(2+v_1(\delta_1+\gamma))(\delta_1+\gamma)} +$$

$$+ \frac{(\theta k_1 + \gamma(\frac{(c+s_2)(\delta_2+\gamma)+(\theta k_2+\gamma p_1)(1+v_2(\delta_2+\gamma))}{(2+v_2(\delta_2+\gamma))(\delta_2+\gamma)}))(1+v_1(\delta_1+\gamma))}{(2+v_1(\delta_1+\gamma))(\delta_1+\gamma)},$$

$$p_1(\delta_0+\gamma^2)(2+v_1(\delta_1+\gamma))(2+v_2(\delta_2+\gamma)) = (c+s_1)(\delta_0+\gamma^2)(2+v_2(\delta_2+\gamma))+$$
$$+(1+v_1(\delta_1+\gamma))(2+v_2(\delta_2+\gamma))(\delta_2+\gamma)\theta k_1 + \gamma(c+s_2)(\delta_2+\gamma)(1+v_1(\delta_1+\gamma))+$$
$$+\gamma(1+v_1(\delta_1+\gamma))(1+v_2(\delta_2+\gamma))(\theta k_2+\gamma p_1),$$

$$p_1((\delta_0+\gamma^2)(2+v_1(\delta_1+\gamma))(2+v_2(\delta_2+\gamma)) - \gamma^2(1+v_1(\delta_1+\gamma))(1+v_2(\delta_2+\gamma))) =$$
$$= (c+s_1)(\delta_0+\gamma^2)(2+v_2(\delta_2+\gamma)) + (1+v_1(\delta_1+\gamma))(2+v_2(\delta_2+\gamma))(\delta_2+\gamma)\theta k_1+$$
$$+\gamma(1+v_1(\delta_1+\gamma))(1+v_2(\delta_2+\gamma))\theta k_2 + \gamma(c+s_2)(\delta_2+\gamma)(1+v_1(\delta_1+\gamma)).$$

Let us denote $\delta_i + \gamma$ as α_i , then optimal prices equal to:

$$\begin{cases} p_1^* = \frac{\gamma(1+v_1\alpha_1)\{\alpha_2(c+s_2)+(1+v_2\alpha_2)\theta k_2\}+\alpha_2(2+v_2\alpha_2)\{\alpha_1(c+s_1)+\theta k_1(1+v_1\alpha_1)\}}{\delta_0(4+2v_2\alpha_2+2v_1\alpha_1+v_1v_2\alpha_1\alpha_2)+\gamma^2(3+v_2\alpha_2+v_1\alpha_1)}, \\ p_2^* = \frac{\gamma(1+v_2\alpha_2)\{\alpha_1(c+s_1)+(1+v_1\alpha_1)\theta k_1\}+\alpha_1(2+v_1\alpha_1)\{\alpha_2(c+s_2)+\theta k_2(1+v_2\alpha_2)\}}{\delta_0(4+2v_2\alpha_2+2v_1\alpha_1+v_1v_2\alpha_1\alpha_2)+\gamma^2(3+v_2\alpha_2+v_1\alpha_1)}. \end{cases} \quad (45)$$

It can be clearly seen that in this case optimal retail prices are dependent on contract parameter ?i, which stands for a discount defined during the negotiation period. All other parameters, such as optimal prices, wholesale price, order quantities and profits, are determined according to the chosen discount.

Now let us consider the second situation when $Q_i(p) > \overline{Q_i}(p)$. In this case dealers' profit functions can be formalized according to (28):

$$\pi_i = Q_i(p_i - c - s_i) - \frac{w_i - s_i}{v_i}\left(\frac{s_i}{2} + (w_i - s_i)\left(\frac{w_i}{v_i} - \frac{1}{2}\right)\right) =$$
$$= P_i - \frac{w_i - s_i}{v_i}\left(\frac{s_i}{2} + (w_i - s_i)\left(\frac{w_i}{v_i} - \frac{1}{2}\right)\right)$$
$$\Rightarrow \frac{\partial \pi_i}{\partial p_i} = \frac{\partial P_i}{\partial p_i}.$$

Therefore, coordination is achieved no matter what contract parameters are chosen. In this sense manufacturer focuses on those parameters, which yield higher supply chain profit, and makes his choice based on the analysis of these two cases.

$$\frac{\partial \pi_i}{\partial p_i} = -(\delta_i + \gamma)(p_i - c - s_i) + \theta k_i - \delta_i p_i + \gamma(p_j - p_i) = 0.$$

The reaction functions:

$$\begin{cases} p_1 = \dfrac{c+s_1}{2} + \dfrac{\theta k_1 + \gamma p_2}{2(\delta_1+\gamma)}, \\ p_2 = \dfrac{c+s_2}{2} + \dfrac{\theta k_2 + \gamma p_1}{2(\delta_2+\gamma)}. \end{cases} \tag{46}$$

Now let us express optimal prices:

$$p_1 = \frac{c+s_1}{2} + \frac{\theta k_1 + \gamma\left(\dfrac{c+s_2}{2} + \dfrac{\theta k_2 + \gamma p_1}{2(\delta_2+\gamma)}\right)}{2(\delta_1+\gamma)},$$

$$4p_1(\delta_0+\gamma^2) = 2(c+s_1)(\delta_0+\gamma^2) + 2\theta k_1(\delta_2+\gamma) + \gamma(\delta_2+\gamma)(c+s_2) + \gamma\theta k_2 + \gamma^2 p_1,$$

$$\begin{cases} p_1^* = \dfrac{2(c+s_1)(\delta_0+\gamma^2) + (\delta_2+\gamma)(2\theta k_1 + \gamma(c+s_2)) + \gamma\theta k_2}{4\delta_0 + 3\gamma^2}, \\ \\ p_2^* = \dfrac{2(c+s_2)(\delta_0+\gamma^2) + (\delta_1+\gamma)(2\theta k_2 + \gamma(c+s_1)) + \gamma\theta k_1}{4\delta_0 + 3\gamma^2}. \end{cases} \tag{47}$$

The comparison of formulas (47) and (45) leads to a conclusion that in the first case the optimal retail price would be always higher, which means that, according to the law of demand, in the second case lower prices enforce higher order quantity. This proves that in the second case dealers' order quantities would meet the requirement $Q_i > \overline{Q_i}$.

In order to determine optimal strategy for the manufacturer, it is necessary to compare supply chain profit $Q_i(p_i - s_i - c)$ under both (47) and (45) for each separate case. It is also possible to insert in profit function $Q_i(p_i - s_i - c)$ equations dependent on v_i (47) and, under first-order conditions, find through market values and players' costs expressions for optimal discounts v_1, v_2 for the first situation.

9.4. Optimal parameters for the two-part tariff contract

In this case strong criterion of optimality gives the same result as for the wholesale contract:

$$\pi_i(p) = Q_i(p)(p_i - c - w_i) - F_i,$$

$$\frac{\partial \pi_i}{\partial p_i} = \theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i+\gamma)(p_i - c - w_i),$$

$$\frac{\partial P}{\partial p_i} = \frac{\partial \pi_i}{\partial p_i},$$

$$\theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i+\gamma)(p_i - c - w_i) =$$

$$= \theta k_i - \delta_i p_i + \gamma(p_j - p_i) - (\delta_i+\gamma)(p_i - c - s_i) + \gamma(p_j - c - s_j),$$

$$w_i = s_i + \frac{\gamma}{\delta_i+\gamma}(p_j - c - s_j). \tag{48}$$

Expression for the contract parameter is similar to the case of the wholesale contract, with the only difference in controlling parameter F_i, which is an independent contract parameter allowing to redistribute supply chain profit between manufacturer and dealer, while under the wholesale contract maximum profit can be distributed in an exclusive and predefined way.

Therefore, due to similarity in formulas for these two contracts, optimal retail prices are equivalent to (37).

10. Bargaining Power in Contract Decision-Making

According to Kannan (2011), the final choice on the type of contract to be implemented is based on supply network profit allocation between the participating members. This leads to the notion of the bargaining power and the ways it can be distributed among the supply network members, as, following Choi and Triantis (2012), when two parties enter into a contract, their relative bargaining power affects the terms of their deal.

Although bargaining power is often cited as a critical determinant of contractual terms, neither the meaning of power nor the path of its influence is very clear (Choi and Triantis, 2012). The slipperiness of the term is due, at least partly, to the fact that bargaining power frequently boils down to a tautology: one party had bargaining power when the resulting agreement is more favorable to that party than its counterpart.

To understand what a bargaining power is, consider price is a function of the manufacturer's and dealer's respective perceptions of the two reservation prices (each party's own and that of her counterpart). The perceived bounds for the bargaining range, and the price ultimately chosen within this range, are determined by a mix of factors that might be exogenous or endogenous to the negotiations. Choi and Triantis (2012) divide these factors into five distinct categories:

- Demand and supply conditions
- Market concentration
- Private information
- Patience and risk aversion
- Negotiating skills and strategy

The first category of exogenous factors consists of the demand and supply conditions in the relevant market. When there is a significant increase in the demand for the product or reduction in the supply, the market price will tend to increase and manufacturer is often said to have increased bargaining power.

Second category of exogenous factors is market concentration. A monopolist's market power is often referred to as its bargaining power. A dealer's no-agreement alternative is limited by the fact that there are no other manufacturers available in the market and his reservation price is correspondingly higher than if he could purchase the same good from a competitor. Typically, market concentration on the seller side increases price and concentration on the buyer side decreases it.

A third category of exogenous factors contains informational advantages that one party may enjoy by knowing more about the other party, the market or by concealing information about itself. A party with private information can be thought of as having a type of monopoly originating from having private access to valuable information.

Fourth category is containing company's characteristics, such as patience and risk aversion, that may determine where the agreed price will fall within a given bargaining range. Bold parties, for example, may do better than timid players, and the patient negotiator typically enjoys higher returns than the impatient opponent. Patience may be, in turn, a function of other factors, such as the solvency and liquidity constraints, or the ability to diversify risks of an unfavorable bargaining outcome.

In the fifth category, there are various negotiating tactics that can change the actual or perceived reservation price of either party, so as to induce a favorable shift in the bargaining range. For example, a party might take steps to worsen (or appear to worsen) the opponent's outside opportunities, through credible threats or otherwise. Strategic negotiators also exploit the cognitive biases and errors of their opponents, particularly the tendency of some individuals to escalate commitment and be overconfident in their abilities.

In any given contract transaction, one or more of these factors might be in action. Which ones are present usually determines the exact path by which unequal bargaining power affects given contract design. This means that a factor or a combination of certain factors gives one party the opportunity to influence the contract terms in his own favor. In other words, having more bargaining power refers to *the ability of one party to influence the choice of contract parameters in such a way, that this party receives more benefits from the contract.*

For the purposes of the current research, it is assumed that the party, which enjoys more bargaining power in negotiations, uses it to receive additional benefits from the contract in terms of winning a bigger share of total supply network profit. This means, that during the negotiation period, contract parameters will be chosen in favor of the most powerful party, nevertheless, being accepted as an optimal solution by all the supply chain members.

11. Contract selection modelling in Supply networks

Based on the results of the theoretical studies, presented in Chapter 9, special software for the improved contract selection methodology was developed. It computes optimal parameters for all four types of contracts, studied in current paper, so that these contracts coordinate a given supply network and return the highest possible profits, according to their type. Moreover, this software tool also allows graphical representation of supply network profit function dynamics, while changing certain parameters for manufacturer, dealers and the market.

Software tool was developed in Visual Studio 2012 using C# programming language. Graph construction was carried out in ZedGraph frame. Its functionality is presented in the Figure 6 below.

It is necessary to give some comments on revenue-sharing contract parameters approximation, as well as optimal discounts computation. Analytically, for the revenue-sharing contract, the problem was solved in terms of weak coordination, as if the criterion (49) for strong coordination is followed, then equation for w_i would take the following form (50):

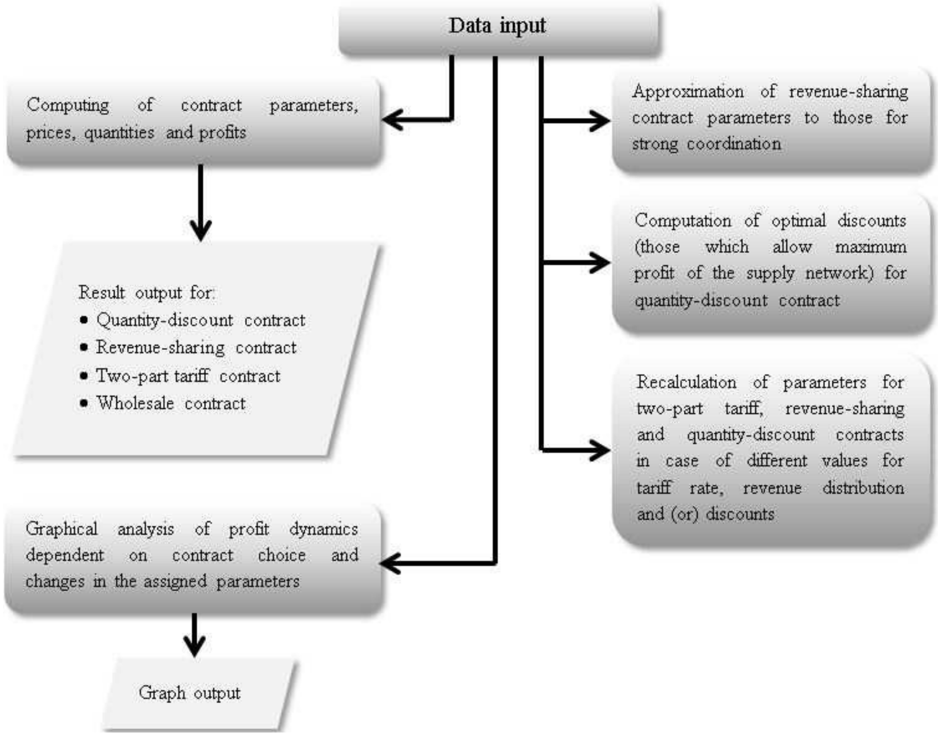

Fig. 6: Software functionality

$$\frac{\partial \pi_i}{\partial p_i} = \phi_i \frac{\partial P}{\partial p_i}, \tag{49}$$

$$w_i = \phi_i(s_i + c) - c + \frac{(\delta_1 + \gamma)(s_1 - w_1)}{2p_1(\delta_1 + \gamma) - \gamma p_2}. \tag{50}$$

Equation (50), in turn, led to problem insolvability due to the last additive component. Therefore, the proposed algorithm of approximation chase is based on the method of drawing near this last component, initially assuming that it equals to 0 and then gradually increasing its value in different combinations. Since profit function is concaved, the chase goes on until supply network profit keeps growing. As soon as the next iteration gives value for a profit function, which is smaller than the one given at a previous step, search cycle is stopped. Hence, approximation for w_i in terms of strong coordination would look as follows (51).

$$\begin{cases} w_1 = \phi_1(s_1 + c) - c + e_1, \\ w_2 = \phi_2(s_2 + c) - c + e_2, \end{cases} \tag{51}$$

where e_1, e_2 are the algorithmically found approximations. Testing showed that these approximations return higher values for supply network profit function than previously used weak coordination parameters.

As for optimal discounts computation, the problem solution has resulted in two different options of pricing and quantity decisions, namely, when dealer i orders quantity $Q_i \leq \overline{Q_i}$ and when dealer i orders quantity $Q_i > \overline{Q_i}$. These two sets of decision options result in four separate cases. Software makes computations of optimal discounts for each case and then returns the one, which maximizes supply network total profit.

Initially, the program requires to input certain parameters, including market parameters: θ potential market size, δ_1, δ_2 and γ demand function parameters, k_1, k_2 first and second dealer's market shares accordingly; and cost parameters: c dealers' marginal costs, s_1, s_2 manufacturer's operating expenses to fulfill the orders of an associated dealer. For certain contracts it is also necessary to insert additional initial parameters, such as shares of revenue for revenue-sharing contract and discounts for quantity-discount contract.

Developed software will be first applied for modelling numerical examples to show the mechanics and draw some conclusions, which then will be tested on real-life cases. Both modeling examples and cases were selected to cover the notion of different bargaining power distribution between the supply chain members, which was discussed in previous Chapter. Consequently, first example assumes the situation of strong manufacturer and is later illustrated with Audi Russia (Volkswagen group) case study, second example assumes the situation of strong dealers and is supported by ProtechDry Portugal (Impetus group) case study and the last example assumes negotiation between equally powerful parties, which is illustrated with Heineken (Local wholesaler) case study.

11.1. Coordinating Contract with Strong Manufacturer

Let's consider the situation of initially strong manufacturer, who can insist on contract parameters in his own favor. In this case manufacturer tries to gain a relatively bigger share of profit from the supply network, while dealers would accept these unfavorable conditions, as they have limited bargaining options.

Table 2 below summarizes market conditions and contract parameters that would correspond to a described situation.

Table 2: Initial data set for the case of strong manufacturer

θ	γ	δ_1	δ_2	k_1	k_2	c	s_1	s_2	ϕ_1	ϕ_2	v_1	v_2	F_1	F_2
200	0.5	1	1	0.45	0.55	10	35	40	0.3	0.3	0.1	0.15	160	170

The potential market size equals to 200 conditional units, which is more or less equally divided between dealers, as first dealer has 45% market share, while second covers the remaining 55%. Given γ, ranging from 0.1 to 0.9, reflects market elasticity, while $\gamma + \delta_i$ shows price demand elasticity of a given dealer. Therefore, it is assumed that initially market is characterized by medium elasticity.

From mathematical point of view, manufacturer's power would directly affect given contract parameters, such as ϕ_1 and ϕ_2, which are relatively low in order to reflect lower dealer's profits. Similarly, dealer's discounts v_1 and v_2, which can range from 0 to 1, will be quite small as well.

Given the initial data set, Table 3 below gives an overview for the resulting prices and order quantities, while Table 3 aims to summarize the modeling results in terms of listing the profits achieved by all the participants of a supply network under different contract rules.

Table 3: Optimal prices and quantities for the case of strong manufacturer

	p_1^*	q_1^*	w_1^*	p_2^*	q_2^*	w_2^*
Wholesale contract	70	24	44.17	77.5	29	48.33
Revenue-Sharing	65,2	29	4.7	72,7	34	5.4
Quantity-discount	66,4	28	37,8	75	31	44,65
Two-part tariff	70	24	44.17	77.5	29	48.33

Table 4: Profit function values summary for the case of strong manufacturer

	π_1^*	π_2^*	π_{s1}^*	π_{s2}^*	π_s^*	P_1^*	P_2^*	P^*
Wholesale contract	380	555.8	220	241.6	461,7	600	797.5	1397,5
Revenue-Sharing	141,1	218,3	445,3	554,7	1000	586,5	773	1359,5
Quantity-discount	560	703,9	39,3	72	111,3	599,2	776	1375,2
Two-part tariff	220	385,8	380	411,7	791,7	600	797.5	1397,5

As for the Table 4 and further in this Chapter, π_1^*, π_2^* - are optimal profits for the first and the second dealers accordingly; π_{m1}^*, π_{m2}^* - are optimal profits of the manufacturer in the distinct supply chains with each dealer; π_m is total optimal manufacturer profit; P_1^*, P_2^* - are separate supply chains optimal profits; P^* - is optimal total supply network profit under a specific contract type.

It can be clearly derived from the obtained results that quantity-discount and wholesale contracts would not be chosen in a situation, when manufacturer is a strong party, as both these contacts provide him with less than average profits. Revenue-sharing and two-part tariff contracts are more suitable for manufacturer, knowing that he can claim a bigger part of the total profit.

To understand how these contracts will be able to coordinate supply network relationships under changing market conditions, developed software is enabled with Graphical analytical toolkit. Notable, that graphs show only three types of contracts wholesale, revenue-sharing and quantity-discount, as two-part tariff contract behaves perfectly identical to wholesale contract with Y-shift equal to the value F. The resulting graphs showing the behavior of the profit function for the case of strong manufacturer are presented in the Appendix 1, while main findings are summarized below.

If marginal costs c increase from 7 to 15 monetary units (see Appendix 1, Fig. 31 - 33), supply network's total profit, as well as manufacturer's and dealers' profits, tend to decrease. Notably, the safest contracts for manufacturer in this case are wholesale and quantity-discount, as manufacturer's profit function is less sensitive to negative effects under their conditions.

At the same time, with the increase in manufacturer's operating expenses for the order fulfillment from 30 to 40 monetary units (see Appendix 1, Fig. 34 - 36), total profit of supply network is decreasing. Profit of the second dealer is growing proportionally to decrease in first dealer's profits. As for manufacturer, all the studied contracts share little sensitivity to negative effects. Therefore, as quantity-discount and wholesale contracts return the smallest profits, revenue-sharing and two-part tariff are most suitable in this case.

The influence of market parameters is defined by γ, ranging from 0.1 to 0.9, parameter that is connected to switching customers' behavior and reflects market elasticity, and δ_i, ranging from 0.3 to 2, parameter that is connected to marginal customers' behavior and reflects price sensitivity. Thus, $\gamma + \delta_i$ shows price demand elasticity for the dealer i.

With γ increase (see Appendix 1, Fig. 37 - 39), elasticity of the market increases accordingly, which leads to further weakening of both dealers. In such market conditions, wholesale or two-part tariff contracts would be the most suitable option for the manufacturer, as under these contracts profit function stays within a specified frame, having a corridor with maximum and minimum borders, instead of constantly falling down, like it happens under all other contracts. Moreover, wholesale contract in a situation of increasing market elasticity considerably drives up manufacturer's own profits. Thus, in case of strong manufacturer and increasing market elasticity γ, two-part tariff contract is the most suitable option.

On the other hand, while price sensitivity for first dealer's products δ_1 is increasing (see Appendix 1, Fig. 40 - 42), total profit of supply network is decreasing, as well as profit of the first dealer itself. A steep increase in price sensitivity results in a heavy decrease in the manufacturer's profit under both wholesale and quantity-discount contracts. In this sense, revenue-sharing contract gives the best safety to manufacturer, as it has low sensitivity to changes in both δ_i and in γ.

Other parameters from the set of external environment features that might influence the profit function are dealers' market shares k_1 and k_2. In other words, a way the market is divided between the two players. In order to track changes in the profit function values, market share of the first dealer is increased from 0.3 to 0.8, while market share of the second dealer decrease accordingly from 0.7 to 0.2 (see Appendix 1, Fig. 43 – 45). This parameter reflects market concentration in a way it is possible to do so for an oligopolistic market.

As it was expected, with the increase of a market share the profit of an associated dealer is increasing as well, while its competitor is losing his profit. Another obvious conclusion is that the more severe is competition the smaller is total supply network profit, as both dealers have strong incentives to lower prices following the rules of Bertrand competition. In other words, it can be stated that supply network profit increases proportionally with the increase in market concentration.

As for the manufacturer, in a situation of low market concentration and, therefore, equal and relatively weak dealers, most optimal decision would be to operate under two-part tariff contract, as it returns the highest profit. At the same time, in a situation of high market concentration, with one dealer being sufficiently more powerful then another, but still less powerful then manufacturer, revenue-sharing would be more favorable.

From the conducted research it can be concluded that for the case of a strong manufacturer, when he has sufficient bargaining power to pursue contract decisions in its own favor, two-part tariff contract is the most optimal contract choice, as it behaves identically to the wholesale contract, nevertheless, allowing profit reallocation in favor of a powerful manufacturer. Revenue-sharing contract has fewer advantages, but generates much stable revenue streams under volatile market conditions and, therefore, can be considered as an optimal choice for some specific markets.

11.2. Coordinating Contract with Equal Power Participants

In turn, let's consider the situation when manufacturer and dealers initially have almost equal bargaining power and, consequently, none of the supply network participants can claim a bigger share of profit. Therefore, given contract parameters, such as revenue shares ϕ_1 and ϕ_2, as well as dealers' discounts v_1 and v_2 and tariff rates F_1 and F_2 would be considerably fairer.

Table 5 below summarizes market conditions and contract parameters that would correspond to a given situation. It is assumed that potential market conditions stay similar to the ones described in a previous example.

Table 5: Initial data set for the case of equal power distribution

θ	γ	δ_1	δ_2	k_1	k_2	c	s_1	s_2	ϕ_1	ϕ_2	v_1	v_2	F_1	F_2
200	0.5	1	1	0.45	0.55	15	35	40	0.5	0.5	0.4	0.45	100	110

Given the initial data set, Table 6 gives an overview for the resulting prices and order quantities, while Table 7 summarizes the results in terms of listing the profits achieved by all the participants of a supply network under different contracts applied.

Table 6: Optimal prices and quantities for the case of equal power distribution

	p_1^*	q_1^*	w_1^*	p_2^*	q_2^*	w_2^*
Wholesale contract	72,5	21	43,3	80	26	47,5
Revenue-Sharing	68,2	26	11,2	75,7	31	12,9
Quantity-discount	72,9	21	43,4	81,7	24	50,8
Two-part tariff	72,5	21	43,3	80	26	47,5

Table 7: Profit function values summary for the case of equal power distribution

	π_1^*	π_2^*	π_{s1}^*	π_{s2}^*	π_s^*	Π_1^*	Π_2^*	Π^*
Wholesale contract	297,5	455	175	195	370	472,5	650	1122,5
Revenue-Sharing	236,9	321,4	236,9	321,4	601,9	473,8	642,9	1116,7
Quantity-discount	392,9	511,2	88,2	129,6	217,8	481,2	640,7	1121,9
Two-part tariff	197,5	345	275	305	580	472,5	650	1122,5

It can be derived from the obtained results that quantity-discount contract unevenly distributes total supply network profit between the participants in favor of dealers. Wholesale contract seems to have this drawback as well, although it is considerably less overbalanced. Such uneven profit allocation might be compensated with the wise application of two-part tariff contract by choosing appropriate tariff rates. Revenue-sharing contract, in turn, divides profit in a perfectly balanced way, according to predefined negotiated shares. Examination on how these contracts will coordinate supply network relationships under changes in different parameters can be found in the Appendix 2.

Considering changes in marginal costs c from 10 to 20 (see Appendix 2, Fig. 46 - 48) and in operating expenses s_i from 30 to 40 (see Appendix 2, Fig. 49 - 51), the results are similar to the case of strong manufacturer. In a situation of equal power participants, from the dealer's perspective, revenue-sharing contract is the one least sensitive for cost increase, while manufacturer might favor wholesale and quantity-discount as being safer.

Notably, with changes in γ from 0.1 to 0.9 (see Appendix 2, Fig. 52 - 54) some mixed results are observed. On the one hand, supply network profit is the most stable towards changes in the market conditions under quantity-discount and wholesale contracts, while under revenue-sharing contract there a slight decrease in profit is evidenced. On the other hand, under the wholesale contract profit dynamics for manufacturer and dealers tend to be completely the opposite manufacturer's profit is drastically increasing with increase in market elasticity, while dealers' profits suffer significant decrease at the very same moment. This situation seems to be completely inacceptable in a case of equally distributed bargaining power. Therefore, revenue-sharing contract is more reasonable here, as the behavior of manufacturer's and dealers' profit functions follows the same patterns.

All studied types of contracts reacted similarly to changes in δ_1 from 0.3 to 2 (see Appendix 2, Fig. 55 - 57). When price sensitivity is increasing, total profit of supply network is decreasing, as well as first dealer's and manufacturer's profit, which is identical to the results obtained for the case of strong manufacturer earlier. In this situation, revenue-sharing contract gives the best safety to manufacturer, while second dealer would give credit to the wholesale contract.

Expectedly, the observed dynamics for changes in dealers' market shares k_i, with market share of the first dealer growing from 0.3 to 0.8, while market share of the second dealer is decreasing from 0.7 to 0.2 (see Appendix 2, Fig. 58 - 60), are similar to the case of a strong manufacturer. The more severe is competition, the smaller is total supply network profit, as both dealers have strong incentives to lower their retail prices (following the rules of Bertrand competition), disregarding what type of contract is applied. In other words, supply network profit increases proportionally with the increase in market concentration. For the dealers, revenue-sharing contract is the most stable in terms of profit allocation, while for manufacturer, in a situation of equal and relatively weak dealers, most optimal decision would be to operate under two-part tariff contract, and in a situation of one dealer being sufficiently more powerful then another, revenue-sharing would be more favorable.

From the studied example, it can be concluded that for the case of equally distributed bargaining power, optimal contract choice would be revenue-sharing, as it allocates the supply network profit exactly according to the negotiated shares. In addition to that, revenue-sharing contract is less sensitive to changes in market conditions and preserves the same tendencies for both dealers' and manufacturer's profit functions, which is important. Two-part tariff might also be used, if tariff rate is tuned to the supply network needs, but it suffers more sensitivity to costs escalation and unfavorable market environment.

11.3. Coordinating Contract with Strong Dealers

The last numerical example considers the situation, when dealers initially have more bargaining power then the manufacturer and, therefore, impose their decisions on the supply network in terms of business arrangements. Dealers' bargaining power would again influence given set of contract parameters, such as revenue shares ϕ_1

and ϕ_2, dealers' discounts v_1 and v_2 and tariff rates F_1 and F_2. Table 3.5 below summarizes market conditions and contract parameters that would correspond to the situation. It is assumed that potential market conditions stay similar to the previous examples.

Table 8: Initial data set for the case of strong dealers

θ	γ	δ_1	δ_2	k_1	k_2	c	s_1	s_2	ϕ_1	ϕ_2	v_1	v_2	F_1	F_2
200	0.5	1	1	0.45	0.55	17	35	40	0.8	0.9	0.9	0.85	30	40

Given the initial data set, Table 9 below gives an overview for the resulting prices and order quantities, while Table 10 summarizes the modeling results in terms of listing the profits achieved by all the participants of a supply network under different contract types applied.

Table 9: Optimal prices and quantities for the case of strong dealers

	p_1^*	q_1^*	w_1^*	p_2^*	q_2^*	w_2^*
Wholesale contract	73,5	20	43	81	25	47,2
Revenue-Sharing	69.5	25	25.7	77,5	29	35.7
Quantity-discount	72.9	21	43.4	81,7	24	50.8
Two-part tariff	73,5	20	43	81	25	47,2

Table 10: Profit function values summary for the case of strong dealers

	π_1^*	π_2^*	π_{s1}^*	π_{s2}^*	π_s^*	Π_1^*	Π_2^*	Π^*
Wholesale contract	270	420,8	160	179,2	339,2	430	600	1030
Revenue-Sharing	349,1	533,6	87,3	59,3	146,6	436,4	592,8	1029,2
Quantity-discount	304,1	415,8	50,4	72,7	123	419,3	569,3	988,5
Two-part tariff	240	380,8	190	409,2	580	430	600	1030

Behavior of the profit functions of a supply network, manufacturer and dealers is summarized in the Appendix 3. In a situation of changing marginal costs c from 12 to 25 (see Appendix 3, Fig. 61 - 63) and manufacturer's operating expenses s_i from 30 to 40 (see Appendix 3, Fig. 64 - 66), the behavior of profit functions is similar to the cases discussed before. In general, it can be concluded that all types of contracts have little sensitivity for costs escalation, with revenue-sharing contract being the most stable option in terms of revenue streams.

As for the influence of market parameters, profit function behavior under the changes in price sensitivity δ_i, ranging from 0.3 to 2, (see Appendix 3, Fig. 70 – 72) also has insignificant differences from the cases discussed earlier. Nevertheless, changes in market elasticity, ranging from 0.1 to 0.9, (see Appendix 3, Fig. 67 - 69) bring some new interesting insights.

With increase in market elasticity γ, both revenue-sharing and quantity-discount contracts react less intensively than wholesale and two-part tariff contracts, which would probably be an attractive option for powerful dealers. In addition to that, revenue-sharing contract can even provide some growth in total supply network profit due to a slight increase in manufacturer's profit. Nevertheless, quantity-discount is less sensitive to changes in market conditions. Therefore, if dealer runs a risk of losing a part of his market share, optimal choice would be apply a quantity-discount contract, while if he is expecting some growth, application of a revenue-sharing contract would enforce a steeper profit growth.

As it was expected, the observed dynamics for changes in the dealers' market shares k_i, from 0.3 to 0.8 for the first dealer and from 0.7 to 0.2 for the second dealer, (see Appendix 3, Fig. 73 - 75), are similar to the previous cases. The more severe is competition, the smaller is total supply network profit, as both dealers have strong incentives to lower their prices (following the rules of Bertrand competition), no matter what type of contract is chosen. In other words, supply network profit increases proportionally with the increase in market concentration. For the dealers, revenue-sharing contract is the most stable option in terms of profit allocation, while for the manufacturer, in a situation of equal and relatively weak dealers, most optimal decision would be to operate under two-part tariff contract, and in a situation of one dealer being sufficiently more powerful then another, revenue-sharing contract would be preferred.

From the current example, it can be concluded that in any case, quantity-discount contract tends to allocate profit in favor of dealers, no matter what costs and discounts are chosen. Moreover, this type of contract has some characteristics, which might be of use in a situation of strong dealers. Thus, this contract would be an optimal choice in this case. Wholesale contract, in turn, allocates too much profit to the manufacturer, which is very doubtful to be accepted by the dealers enjoying higher bargaining power. At the same time, revenue-sharing contract allows dealers to receive an exact share of total supply network revenue according to the negotiations. However, it this contract type is very sensitive to changes in external market conditions and, therefore, is applicable only for some specific situations.

11.4. Audi Group Case Study

This is a case study based on the data of the year 2010, which was obtained from the interview with a CEO of one of the Audi dealership centers in Saint-Petersburg, Sergey P. Ticholiz, on 16.04.2012. In addition to that, public company reports, as well as open-source data were used in order to obtain some data for the modeling purposes. Detailed information can be found in the research paper "Supply Chain Coordination with revenue-sharing contract: Audi dealers case" (M. Koroleva, 2012).

This is a case of a strong international manufacturer selling its goods through small, compared to manufacturer size, local dealers, who have to compete for the same local market with each other. In 2010, Audi's importing department, in terms of their own branded dealership network, included 46 points of sales in 35 cities across Russia, of which 9 were in Moscow and 3 in Saint-Petersburg.

Volkswagen Group Rus usually encloses 5-year long-term revenue-sharing contracts with its associated dealers. According to the contract terms, an official dealer of Audi, based on his own demand estimations, buys a specific amount of branded Audi cars Q_i from the importing company at a price w_i per car and then resells these cars to the market at a price p_i per unit. The difference between w and p is called dealer's percentage and, therefore $p_i = \phi_i w_i$. Moreover, if a dealer sells more than a certain amount of cars, he receives a bonus from the manufacturing company, which might be interpreted as having a quantity-based discount.

To evaluate the potential market size, Audi sales statistics of the year 2010 was used. Due to lacking information, it is impossible to estimate, how many cars exactly were ordered by dealers in 2010. Therefore, it is assumed that the number of sold cars equals to the number of ordered cars and salvage value therefore equals to zero. Thus, combined dealers' order quantity Q for the region of Saint-Petersburg in 2010 was equal to 1430 car units.

Concerning the actual retail prices, there is a lot of volatility in the car market due to a number of possible car grades, which can range from simple to luxurious. To overcome this problem, retail price p was assumed to be equal to the mathematical average between the lowest and the highest prices of a specific model.

Based on these data, potential market size θ for Audi cars in 2010 in Saint-Petersburg can be estimated as equal to 2 834 885 795 Rub. For the purposes of the current study, it is assumed that all dealers have equal market shares, as, according to the interview (Sergey Ticholiz, 2012), their competition is quite intense. An additional analysis, presenting different possible levels of market concentration will be presented later in this section.

Concerning market elasticity γ, as car buyers are very likely to switch between dealers in case of lower prices, γ is assumed to be equal to 0,7 in order to reflect the situation. At the same time, price sensitivity δ tends to be medium and equals to 1, as Audi cars fall into a category of luxury goods with less price-sensitive customer audience.

Following Sergey Ticholiz (2012), dealer's marginal costs c can be approximately estimated as being equal to 70 000 000 Rub, while operating expenses of Audi Russia (s_i) in 2010 were 474 000 000 euros (from Audi Group Annual Financial Statement). Euro exchange rate for 31.12.10 was equal to 40.3 Rub / Euro. Therefore, costs of Audi Russia to fulfill all the associated dealers' orders in 2010 were equal to 19 102 200 000 Rub, while the costs s_i to fulfil the order of one dealer in Saint-Petersburg can be estimated as 181 925 700 Rub.

As it was mentioned earlier, in terms of bargaining power, this is the case of having a strong manufacturer at one side and a number of small, competing dealers on the other side, which is reflected in contract parameters. According to Sergey Ticholiz (2012), in 2010 the distribution of profit between manufacturer and dealer was 90% manufacturer's share and 10% dealer's share (ϕ). At the same time, quantity based discount available (v) was 5% at maximum. As for F_1, F_2, after modelling the wholesale contract, their initial values were set equal to 150 000 Rub, as to redistribute the profit according to the situation of extremely strong manufacturer.

Table 11 below summarizes market conditions and contract parameters that would correspond to the described situation, with M standing for million Rubles.

Table 11: Initial data set for Audi case

θ	γ	δ_1	δ_2	k_1	k_2	c	s_1	s_2	ϕ_1	ϕ_2	v_1	v_2	F_1	F_2
2834M	0.7	1	1	0.5	0.5	70M	181M	181M	0.1	0.1	0.05	0.05	0.15M	0.15M

Main results for the profit allocation are summarized in Table 12. The results are presented in million Rubles.

Table 12: Profit function values summary for Audi case

	π_1^*	π_2^*	π_{s1}^*	π_{s2}^*	π_s^*	Π_1^*	Π_2^*	Π^*
Wholesale contract	199420	199420	139594	139594	279188	339015	339015	678030
Revenue-Sharing	31692	31692	285232	285232	570349	316924	316924	633722
Quantity-discount	310062	310062	12678	12678	25276	322700	322700	645401
Two-part tariff	494200	49420	289594	289594	579188	339015	339015	678030

As it can be clearly seen from the Table 12, Audi Russia has chosen revenue-sharing contract to be the one coordinating their supply network, as initially it returns the company, as a manufacturer, the highest profit in absolute terms. Nevertheless, wholesale and two-part tariff contract results show that there still exists room for supply network optimization in terms of increasing system-wide total profit. Moreover, with the application of a two-part-tariff contract, this profit can be reallocated according to the power distribution with the usage of corresponding tariff rate, which would result in higher total supply network profits, as well as higher profits for both dealers and Audi Group.

Let's now see how these contracts will be able to coordinate Audi's supply network relationships under changing market conditions. In case of changes in dealer's marginal costs c, in a range from 40M to 100M Rub., profit functions would look as follows (Fig. 7 – 9):

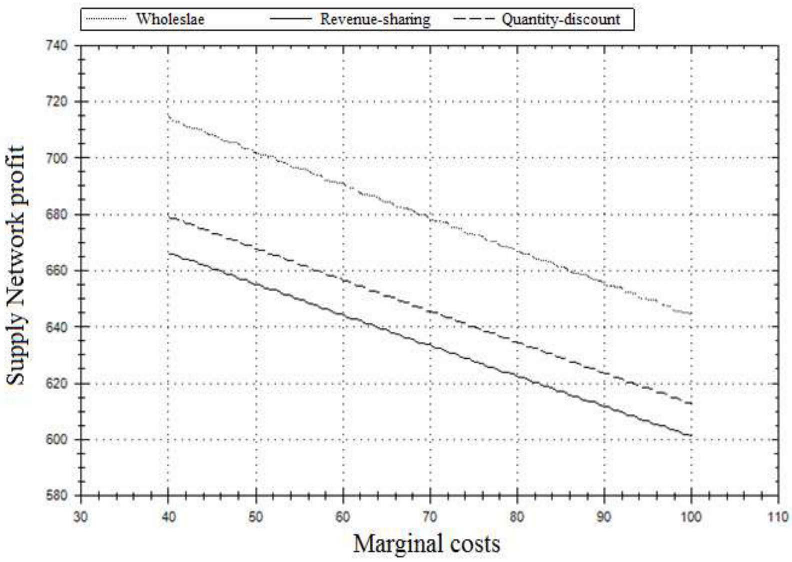

Fig. 7: Audi supply network profit function under volatility of marginal costs

The behavior of profit functions for Audi's supply network is similar to that of a numerical example for strong manufacturer and brings the same conclusions: the

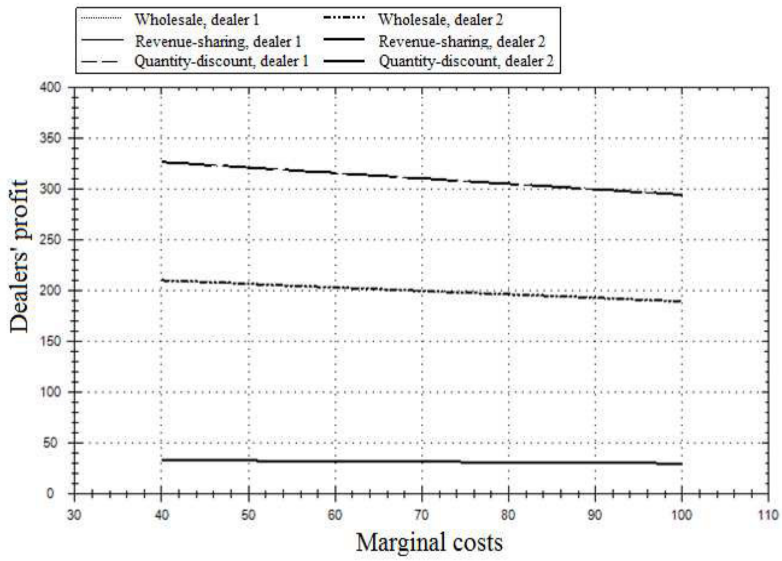

Fig. 8: Audi dealers' profit function under volatility of marginal costs

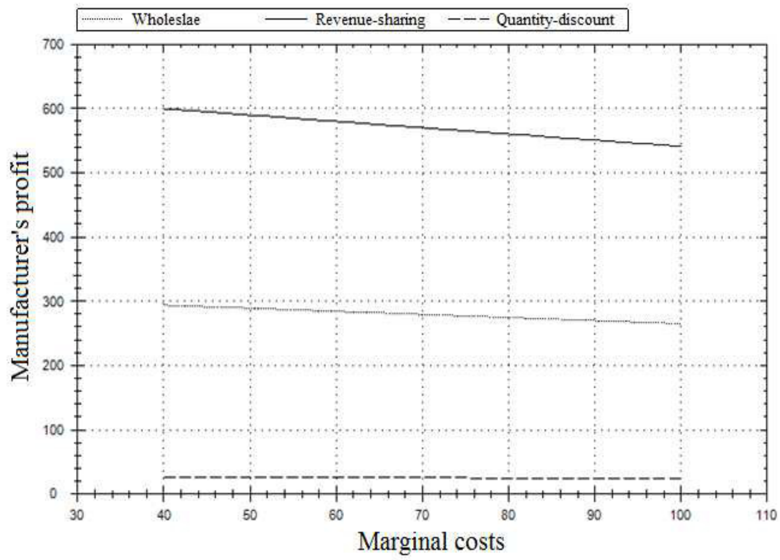

Fig. 9: Audi profit function under volatility of marginal costs

safest contracts for Audi would be wholesale and quantity-discount, as company's profit function is less sensitive to the dealer's costs escalation.

Consequently, the behavior of profit function in case of changes in Audi's operating expenses to fulfill the orders of their dealers, from 160M to 200M Rub, would be similar to that of a studied example as well (see Appendix 4, Fig. 77 - 79). With the increase in Audi Russia operating expenses for order fulfillment, total profit of the whole supply network is decreasing. Moreover, profit of the second dealer is growing proportionally to the decrease in first dealer's profits. All of the studied contracts share little sensitivity to negative effects of the changes in cost structure, thus, revenue-sharing and two-part tariff are the most suitable contracts for Audi Group in this case.

As for the influence of different market parameters, including market elasticity γ, ranging from 0.1 to 0.9, and price sensitivity δ_i, ranging from 0.3 to 2, the behavior of Audi supply network profit functions can be found in the Appendix 4 (Fig. 80 - 84). In general, main results are similar to those, attained for the numerical example.

Notably, γ was initially quite high in the Audi case, reflecting the situation of equally small dealers weakened by their intense competition. In a situation of growing market elasticity γ, wholesale or two-part tariff contracts would be the most suitable options for Audi Russia, as they save company's profits from constantly falling down, keeping the profit function within the corridor, as opposed to other contract types. Nevertheless, increase in price sensitivity δ leads to a heavy decrease of Audi's profit under wholesale and quantity-discount contracts. In this sense, revenue-sharing contract gives the best safety in a volatile market situation, as it has low sensitivity to changes in both δ_i and in γ.

Now the assumption of initially equal market shares k_1 and k_2 is to be tested. Market share of the first dealer would be increased from 0.3 to 0.8, while market share of the second would decrease from 0.7 to 0.2 accordingly. Consequently, the behavior of profit function would look as follows (Fig. 10 - 12):

As it was expected, with the increase of his market share, profit of an associated dealer is increasing as well, while its competitor's profit is falling proportionally. Another evident conclusion is that the more severe is the competition, the smaller is total Audi supply network profit, as under the rules of Bertrand competition both dealers have strong incentives to lower their prices in order to attract consumers. For Audi, in a situation of facing equally weak dealers, the most optimal decision would be to operate under two-part tariff contract, as it returns the highest profit. If concentration on the market would be eventually increasing, revenue-sharing contract becomes more favorable for the Audi Group.

All in all, this case study goes in line with the results attained in a numerical example earlier in this Chapter. According to the data available, for Audi Russia Group, the most optimal contract choice is two-part tariff contract, as it provides enough safety towards volatile market conditions, while optimizing the supply network economic performance in terms of returning the highest possible total profit, in addition allowing profit reallocation in favor of manufacturer. Revenue-sharing contract, which is currently used by company, is suitable for specific market conditions, such as growing price sensitivity of customers, which might be the case during the economic crisis or due to political environment.

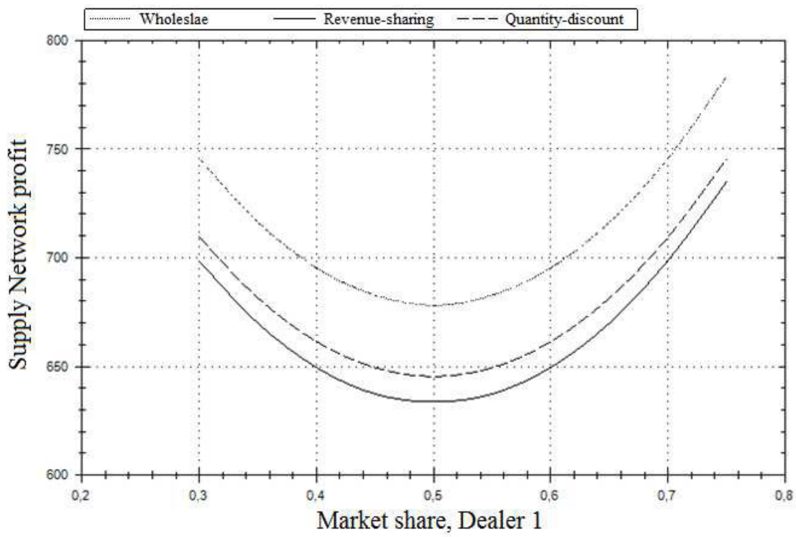

Fig. 10: Audi supply network profit function under changes in market concentration

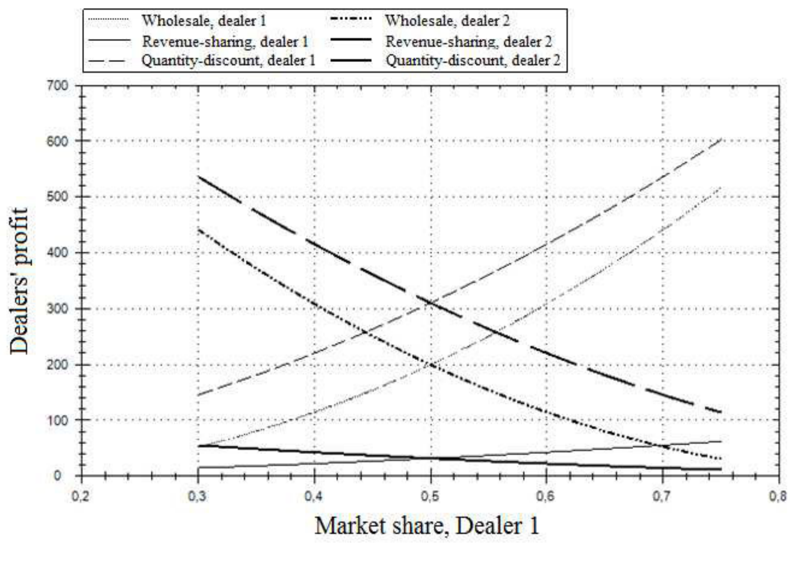

Fig. 11: Audi dealers' profit function under changes in market concentration

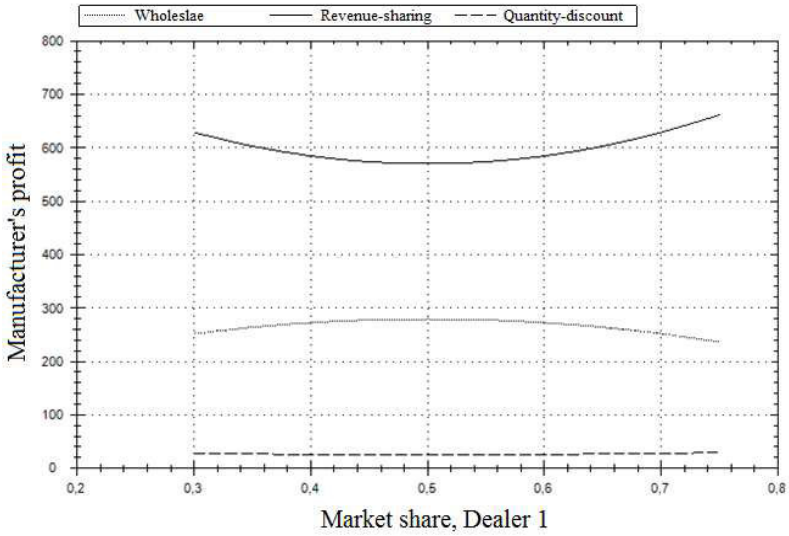

Fig. 12: Audi profit function under changes in market concentration

11.5. Heineken Case Study

Heineken case study is based on the data of the year 2015, which was obtained from the confidential interview with a middle manager responsible for procurement and logistics of the medium chain pub in Saint-Petersburg on 21.08.2015. In addition to that, company's contract offers and warehouse documentation were used in order to attain the necessary data.

This is a case of equal power parties, with a beer wholesaler selling products to separate pubs in the center of Saint-Petersburg. Concerning the dealers' side, restaurant and foodservice market in Saint-Petersburg is extremely competitive, with huge chain players dominating the market at one side and medium-to-small local companies altogether comprising the majority of the market (more than 50% market share) at another. According to Rosstat, the number of cafes, restaurants, and other food outlets in Russia currently stands at about 88,000 and almost 88 percent of outlets are independent non-chain cafes and restaurants.

As for the supplier side, big alcohol manufacturers, such as Heineken Group, have specific distribution requirements, which are more or less similar worldwide. In order to have direct relationships with Heineken Group any buying company should purchase and realize certain volumes of their product on a monthly or a weekly basis. If company cannot satisfy a minimum qualification level, it has to purchase Heineken products through wholesalers, who accumulate orders from numerous smaller companies. Being able to cumulate the required purchase volume, these wholesalers make purchases directly from the Heineken Group and redistribute down the supply system.

Therefore, in terms of bargaining power distribution, this is a case of a medium wholesale company reselling branded beer to two medium pubs, which reflects the situation of equal power participants.

Consequently, the two pubs chosen for analysis are situated next to each other in one street in the Saint-Petersburg city center. Both are buying certain amount of beer Q_i from the wholesaler at a price w_i per liter of product and then resell it in their point of sales at a price p_i per liter. It is assumed that they are serving the same sort of beer "Heineken" in exactly the same way, so that it is completely indistinguishable to consumers. Moreover, it is assumed that consumers make their buying decision based on the retail price, disregarding pubs' location (as they are situated next to each other), reputation, interior design, etc. Nevertheless, the consumers are characterized by a certain degree of loyalty to one of the pubs, as this is an important notion for the foodservice industry.

From the interview with a company manager (2015), a small-to-medium pub in the city center is able to sell up to 1000 liters of one specific well-known brand of beer per week. Therefore, as beer is an FMCG product, it is assumed that all beer ordered from the wholesaler is realized during the same week. Thus, total potential demand for Heineken sort of beer in that specific place of the city is equal to 2000 liters per week. Placing more efforts in promotion, first pub enjoys a slightly bigger market share $k_1 = 0.6$, compared to the rival's $k_2 = 0.4$. Therefore, order quantities are $Q_1 = 1200$, $Q_2 = 800$ liters of Heineken per week.

The retail price p of a Heineken beer is 180 Rub per 0,33 liters, which makes it 540 per liter in retail. This subsumes the potential market value θ to be equal to 1 080 000 Rub per week. At the same time bar's marginal costs c equal approximately 150 000 Rub. per week, while wholesaler costs to fulfill the order are 190 Rub. per liter of Heineken. Then, $s_1 = 228\ 000$ Rub. and $s_2 = 152\ 000$ Rub. per week.

Concerning market elasticity γ, consumers are not very likely to switch between small pubs in case of price decrease, as there is a significant percentage of loyal customers in the target audience. Therefore, γ is assumed to be equal to 0.3, reflecting considerably low market elasticity. On the other hand, price sensitivity δ tends to be medium, as the target audience seems to be not very price-sensitive to out-of-home FMCG products, and therefore equals to 1.

In terms of bargaining power, equal power distribution is reflected in contract parameters in a following manner. Thus, the distribution of profit between the wholesaler and the pubs is assumed to be 50% share of the wholesaler and 50% pub's share (ϕ). Similarly, quantity based discount (v) is 50% for the first pub and 40% for the second one. As for F_1, F_2, after modelling the wholesale contract, their initial values were set as 900 and 1000 Rub. accordingly, as to reallocate profit more evenly.

Table 13 below summarizes market conditions and contract parameters that would correspond to the described situation, with T standing for thousand rubles.

Table 13: Initial data set for Heineken case

θ	γ	δ_1	δ_2	k_1	k_2	c	s_1	s_2	ϕ_1	ϕ_2	v_1	v_2	F_1	F_2
1080T	0.3	1	1	0.6	0.5	150T	228T	152T	0.5	0.5	0.5	0.4	900	1000

Main results are summarized in Table 14, in thousand rubles.

As it can be clearly seen from the Table 14, supply network in terms of total profit will be optimized under the wholesale or two-part tariff contract. While the

Table 14: Profit function values summary for Heineken case

	π_1^*	π_2^*	π_{s1}^*	π_{s2}^*	π_s^*	Π_1^*	Π_2^*	Π^*
Wholesale contract	11789	4466	2439	2012	4452	14229	6497	20708
Revenue-Sharing	6956	3270	6956	3270	10227	13913	6541	20454
Quantity-discount	11180	5620	2412	1155	3567	13833	6776	20609
Two-part tariff	10889	3466	3339	3012	6352	14229	6497	20708

wholesale contract better suits the interests of the stronger pub, wholesaler would favor revenue-sharing contract. At the same time, relatively weaker pub would choose quantity-discount contracts. Most probably, this indicates that final decision on the contract type will be made based on specific market conditions or negotiation power, as the cases of completely even bargaining power distribution are extremely rare.

Nevertheless, from the results of modeling on a numerical example, it was conducted that quantity-discount and wholesale contracts unevenly distribute total supply network profit. Namely, these contracts allocate a bigger share of profit to the dealers. Therefore, the most balanced contract is two-part tariff, in case the tariff rates are chosen appropriately. In turn, revenue-sharing contract as well divides total supply network profit in a balanced way, according to predefined negotiated shares.

Let's examine how these contracts will be able to coordinate supply network relationships in foodservice industry under changing market conditions. The behavior of profit function in case of changes in pubs' marginal costs c from 100 to 200 thousand Rub. would look as follows (Fig. 13 - 15):

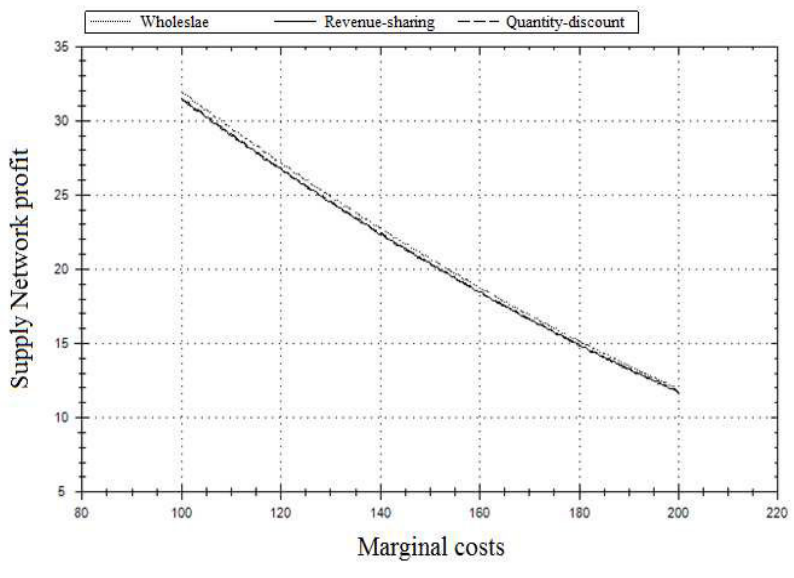

Fig. 13: Heineken supply network profit function under volatility of marginal costs

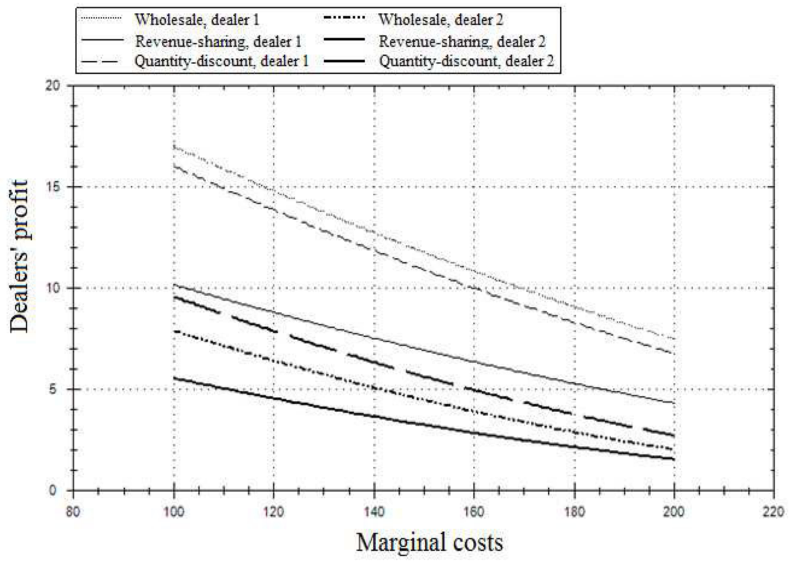

Fig. 14: Bar profit function under volatility of marginal costs

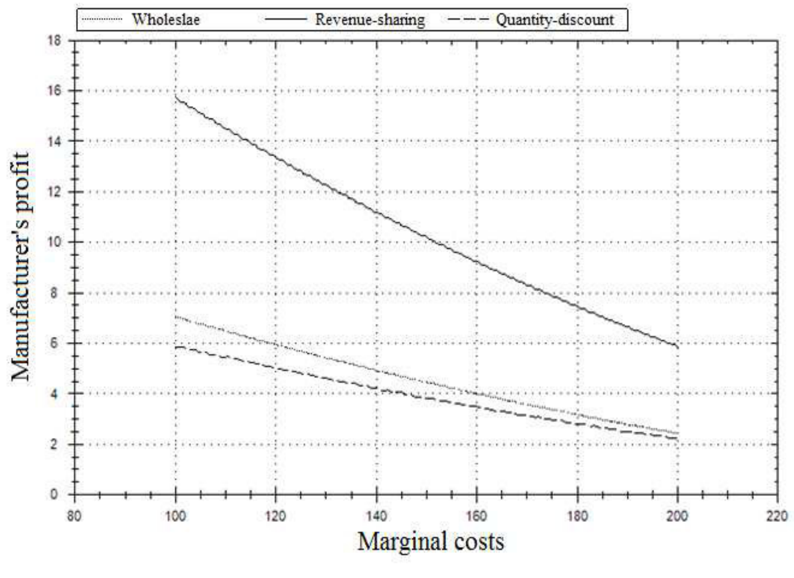

Fig. 15: Beer wholesaler profit function under volatility of marginal costs

The behavior of profit function in case of changes in the wholesaler's operating expenses to fulfill the orders of the pub with a higher market share, growing from 200 to 250 thousand Rubles, would be as follows (Fig. 85 - 87):

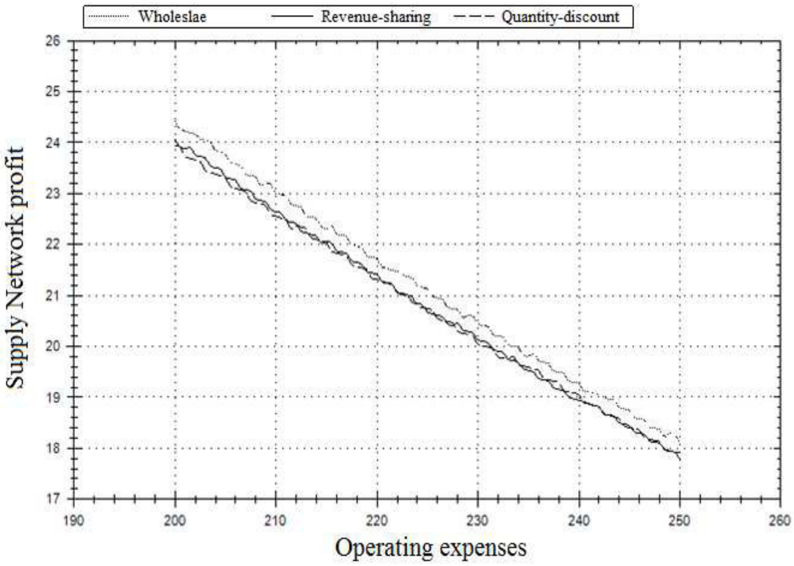

Fig. 16: Heineken supply network profit function under volatility of operating expenses

In line with the results obtained from a numerical example, from the pub's perspective, revenue-sharing contract shows the smallest sensitivity for costs escalation, while beer wholesaler would favor wholesale and quantity-discount contracts as providing more safety.

Graphs, showing the reaction of the profit function on changes in market elasticity and consumer price sensitivity δ can be found in the Appendix 5 (Fig. 88 – 90). Supply network profit proved to be the most stable in terms of profit towards changes in the market conditions under quantity-discount and wholesale contracts. Nevertheless, under the wholesale and two-part tariff contracts, profit dynamics for the beer wholesaler and pubs proved to be completely the opposite. Such a situation seems to be inacceptable in case of equally distributed bargaining power. Therefore, revenue-sharing contract is more reasonable, as the wholesaler's and pubs' profit functions follow the same tendencies.

The last set parameters that might influence the profit function is market concentration, reflected by pubs' market shares k_1 and k_2. Assume, that the market share of the first pub is increasing from 0.3 to 0.8, while market share of the second dealer is decreasing accordingly from 0.7 to 0.2. Thus, the behavior of profit function in case of changes in the market shares would be as follows (Fig. 19 - 21):

The observed dynamics again prove that the more severe is competition, the lower is total supply network profit, no matter what type of contract is applied. In other words, supply network profit increases proportionally with the increase in

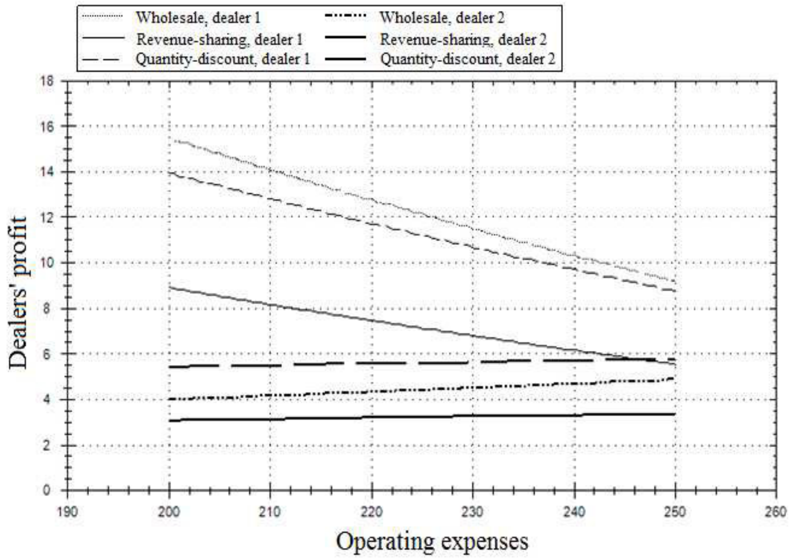

Fig. 17: Bar profit function under volatility of operating expenses

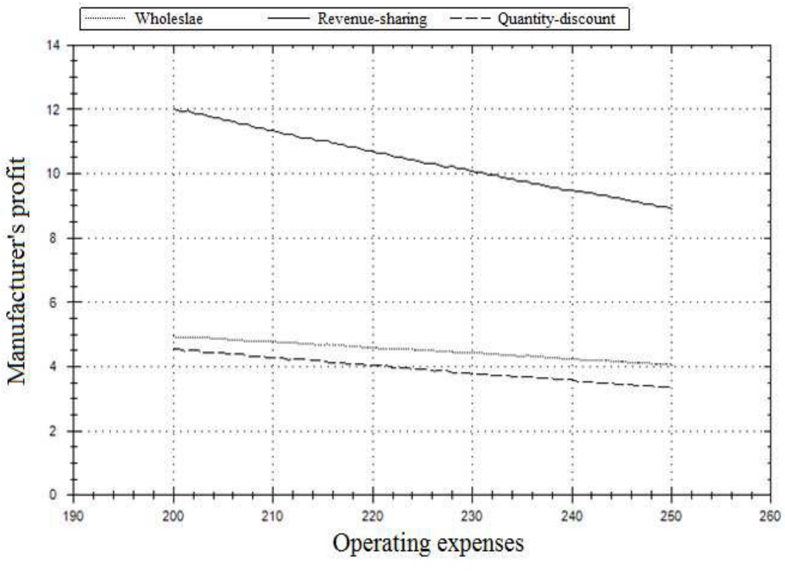

Fig. 18: Beer wholesaler profit function under volatility of operating expenses

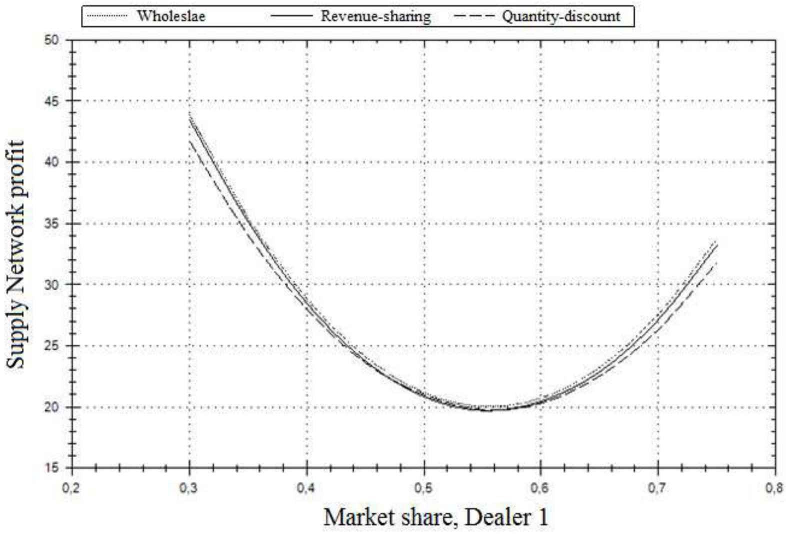

Fig. 19: Heineken supply network profit function under changes in market concentration

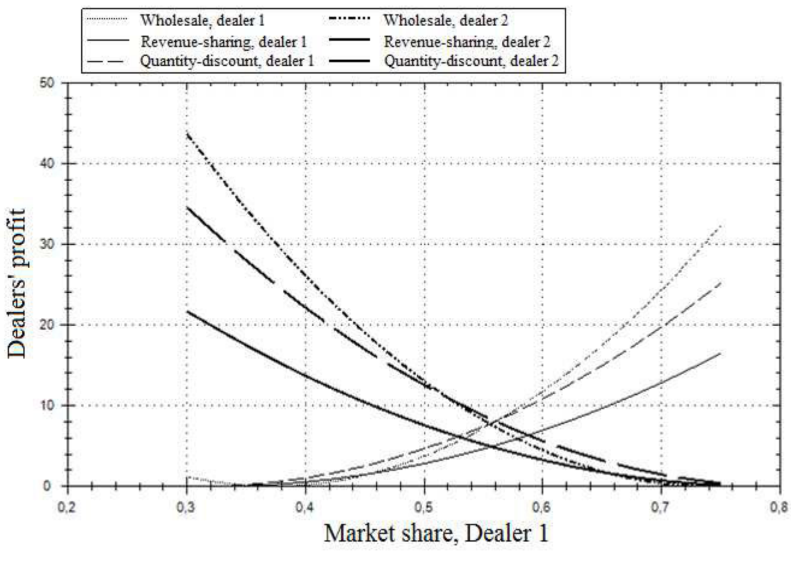

Fig. 20: Bar profit function under changes in market concentration

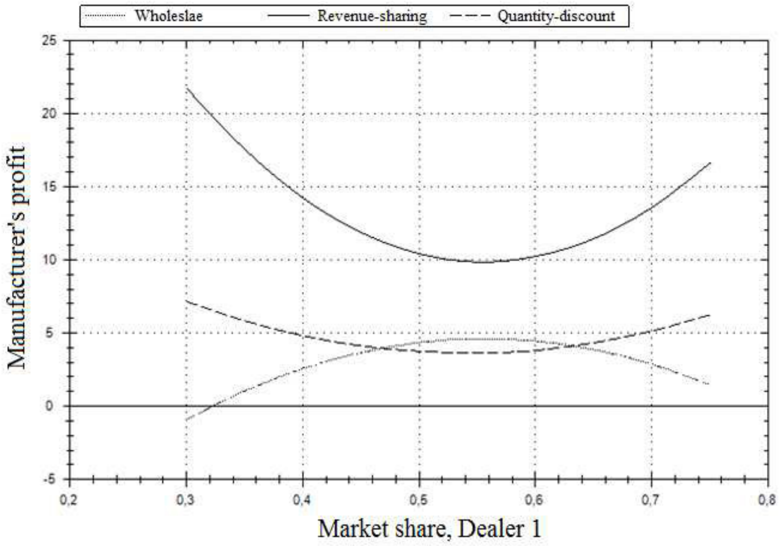

Fig. 21: Beer wholesaler profit function under changes in market concentration

market concentration. For the bars, revenue-sharing contract is the most stable in terms of profit allocation and revenue streams, while for the beer wholesaler optimal choice depends on the market concentration. Thus, in a situation of equally small and relatively weak bars, the optimal decision for the beer wholesaler would be to operate under a two-part tariff contract, however, in a situation when one bar has a sufficiently bigger market share, for the wholesaler revenue-sharing contract is more favorable.

As for the case of a Heineken beer wholesaler reselling products to different pubs of Saint-Petersburg, optimal choice is a revenue-sharing contract, as it allocates the supply network profit exactly according to the negotiated shares. In addition to that, revenue-sharing contract is less sensitive to volatile market conditions and preserves the same tendencies for both bars and the wholesaler, which should be taken into account assuming that parties have equal bargaining power. Bars should also favor revenue-sharing contract, as it provides them with the most stable revenue streams, ensuring a considerate protection in case of costs escalation.

11.6. ProtechDry Case Study

This is a case study based on the data of the year 2015, which was obtained from the interview with a senior manager of ProtechDry company on 11.03.2015 for Integrated Marketing Communications course in Nova SBE, Portugal. As an additional source of information, ProtechDry and Impetus Group reports and financial statements for the years 2014-2015 were studied. Detailed information can be found in the research paper "ProtechDry Integrated Marketing Communications" (M. Koloreva, N. Kowalczyk, T. S. Baena, F. M. de Mello, M. B. Moura Costa, 2015).

ProtechDry is a Portuguese brand that belongs to Impetus Group, specializing in the production of Cut and Sew and seamless products. ProtechDry is an innovative solution, developed in 2010 by the Impetus R and D department and launched in the Portuguese market as a separate entity. ProtechDry is ultra-absorbent, washable and anti-odor underwear that was specially designed for people with light incontinence and is supposed to replace the need of using pads.

As ProtechDry is legally separated from their parent company, they had to develop their own distribution network, not connected to the one used by Impetus Group. As a strategic decision, for the past few years, ProtechDry was sold alongside other incontinence products through grocery retail channels. Grocery retail in Portugal is heavily dominated by domestic players, with few international companies operating in the market. The two largest chain retailers are Sonae Modelo Continente and Jeronimo Martins, which together captured a substantial 36% share of the overall value sales in grocery retail in Portugal during 2014.

This is one of the perfect examples of unequal bargaining power distribution, when a small unknown brand faces huge retail chains, which completely dominate the market and therefore are able to set their own rules.

According to the ProtechDry manager (2015), big retail chains buy small quantities Q_i of ProtechDry underwear for placing it on shelves at a price w_i per package. Then retailers resell the product in the stores at a price p_i per package. As the brand is new to the market, retailers do not buy any sufficient quantities for storage, therefore, it is assumed that they sell everything they buy and salvage value equals to zero.

According to the company report, in 2014 ProtechDry has sold 12 000 packages of underwear, which is taken as combined retailers order quantity Q. Concerning the actual retail prices, there is an even price of 24.99 euros per package, which is set by the company and does not vary over different stores and retail chains. 23% of the price is due to Value Added Tax, the retailer margin is about 7 euros and the distribution costs account for 3.5 euros per unit ($c = 3.5 * Q$). The costs of materials and production compose 4 euros per unit of product ($s = 4 * Q$). The contribution margin of is around 5.9 euros.

For the purposes of the current study, potential market size θ equals in units to order quantity Q and, therefore, is estimated to be around 299 880 euros. Concerning market elasticity γ, consumers in Portugal are extremely likely to switch between retailers in case of lower prices offered by any competitor. Thus, γ is assumed to be equal to 0,8 to reflect this situation. At the same time, price sensitivity δ tends to be medium, as compared to its competitors ProtechDry is in a category of luxury goods, characterized by less price-sensitive consumer audience. Moreover, as this is a niche product serving very specific need of people with light urinary incontinence, which ensures that target customers are even less price sensitive, because the number of available solutions is very limited. Therefore, price sensitivity is set to be $\delta = 0{,}5$.

This is the case of supply network relationships between strong retail chains at one side and a small local brand on the other side, which is reflected in contract parameters. According to the data, received from the interview with the company manager (2015), the profit distribution between ProtechDry and retail chains in 2014 was as follows: 25% share of profit was allocated to ProtechDry and the remaining 75% was retailers' share (ϕ). At the same time, quantity based discount (v) is assumed to be 90%, as all the retail chains in Portugal apply heavy discount policies. As for tariff rates F_1, F_2, after modeling the wholesale contract, their initial values were set as 100 euros, although it seems to be very unlikely that a strong retail chain would pay any tariff to a small company.

As it was already stated above, the competition in grocery retail is very intense, which is reinforced by the fact that market is more or less equally shared between five to six retail giants. In this sense, it is assumed that dealers have equal market shares k_1 and k_2, while an additional analysis with different levels of market concentration will be presented later in this paragraph.

Table 14 below summarizes market conditions, and contract parameters that would correspond to the described situation, with t standing for thousand euros.

Table 15: Initial data set for ProtechDry case

θ	γ	δ_1	δ_2	k_1	k_2	c	s_1	s_2	ϕ_1	ϕ_2	v_1	v_2	F_1	F_2
300t	0.8	0.5	0.5	0.5	0.5	21t	24t	24t	0.75	0.75	0.9	0.9	100	100

Main results of possible profit allocations are summarized in Table 16, in thousand euros.

Table 16: Profit function values summary for ProtechDry case

	π_1^*	π_2^*	π_{s1}^*	π_{s2}^*	π_s^*	Π_1^*	Π_2^*	Π^*
Wholesale contract	3138	3138	5021	5021	10043	8160	8160	16320
Revenue-Sharing	4967	4967	1655	1655	3311	6622	6622	13245
Quantity-discount	5861	5861	2142	2142	4284	8004	8004	16008
Two-part tariff	3038	3038	5121	5121	10243	8160	8160	16320

As it can be derived from the Table 16, ProtechDry's supply network would be optimized under the wholesale or two-part tariff contracts, in terms of total profit. Nevertheless, it is quite obvious that those types of contracts allocate far too big share of profit in favor of a manufacturer, which is a small weak brand in this case. Retail giants, such as Continente and Jeronimo Martins, being able to dictate their own terms, would never accept such conditions. Therefore, most probably, a quantity-discount contract will be chosen for supply network optimization, as it shows much better results than revenue-sharing contract.

The behavior of the profit functions of the supply network, ProtechDry and the retail chains in case of changing retailers' marginal costs c and manufacturer's operating expenses s_i is presented in the Appendix 6 (Fig. 91 - 96). All types of studied contracts show little sensitivity for costs escalation, while an interesting observation is that due to the low consumers' price-sensitivity δ and high market elasticity γ, showing that many customers can be attracted by price reduction, profit decreases less intensively in a situation of increasing costs.

As for the influence of changes in price sensitivity δ_i, within the range from 0.3 to 2, the behavior of profit function would look as follows (Fig. 22–24):

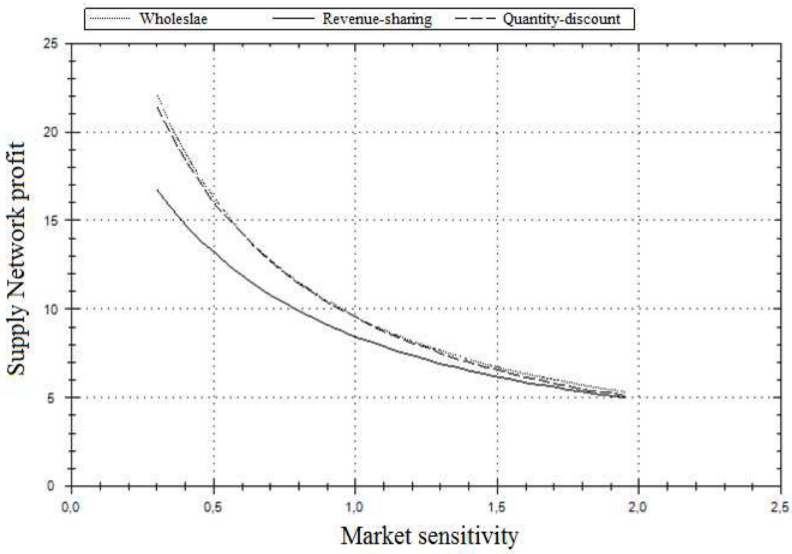

Fig. 22: ProtechDry supply network profit function under changes in price sensitivity

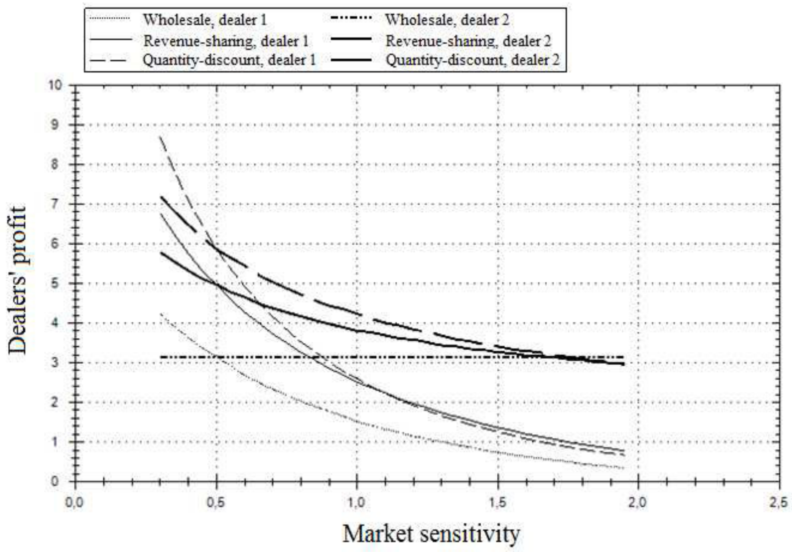

Fig. 23: ProtechDry dealers' profit function under changes in price sensitivity

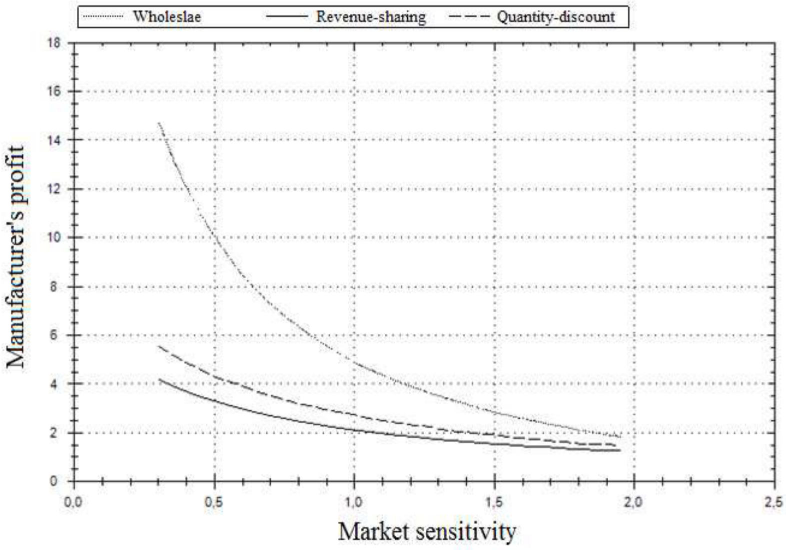

Fig. 24: ProtechDry profit function under changes in price sensitivity

ProtechDry, retail chains' and supply network aggregated profit functions in a situation of changing market elasticity γ, ranging from 0.1 to 0.9, would look as follows (Fig. 25–27):

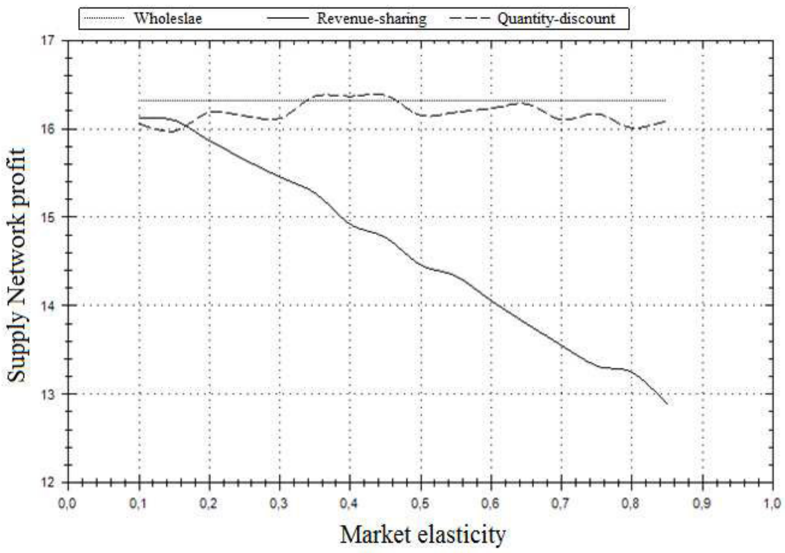

Fig. 25: ProtechDry supply network profit function under changes in market elasticity

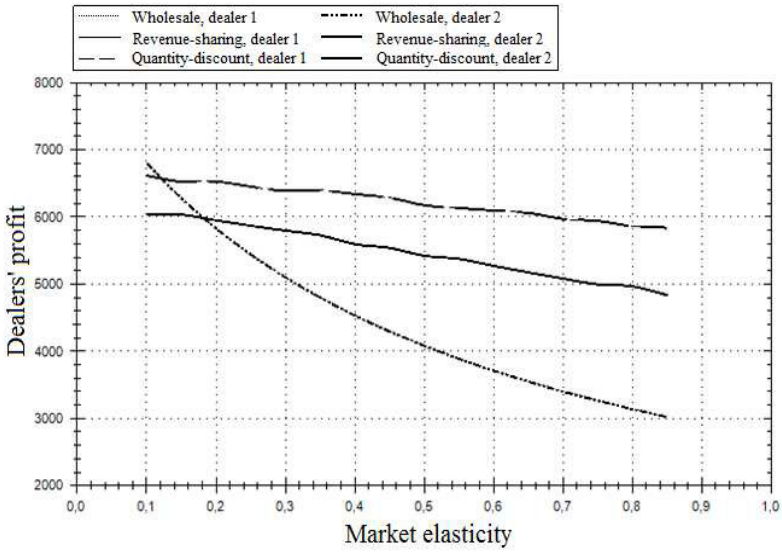

Fig. 26: ProtechDry dealers' profit function under changes in market elasticity

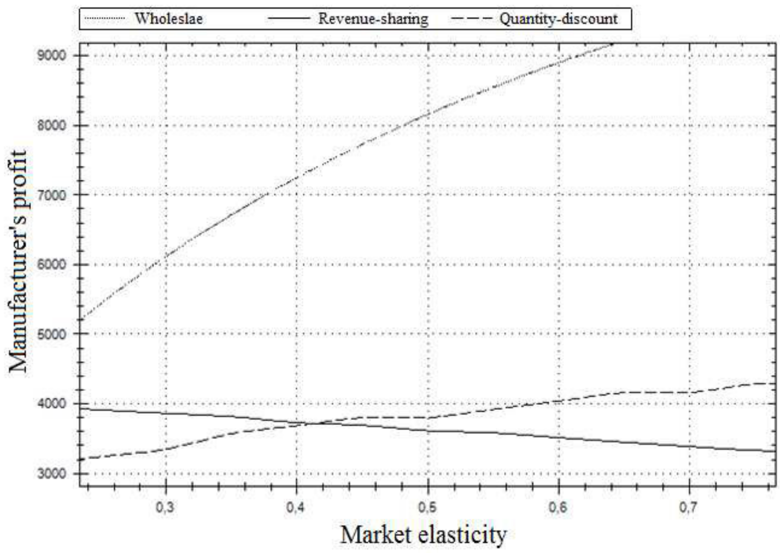

Fig. 27: ProtechDry profit function under changes in market elasticity

Conclusions that can be derived from the Figures 25 - 27, follow the ones made earlier in this paragraph. With increase in market elasticity γ, revenue-sharing and quantity-discount contracts react less intensively than wholesale and two-part tariff contracts, which would attract cautious retailers. At the same time, quantity-discount contract provides some growth in total supply network profit due to slight increase in ProtechDry's profit. Thus, if a retailer runs a risk of losing a part of its market share, optimal choice would be application of a quantity-discount contract, while if a retailer is expecting some growth, revenue-sharing contract would enforce a steeper profit growth. For ProtechDry quantity-discount contract would serve better in highly elastic market.

Considering the possible changes in retailers' market shares k_1 and k_2, from 0.3 to 0.8 for the first retail chain and from 0.7 to 0.2 for the second accordingly, the behavior of profit function would look as follows (Fig. 28 - 30):

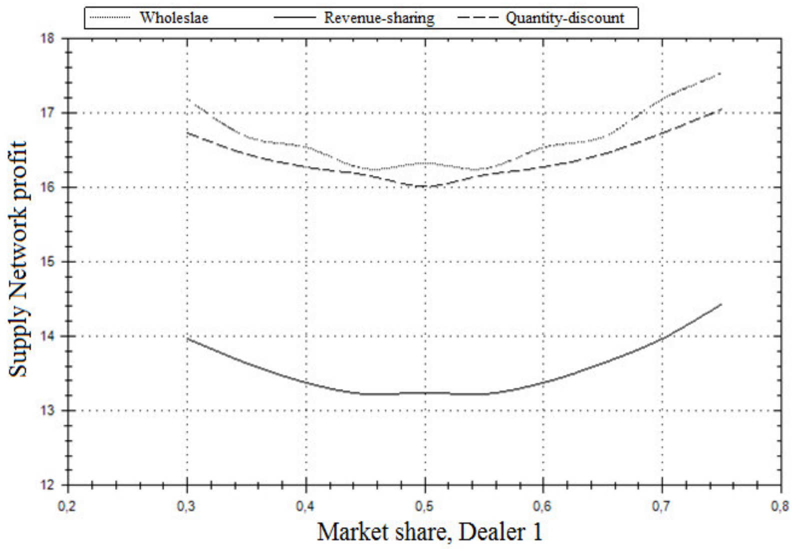

Fig. 28: ProtechDry supply network profit function under changes in market concentration

Following all the other studied cases and examples, with an increase in a market share, profit of the associated retailer is increasing as well, while its competitor's profit is decreasing. Moreover, the more severe is the competition the smaller is total ProtechDry supply network profit. In any case, quantity-discount contract tends to allocate supply network profit in favor of dealers, no matter what costs and discounts were chosen during the negotiation process. This type of contract has some characteristics, which might be useful in a situation of powerful retail chains, especially when they are operating in a highly competitive market, like Portuguese.

Thus, quantity-discount contract would be an optimal choice for powerful retail chains in case of ProtechDry. Wholesale contract allocates too much profit to manufacturer, which is very doubtful to be accepted. At the same time, as opposed to the numerical example, revenue-sharing contract has shown the worst performance in a situation of strong retailers in terms of both total supply network profit and stability towards changing market conditions.

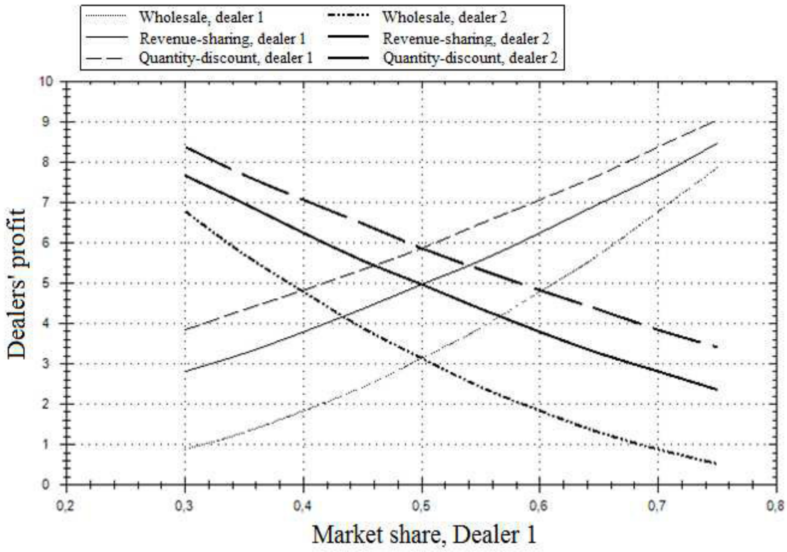

Fig. 29: ProtechDry dealers' profit function under changes in market concentration

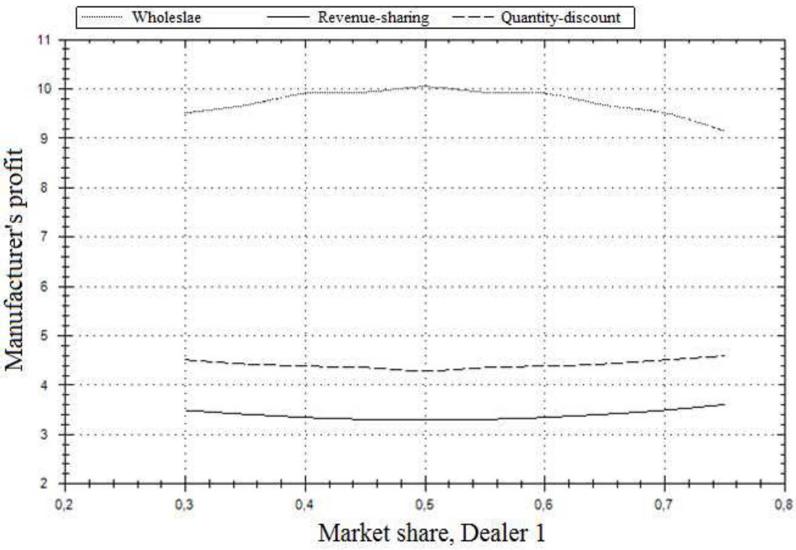

Fig. 30: ProtechDry profit function under changes in market concentration

Most probably, ProtechDry would not have a possibility to affect the choice of the contract type due to extremely low bargaining power. However, despite the fact of returning the lowest profits for the company in absolute terms, quantity-discount contract shows good performance in highly elastic market, providing ProtechDry with opportunities for faster growth.

12. Conclusion

This is the final section, which aims to give an overview of the conducted research and formulate the main conclusions. Hence, discussion concerns in turn main results of the study, limitations to those results and managerial implications.

The objective of the article was methodology improvement of contract selection in cooperative supply networks for achieving higher supply network economic performance, where economic performance stands for total supply network profit. Supply network management is a new line of research within a broader field of supply chain management. Therefore, as a starting point of contract decision-making methodology improvement, the conceptual understanding of supply network phenomena was extended. In general, supply network can be described as a system comprised of individual supply chains, united by an integrated flow of products, services, finances and (or) information, provided that at least two of its members are direct competitors. As a result of defining supply network conceptual framework, the standard newsvendor setting was improved and adapted in order to reflect the situation of competing retailers (dealers).

Nevertheless, in light of adding a new factor of competition, the problem of supply network optimization through coordination could be solved only partially, as the existing methodologies only allow achieving coordination of distinct supply chain pairs (manufacturer-dealer) separately. This suggests that there exists some space for methodology improvement.

The stated objective was successfully achieved by the application of a new supply network setting to the supply chain cooperative game, which was solved regarding the new initial input in the form of competing retailers. Thus, the methodology of contract selection in a supply chain or a set of supply chains was widened by devising a mechanism that allows not only coordination of distinct simple supply chains but also coordination at a system-wide level in the context of competing retailers (dealers). In addition to that, the improved methodology embraces the notion of bargaining power and enables building different scenarios based on the estimation of the negotiation power disposed by the supply network members.

Based on the game-theoretical and mathematical modeling, resulting in the improved methodology, a quantitative software tool was developed aimed at facilitation of methodology application. With the help of this tool, the improved methodology was tested on the real-life cases, matching three main alternatives of bargaining power allocation: strong manufacturer, strong retailers (dealers) and equal power participants. All three cases showed potential for supply network economic performance improvement, in terms of increasing total profit of the system itself, as well as individual profits of each supply network member, which can be achieved through methodology application as a means for coordinating contract selection.

The main results of the study can be summarized as follows:

1. The standard newsvendor model was improved and adapted in order to reflect the situation of competing retailers (dealers), referring to the supply network concept;
2. The methodology of coordination contracts decision-making was improved by devising a mechanism for contract selection for the case of multi-echelon supply network with two competing dealers enabling coordination at a system-wide level;
3. Economic performance improvement potential of developed contract decision-making methodology was empirically proved by testing it on the real-life cases of Audi Russia, Heineken Saint-Petersburg and ProtechDry Portugal;
4. For each case a set of recommendations on contract selection for optimizing system-wide performance was formulated, giving attention to the bargaining power and, therefore, decision priority of all members.

Nevertheless, these findings have some important limitations that are not to be neglected, as they are primarily related to the applicability of the developed methodology in different circumstances.

First of all comes the group of the limitations originating from the newsvendor setting, a supply chain model widely used for studying coordinating contracts. Supply network model developed in the present master thesis was designed as an improved and widened newsvendor model, assuming that retailers compete with each other. Therefore, application of the studied model is limited to one product and one period. This means that if a company sells a range of different products down the supply chain, the improved methodology of contact selection would be able to find optimal solutions for each product separately as if those were separate supply networks with no possibility of interconnections, combinations, cross discounts, mutual contracts, etc. The same is true for the time horizon.

In addition to that, another limitation originating from the newsvendor setting is assumption of perfect information throughout the supply network. Hence, it is not clear, whether the model can be successfully applied in case of incomplete information or in case of the opportunistic behavior, when participants are trying to use their access to private information as a way to receive an advantage.

Moreover, the developed model does not cover the situation of products from competing companies (manufacturers) being distributed through the same retailers. Influence of these products should be studied more thoroughly in order to derive any conclusions on the possible effects concerning the methodology of contract decision-making.

Second set of limitations is related to the rules of market competition applied in the model. For the purposes of the current study it was assumed that retailers set their prices following the rules of Bertrand competition, which limits model application to the markets to a greater extent satisfying these conditions. As a direction for future research, studied methodology can be improved further by application of Cournot competition rules. In addition to that, directly linked to Bertrand competition rules used in the model, come limitations of specific contract types. As due to these rules, the methodology considers only coordinating contracts belonging to a group of price-dependent contracts. Therefore, it would be interesting to study also those contracts related to quantity-dependent group.

However, present research paper derives important theoretical and practical implications.

From the theoretical perspective, this paper develops the research related to the supply network conceptual framework, originated from Bryant (1980) and then developed by Deneckere, Marvel and Peck (1997). Most directly related to the current research are papers of Birge et al. (1998) Carr et al. (1999) and van Mieghem and Dada (1999), who consider the special case of the supply network model with two competing retailers.

Research originality of the paper is granted by an applied procedure that fills in the research gap in papers devoted to development of specific contract selection mechanisms, which are applicable in real life situations. The particular novelty of the research lies in in the improved methodology of contract selection, which is able to achieve a system-wide coordination under the conditions of competing retailers (dealers). Thus, the paper widens the field of supply chain coordination, however, upscaling it to coordination of supply systems, as a broader scope of relationships between companies.

Theoretical implications of the research therefore include extended concept of supply network phenomena and an improved methodology of contract decision-making for a specific case of competing retailers, which was tested and proved to be applicable to the real-life situations. The studied methodology opens a broad area for future research, as it might be improved further in a range of different courses, such as including additional coordinating contracts, applying different competition rules, extending the time horizon or product range, etc.

In the array of managerial implications the most important result is an improved methodology of contract selection and a quantitative software tool, that enable companies to choose a specific contract type in order to maximize supply network economic performance as well as to distribute total profit in a specific desired way. The improved methodology by the means of a software tool was tested on real-life cases and proved to give corresponding results, as well as demonstrated a significant economic performance improvement potential.

Resulting from the case study analysis, which was encompassed by bargaining power distribution between the supply network members, it was noted that the more power is concentrated in the hands of one supply network member and the more he is able, in terms of negotiating abilities, financial resources and personal involvement, to integrate the entire system in pursuing his own goals, the more efficient this supply network becomes from the perspective of total profit. This observation underlines the idea of importance of coordination mechanisms application as a means to improve supply chain efficiency and sustain company's competitiveness in the modern market economy.

Acknowlegments The authors are grateful to N. A. Zenkevich for research guidance and useful discussions on the subjects.

Appendix

1. First Appendix

The behavior of profit function in case of changes in marginal costs c from 7 to 15 would look as follows (Figures 31–33):

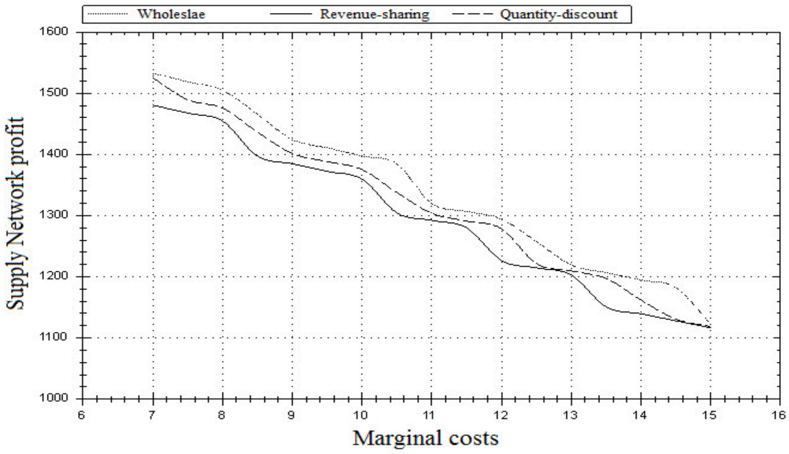

Fig. 31: Supply network profit function under volatility of marginal costs

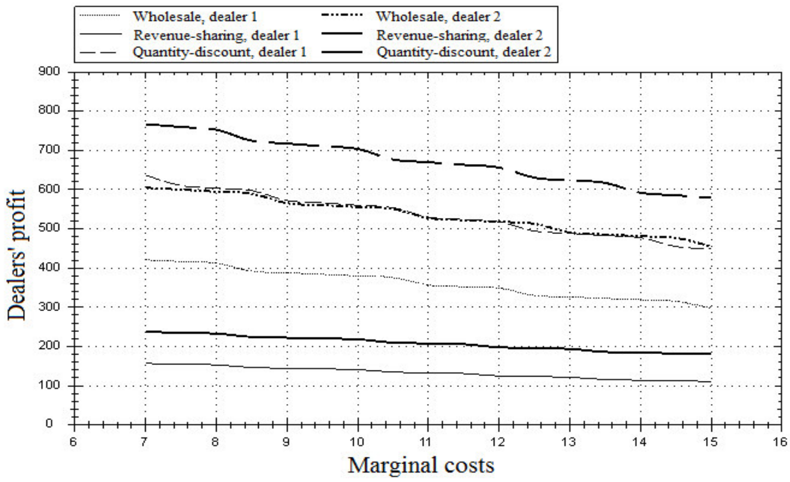

Fig. 32: Dealers' profit function under volatility of marginal costs

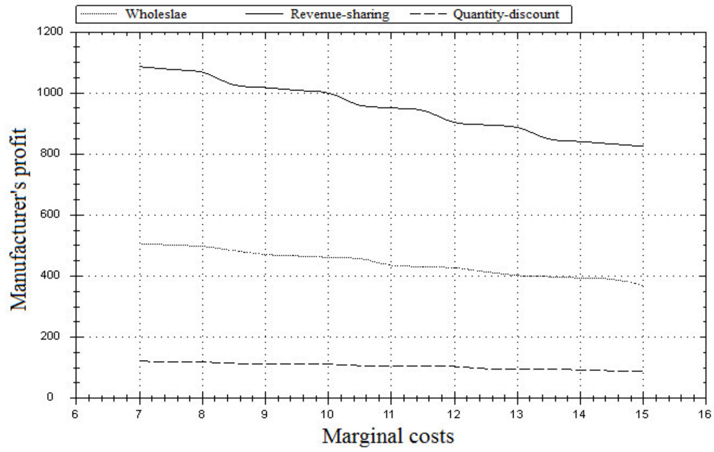

Fig. 33: Manufacturer profit function under volatility of marginal costs

The behavior of profit function in case of changes in manufacturer's operating expenses to fulfill the orders of, say, dealer 1, s_1 from 30 to 40 per unit of good would be as follows (Figures 34–36):

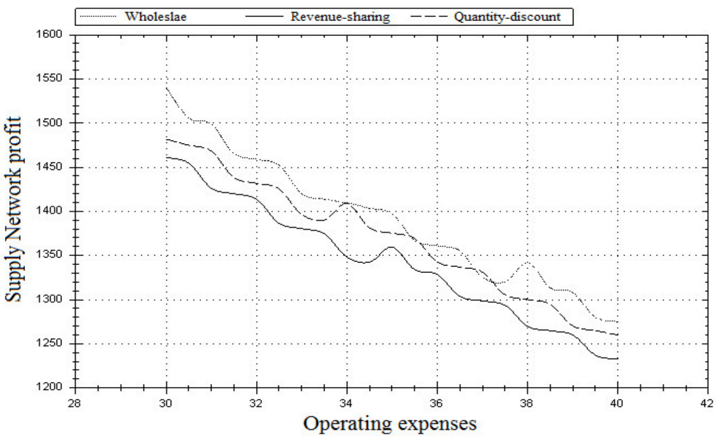

Fig. 34: Supply network profit function under volatility of operating expenses

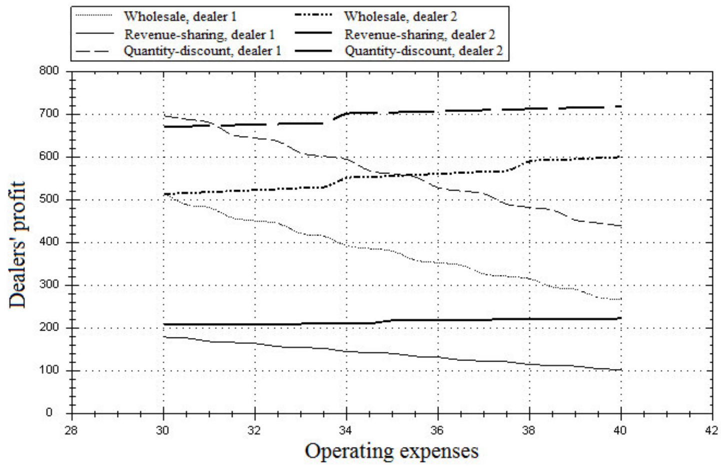

Fig. 35: Dealers' profit function under volatility of operating expenses

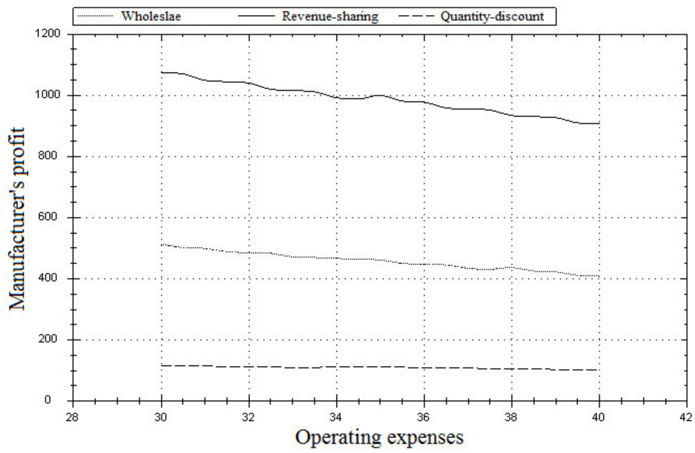

Fig. 36: Manufacturer profit function under volatility of operating expenses

The behavior of profit function in case of changes in market elasticity γ from 0.1 to 0.9 would look as follows (Figures 37–39):

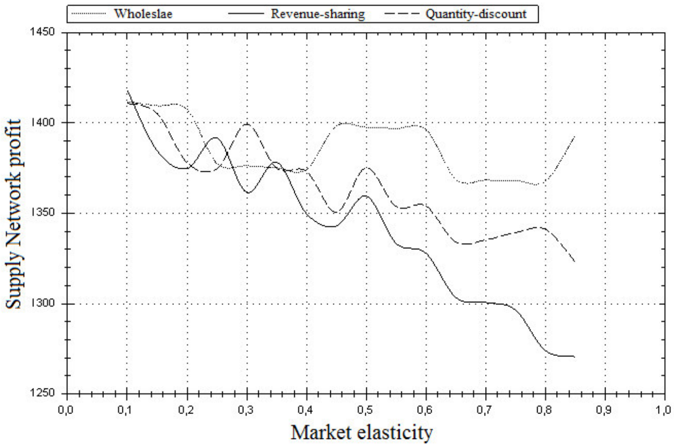

Fig. 37: Supply network profit function under changes in market elasticity

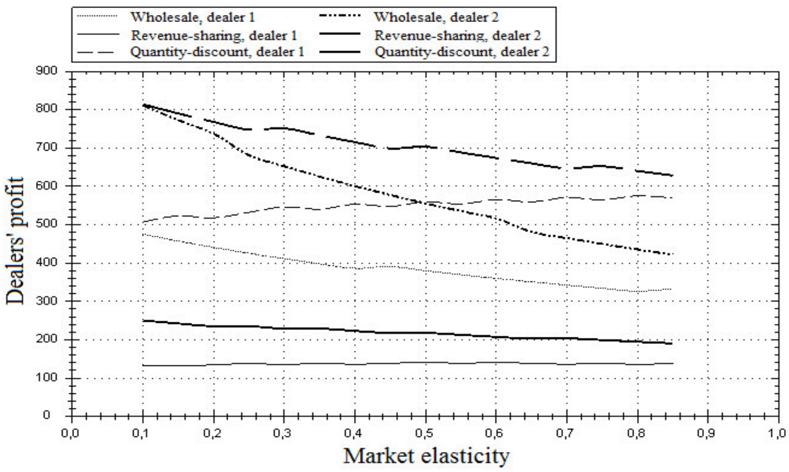

Fig. 38: Dealers' profit function under changes in market elasticity

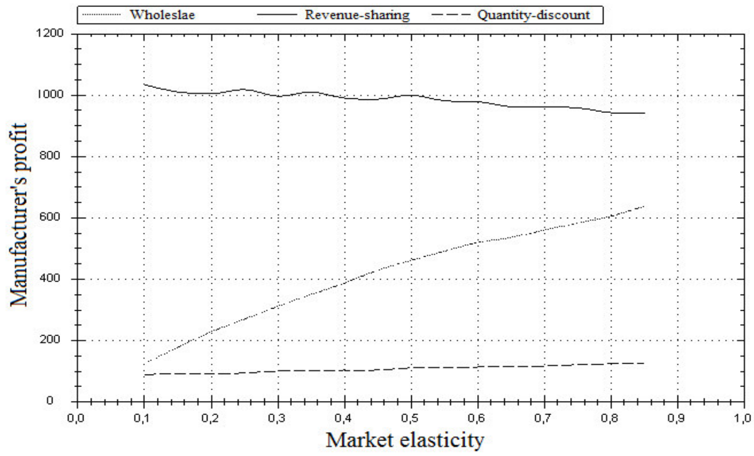

Fig. 39: Manufacturer profit function under changes in market elasticity

The behavior of profit function in case of changes in price sensitivity for dealer 1 products k_1 from 0.3 to 2 would look as follows (Figures 40–42):

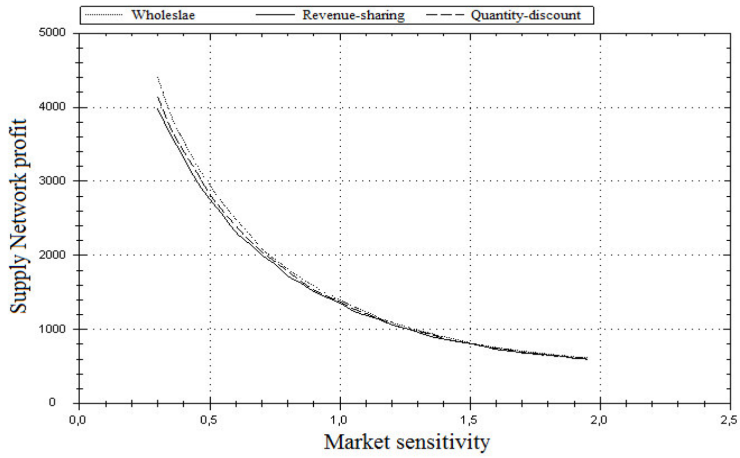

Fig. 40: Supply network profit function under changes in price sensitivity

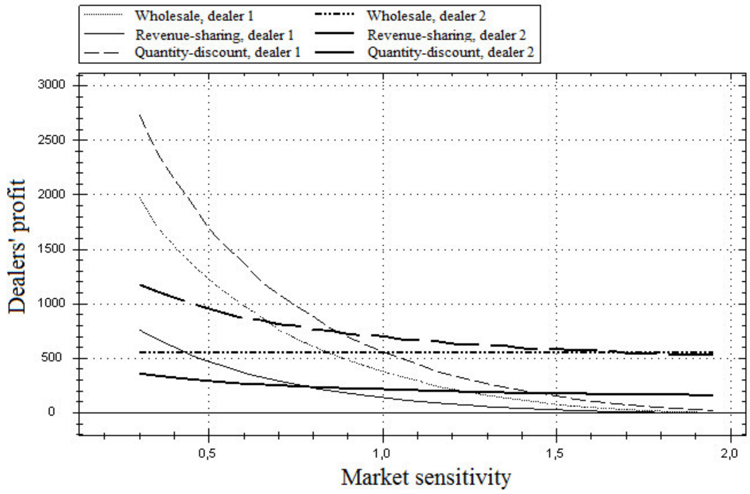

Fig. 41: Dealers' profit function under changes in price sensitivity

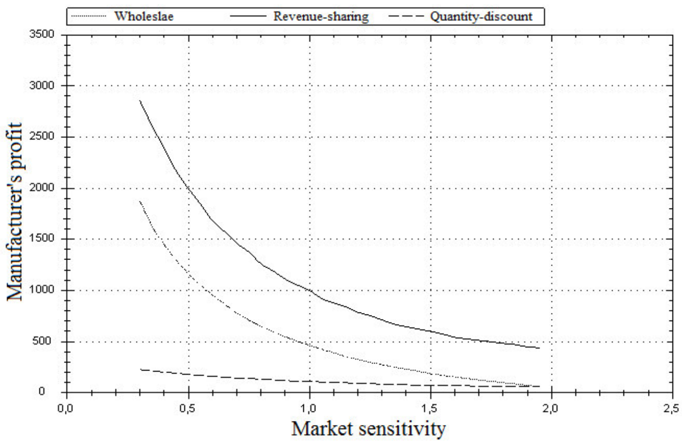

Fig. 42: Manufacturer profit function under changes in price sensitivity

The behavior of profit function in case of changes in dealers' market shares would be as follows (Figures 43–45):

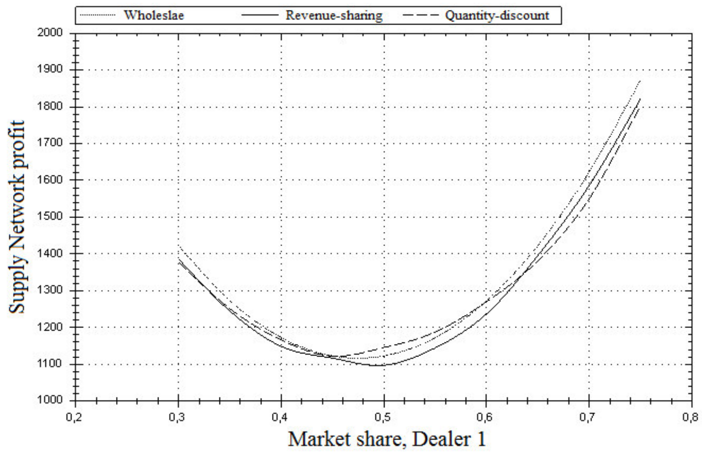

Fig. 43: Supply network profit function under changes in market concentration

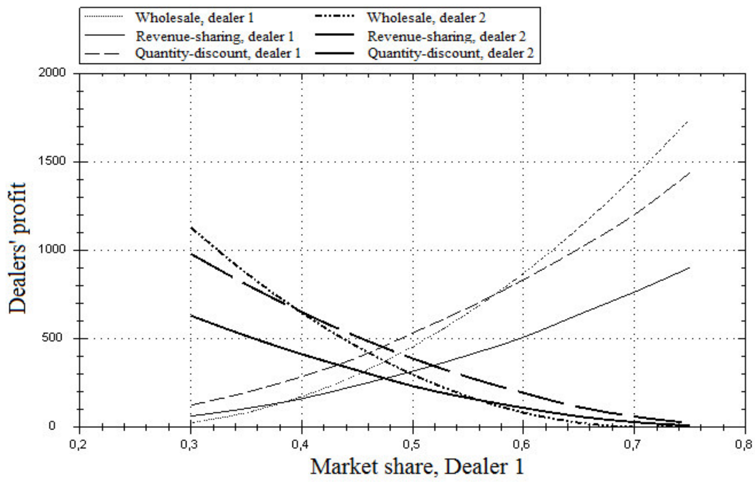

Fig. 44: Dealers' profit function under changes in market concentration

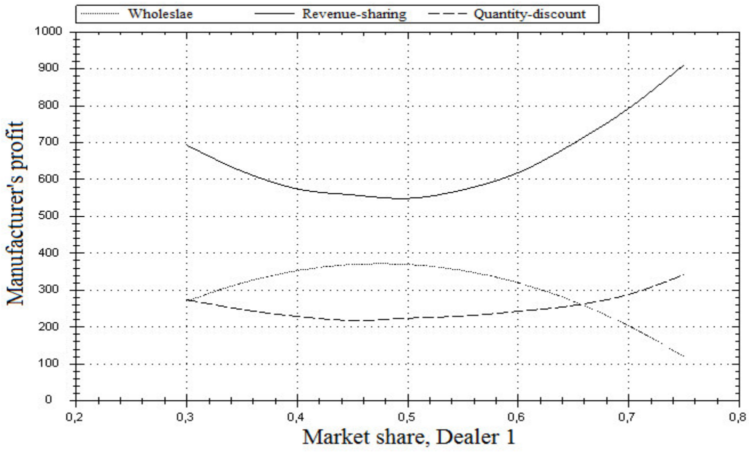

Fig. 45: Manufacturer profit function under changes in market concentration

2. Second Appendix

The behavior of profit function in case of changes in marginal costs c from 10 to 20 would look as follows (Figures 46–48):

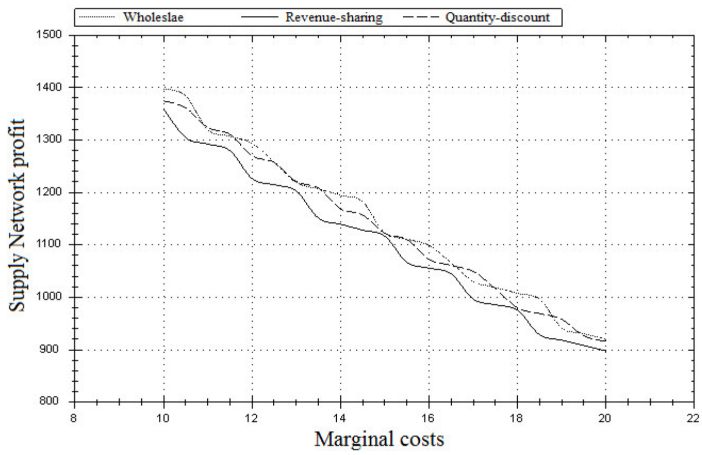

Fig. 46: Supply network profit function under volatility of marginal costs

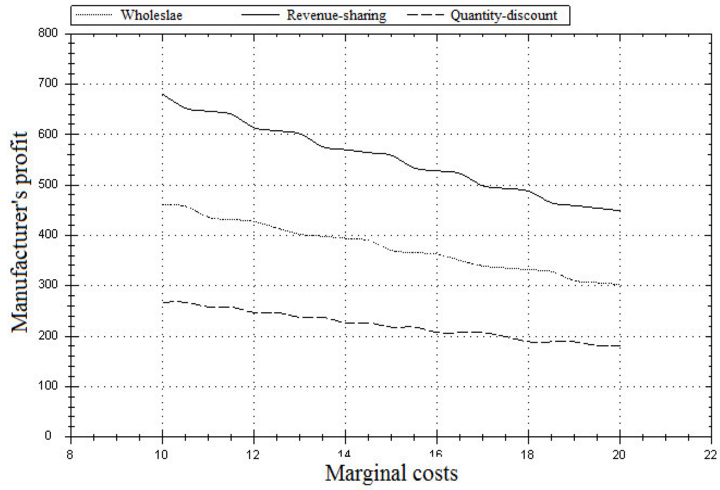

Fig. 47: Dealers' profit function under volatility of marginal costs

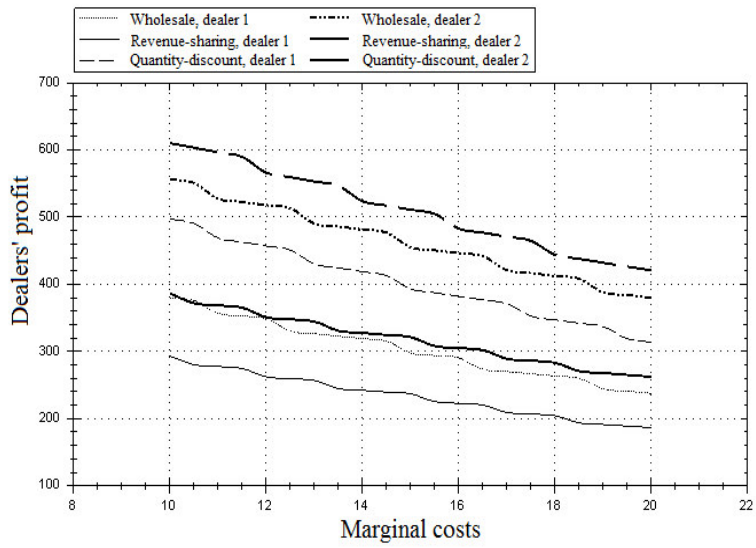

Fig. 48: Manufacturer profit function under volatility of marginal costs

The behavior of profit function in case of changes in operating expenses to fulfill the orders of dealer 1 (s_1) from 30 to 40 per unit of good would be as follows (Figures 49–51):

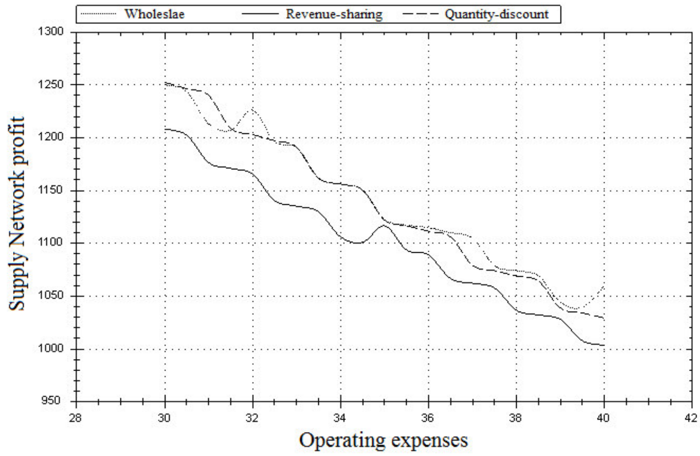

Fig. 49: Supply network profit function under volatility of operating expenses

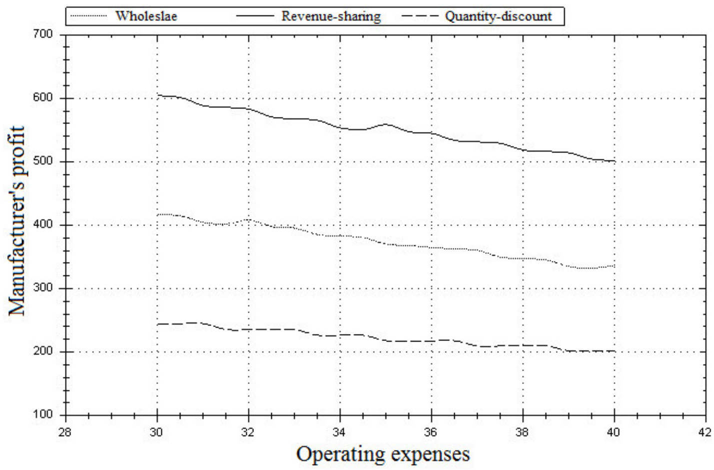

Fig. 50: Dealers' profit function under volatility of operating expenses

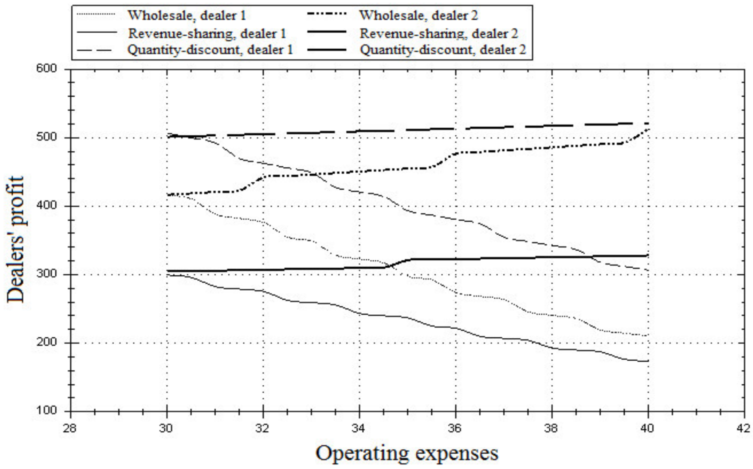

Fig. 51: Manufacturer profit function under volatility of operating expenses

The behavior of profit function in case of changes in market elasticity γ from 0.1 to 0.9 would look as follows (Figures 52–54):

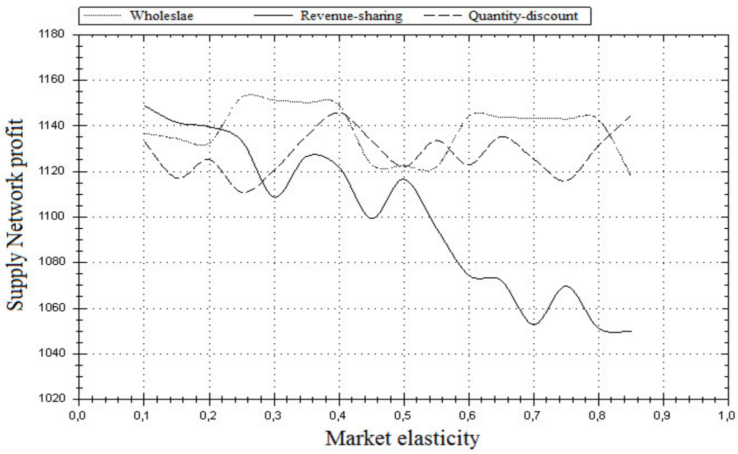

Fig. 52: Supply network profit function under changes in market elasticity

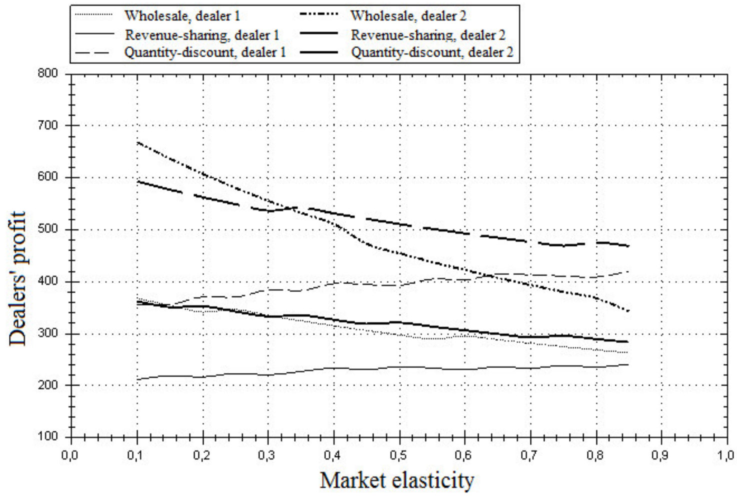

Fig. 53: Dealers' profit function under changes in market elasticity

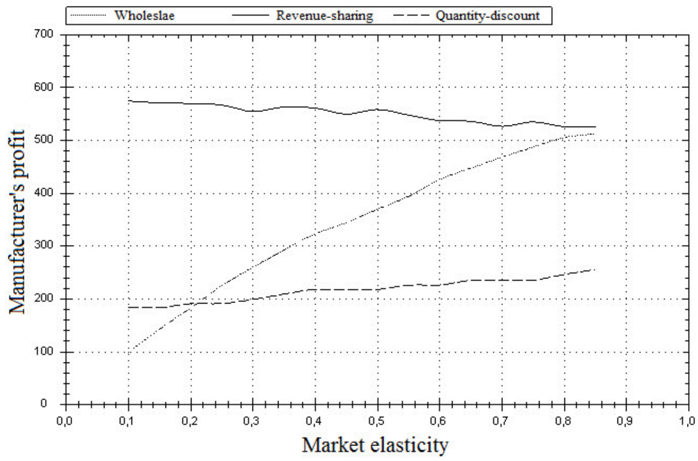

Fig. 54: Manufacturer profit function under changes in market elasticity

The behavior of profit function in case of changes in price sensitivity for dealer 1 δ_1 from 0.3 to 2 would look as follows (Figures 55–57):

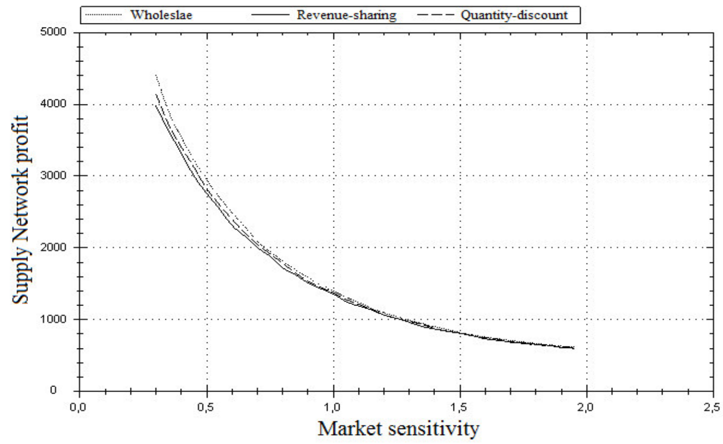

Fig. 55: Supply network profit function under changes in price sensitivity

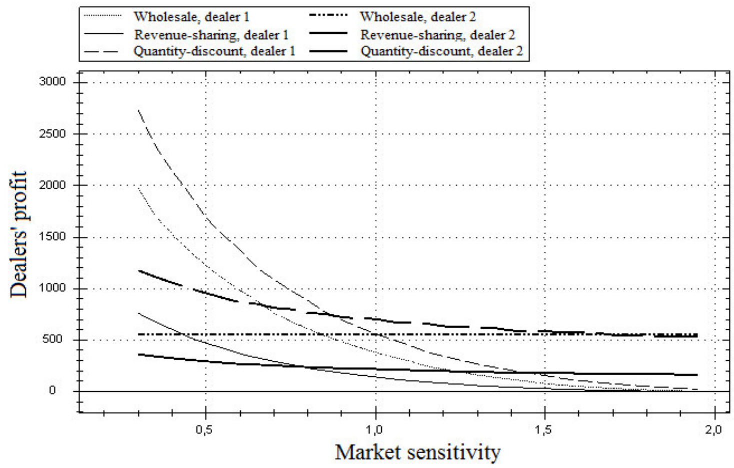

Fig. 56: Dealers' profit function under changes in market elasticity

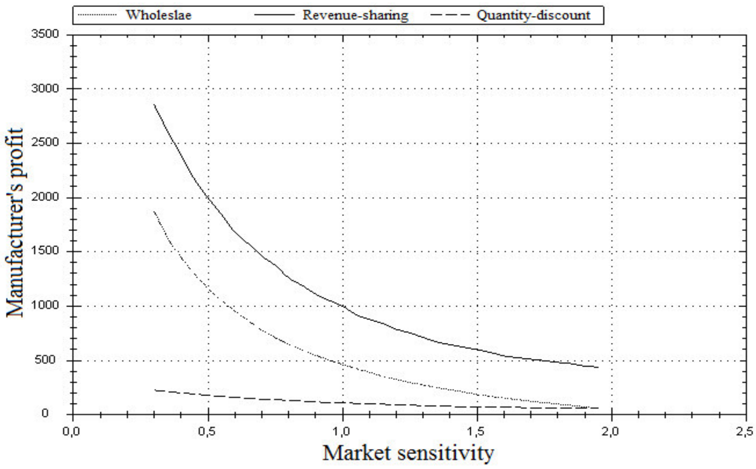

Fig. 57: Manufacturer profit function under changes in market elasticity

The behavior of profit function in case of changes in dealers' market shares would be as follows (Figures 58–60):

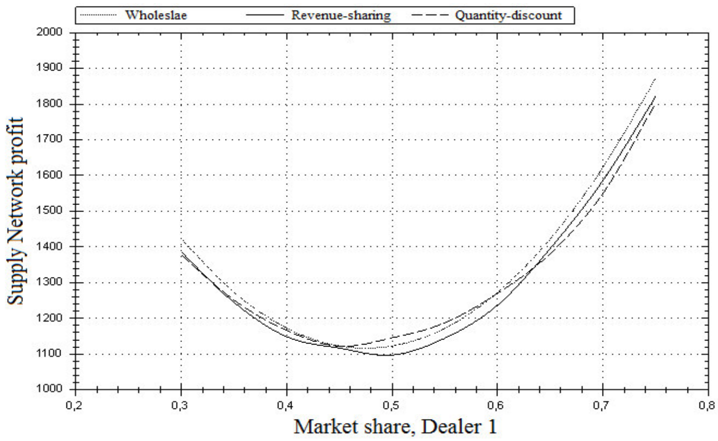

Fig. 58: Supply network profit function under changes in market concentration

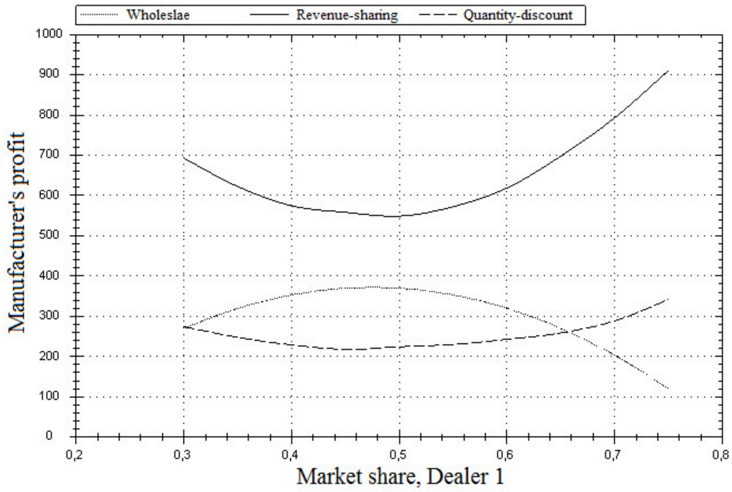

Fig. 59: Dealers' profit function under changes in market concentration

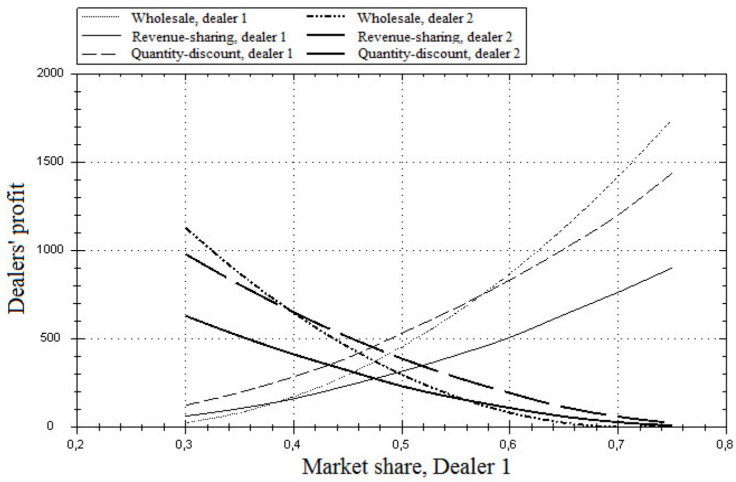

Fig. 60: Manufacturer profit function under changes in market concentration

3. Third Appendix

The behavior of profit function in case of changes in marginal costs c from 12 to 25 would look as follows (Figures 61–63):

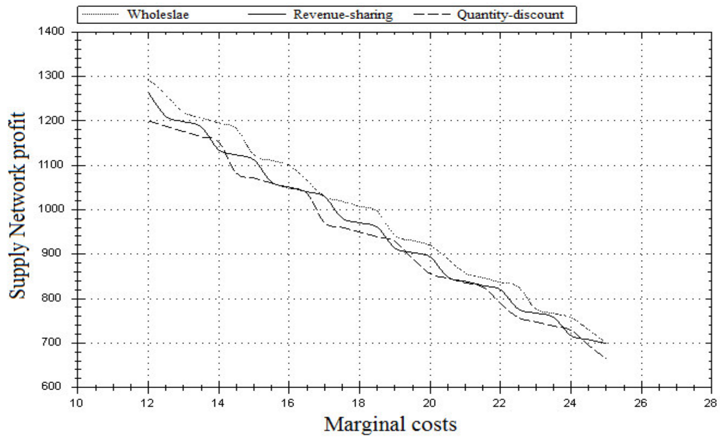

Fig. 61: Supply network profit function under volatility of marginal costs

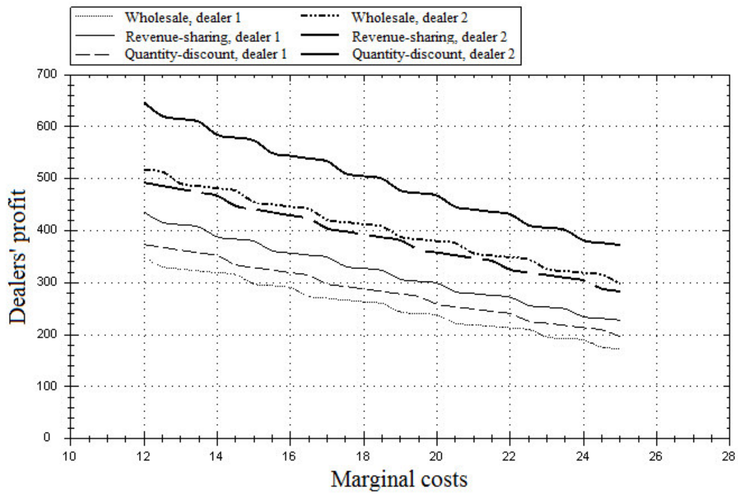

Fig. 62: Dealers' profit function under volatility of marginal costs

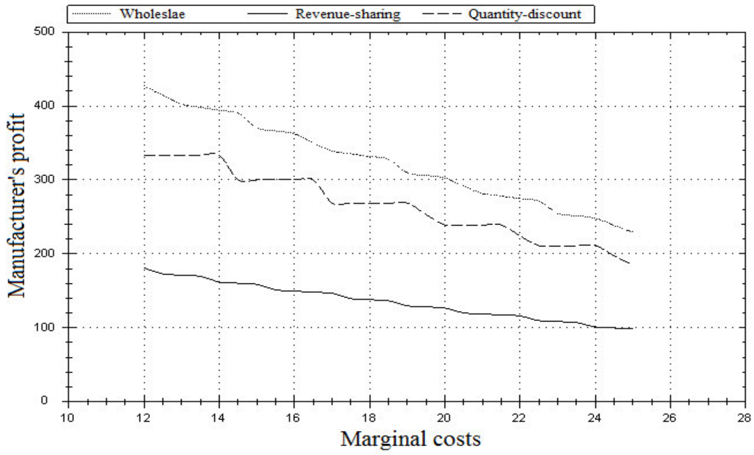

Fig. 63: Manufacturer profit function under volatility of marginal costs

The behavior of profit function in case of changes in manufacturer's operating expenses to fulfill the orders of, say, dealer 1, s_1 from 30 to 40 per unit of good would be as follows (Figures 64–66):

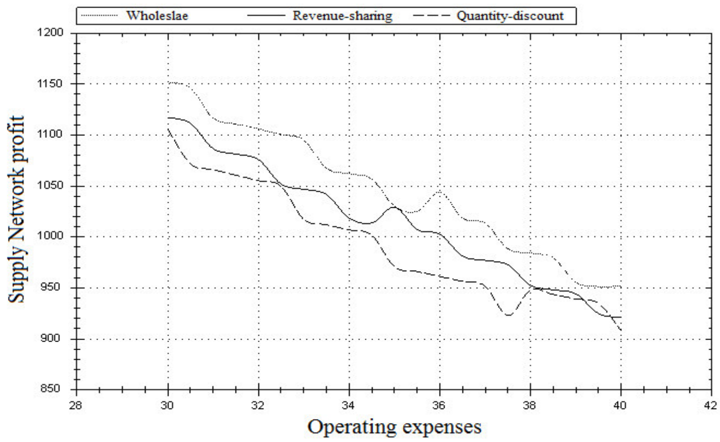

Fig. 64: Supply network profit function under volatility of operating expenses

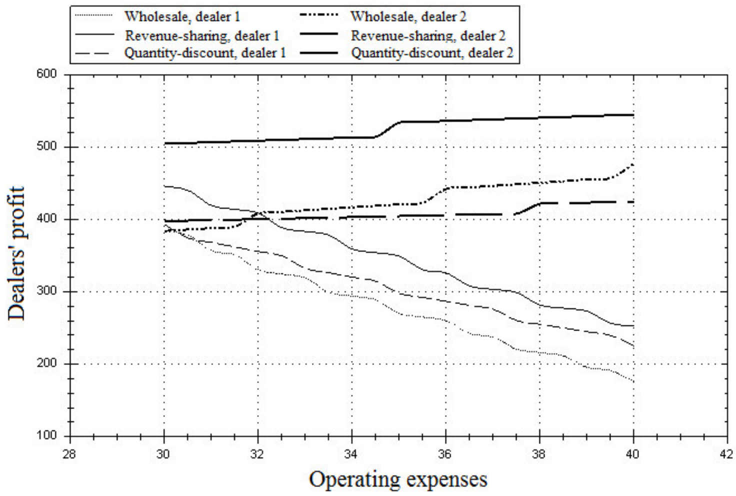

Fig. 65: Dealers' profit function under volatility of operating expenses

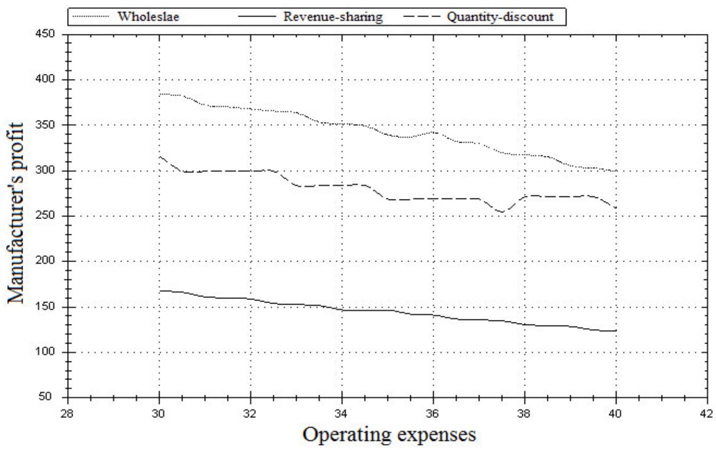

Fig. 66: Manufacturer profit function under volatility of operating expenses

The behavior of profit function in case of changes in market elasticity γ from 0.1 to 0.9 would look as follows (Figures 67–69):

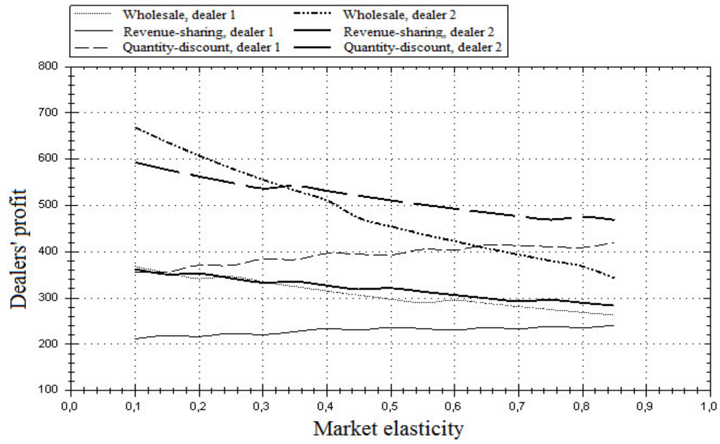

Fig. 67: Supply network profit function under changes in market elasticity

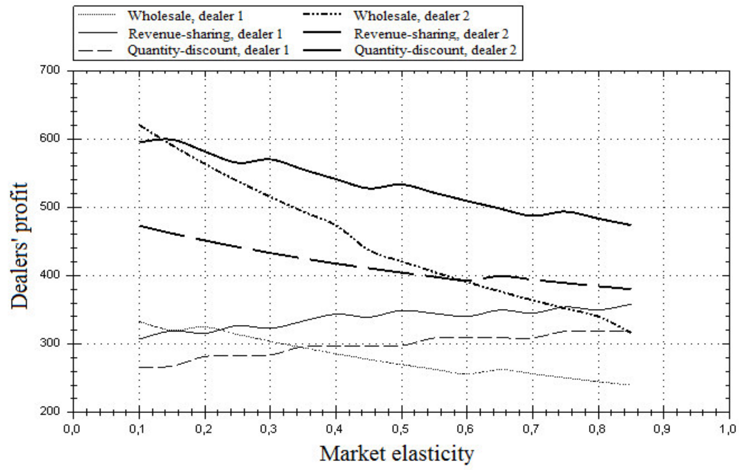

Fig. 68: Dealers' profit function under changes in market elasticity

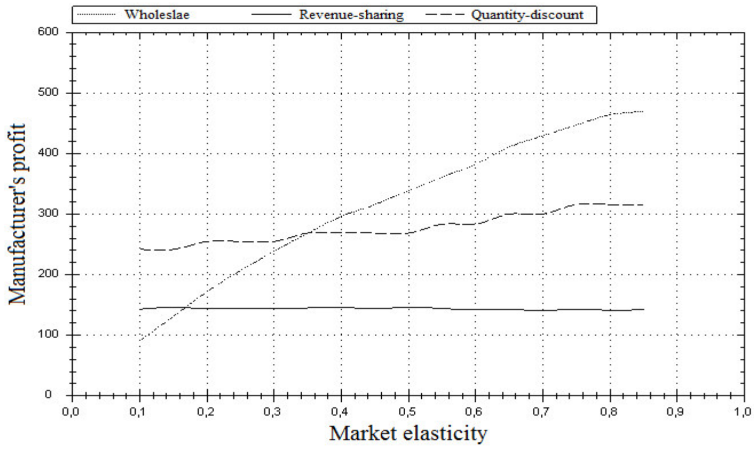

Fig. 69: Manufacturer profit function under changes in market elasticity

The behavior of profit function in case of changes in price sensitivity for dealer 1 products δ_1 from 0.3 to 2 would look as follows (Figures 70–72):

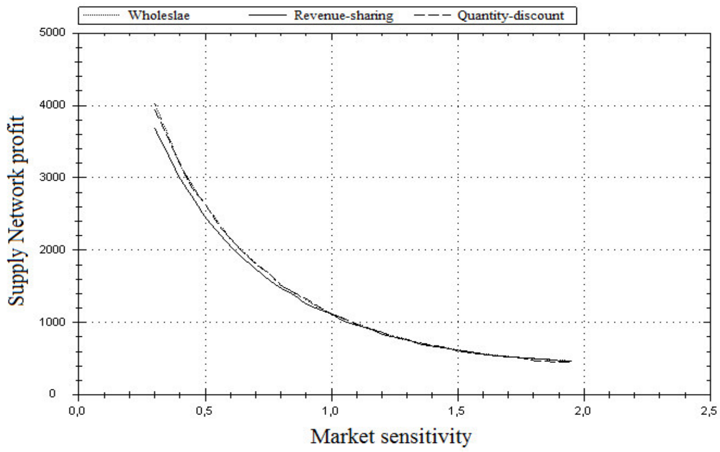

Fig. 70: Supply network profit function under changes in price sensitivity

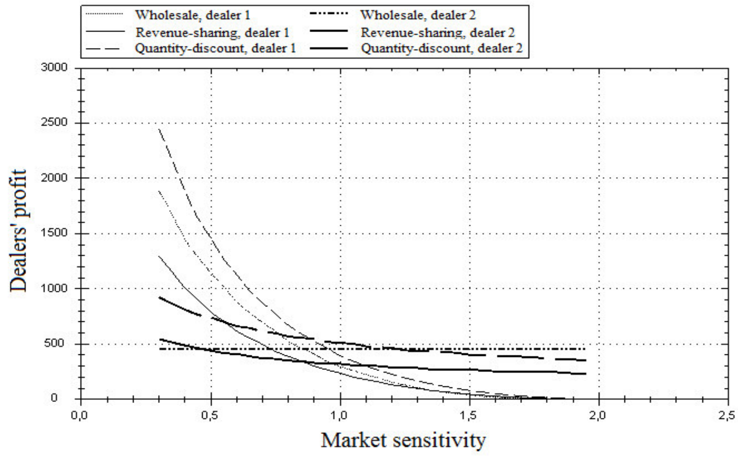

Fig. 71: Dealers' profit function under changes in price sensitivity

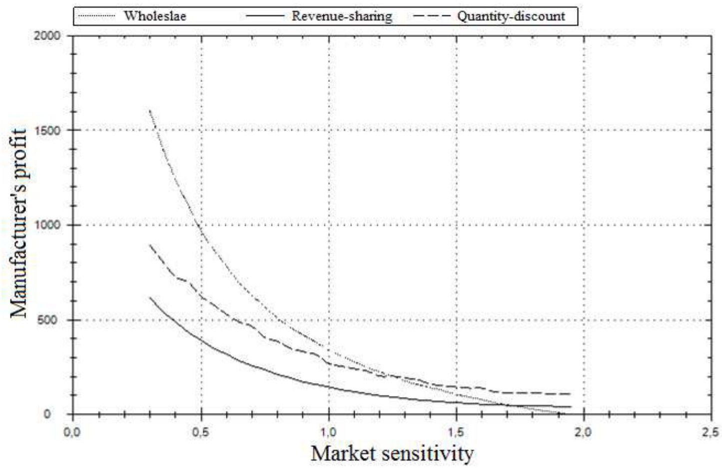

Fig. 72: Manufacturer profit function under changes in price sensitivity

Considering changes in dealers' market shares k_1 and k_2 from 0.3 to 0.8 and from 0.7 to 0.2 accordingly, the behavior of profit function would be as follows (Figures 73–75):

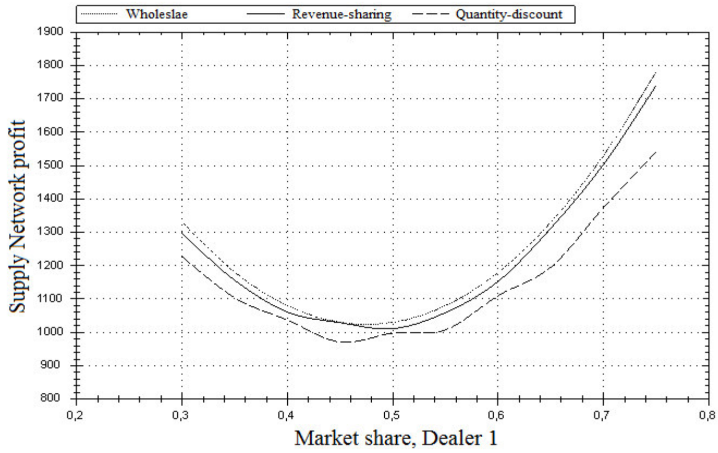

Fig. 73: Supply network profit function under changes in market concentration

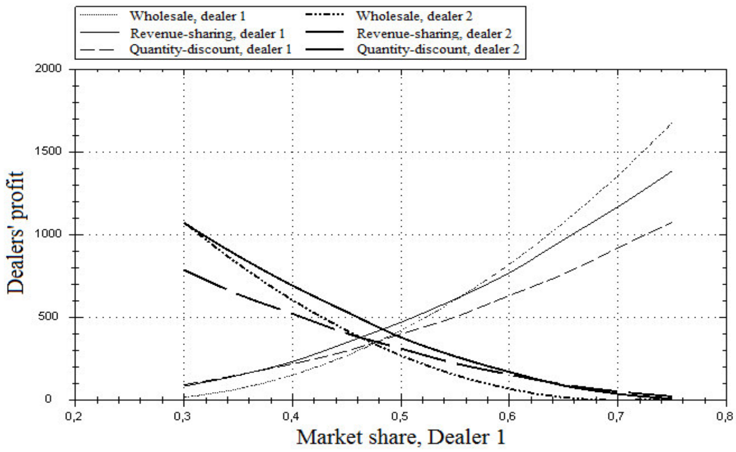

Fig. 74: Dealers' profit function under changes in market concentration

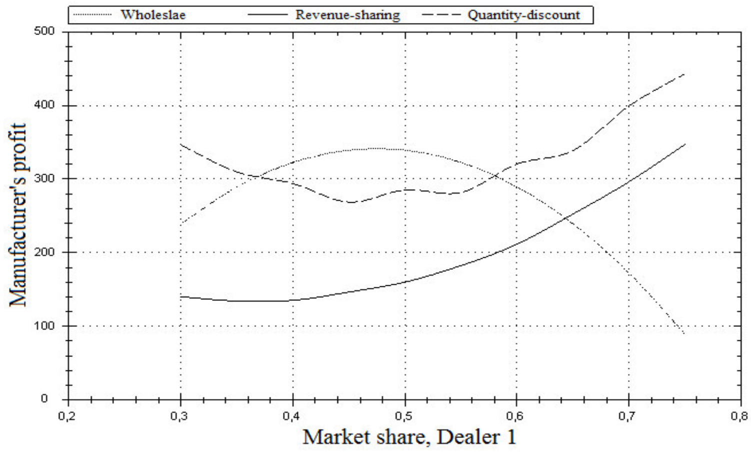

Fig. 75: Manufacturer profit function under changes in market concentration

4. Fourth Appendix

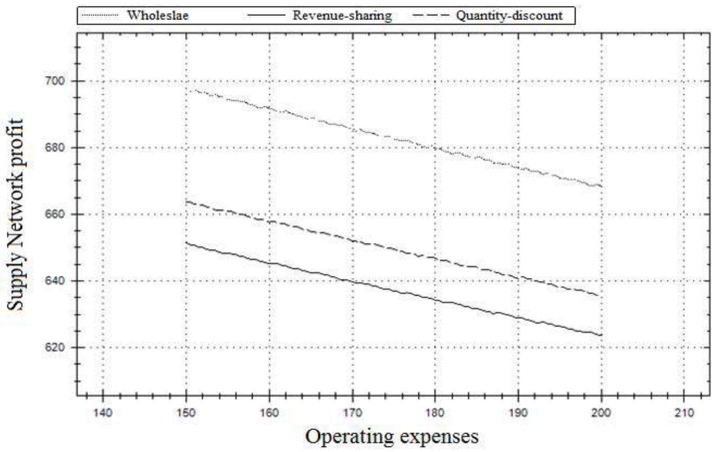

Fig. 76: Audi supply network profit function under volatility of operating expenses

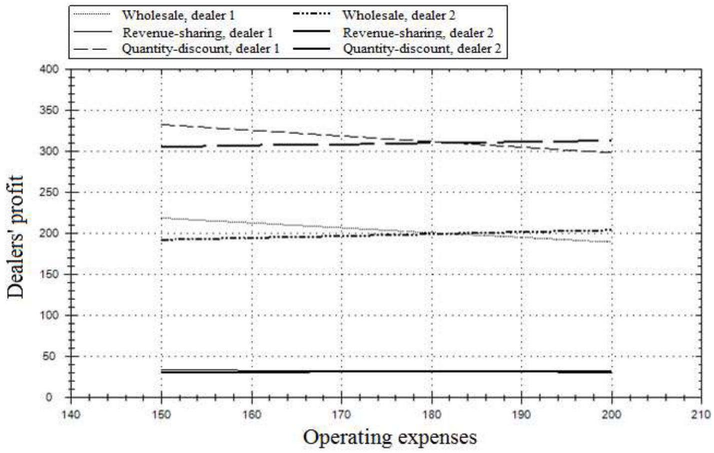

Fig. 77: Audi dealers' profit function under volatility of operating expenses

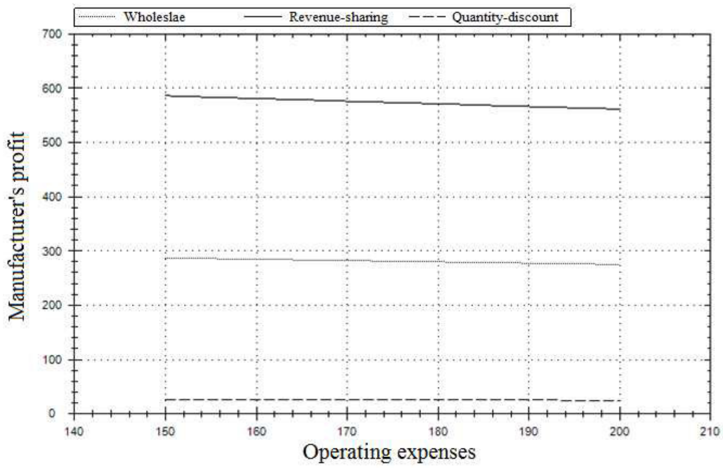

Fig. 78: Audi profit function under volatility of operating expenses

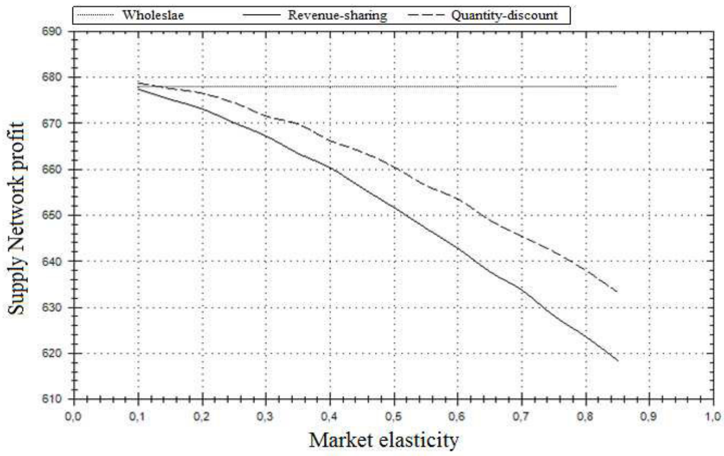

Fig. 79: Audi supply network profit function under changes in market elasticity

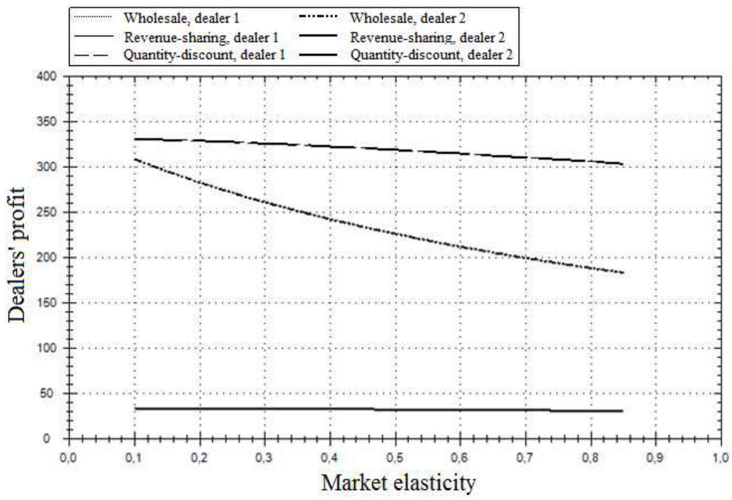

Fig. 80: Audi dealers' profit function under changes in market elasticity

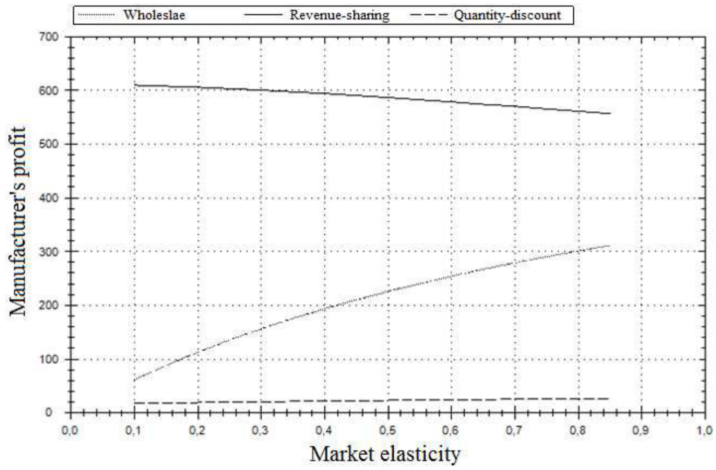

Fig. 81: Audi profit function under changes in market elasticity

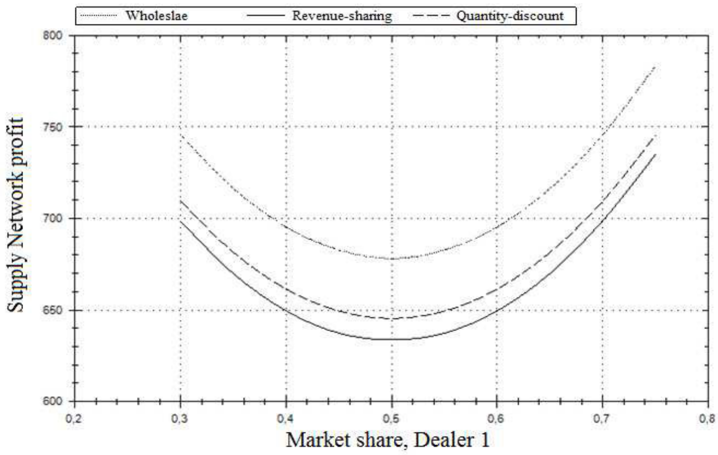

Fig. 82: Audi supply network profit function under changes in price sensitivity

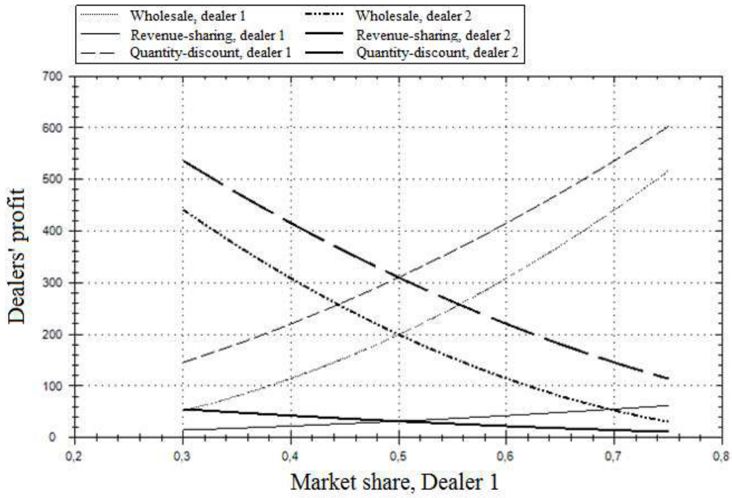

Fig. 83: Audi dealers' profit function under changes in price sensitivity

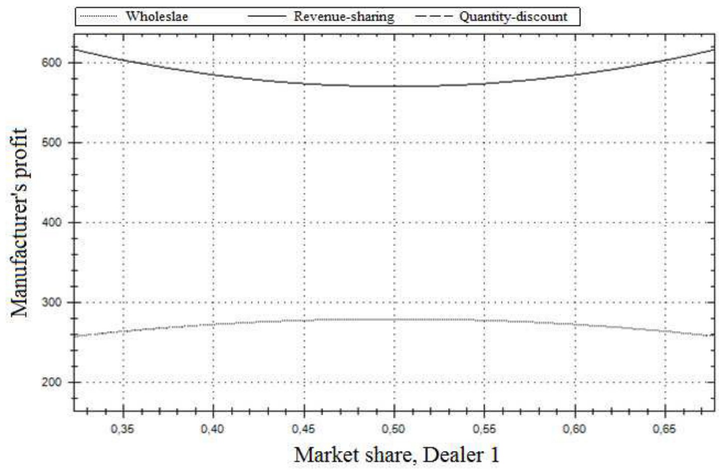

Fig. 84: Audi profit function under changes in price sensitivity

5. Fifth Appendix

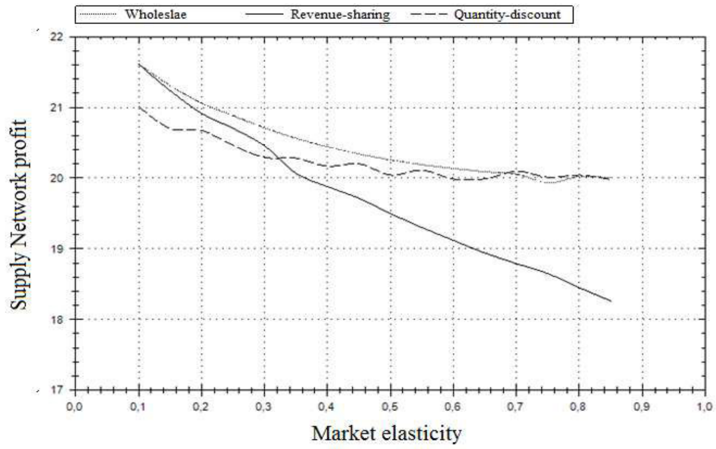

Fig. 85: Heineken supply network profit function under changes in market elasticity

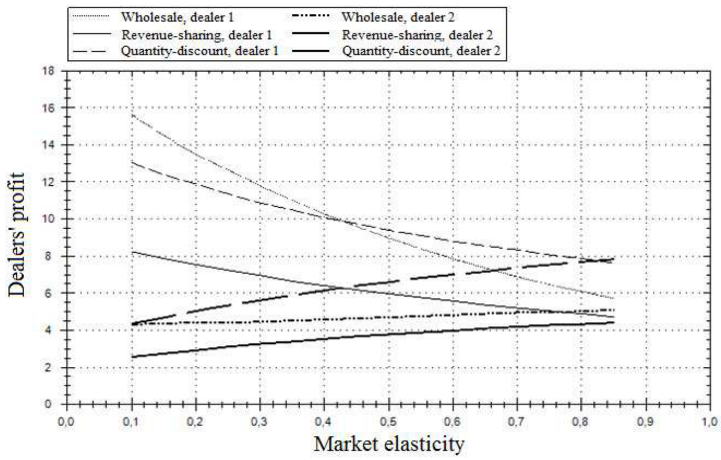

Fig. 86: Bar profit function under changes in market elasticity

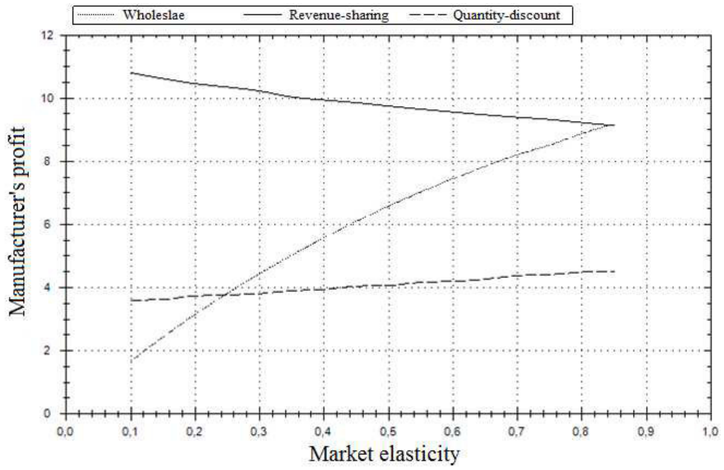

Fig. 87: Beer wholesaler profit function under changes in market elasticity

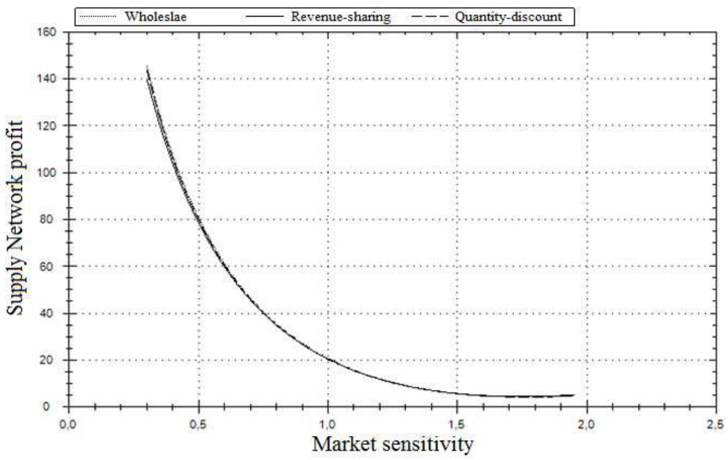

Fig. 88: Heineken supply network profit function under changes in price sensitivity

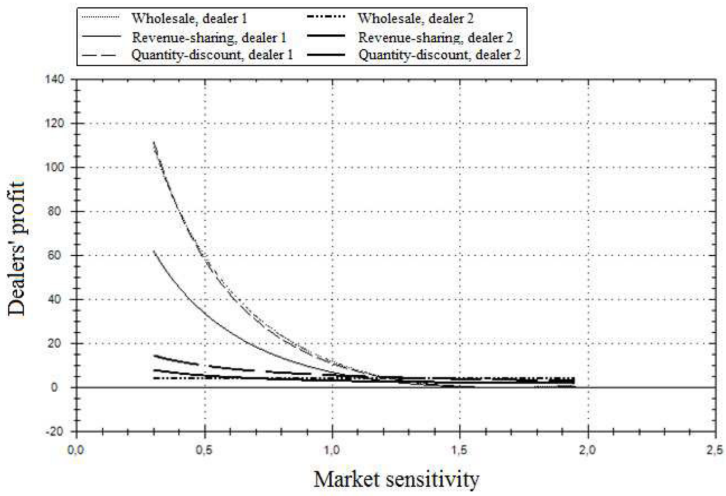

Fig. 89: Bar profit function under changes in price sensitivity

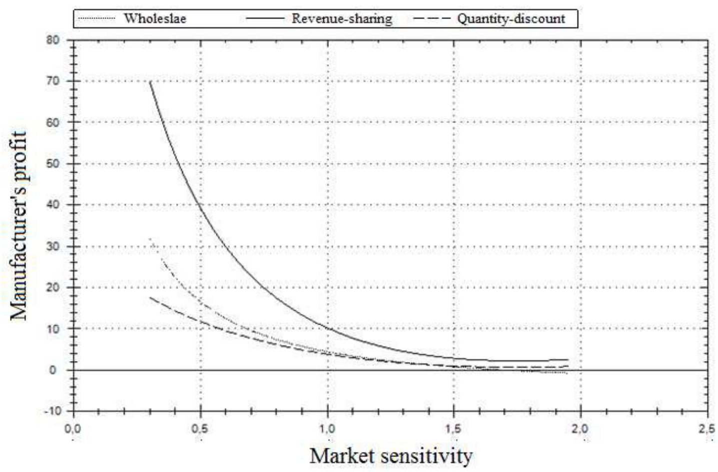

Fig. 90: Beer wholesaler profit function under changes in price sensitivity

6. Sixth Appendix

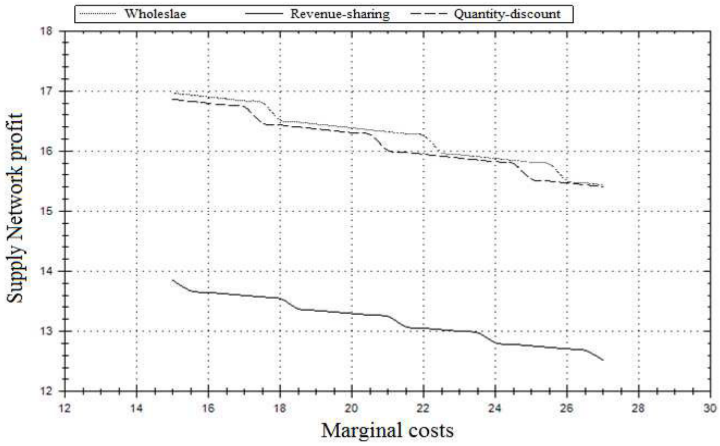

Fig. 91: ProtechDry supply network profit function under volatility of marginal costs

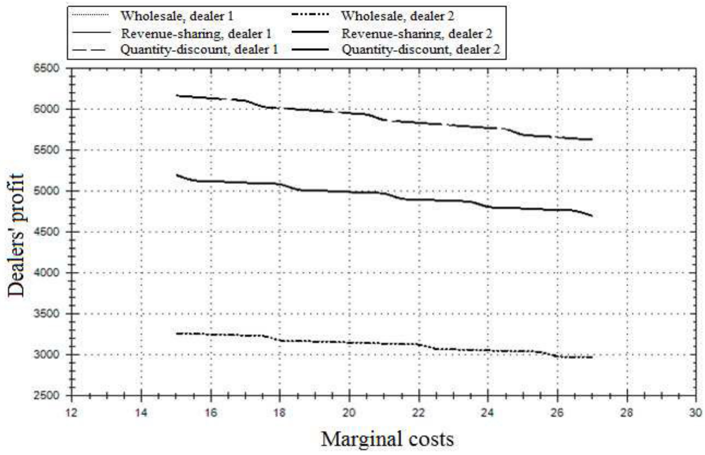

Fig. 92: ProtechDry dealers' profit function under volatility of marginal costs

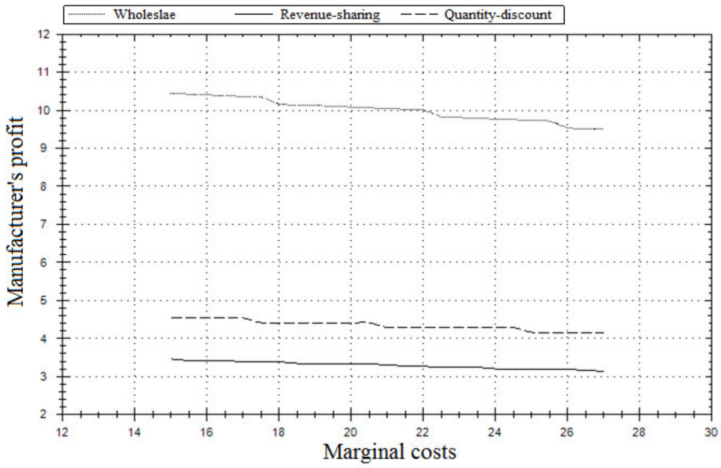

Fig. 93: ProtechDry profit function under volatility of marginal costs

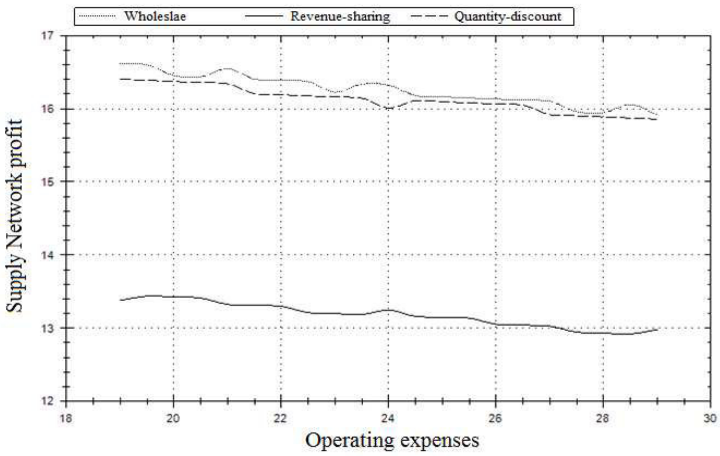

Fig. 94: ProtechDry supply network profit function under volatility of operating expenses

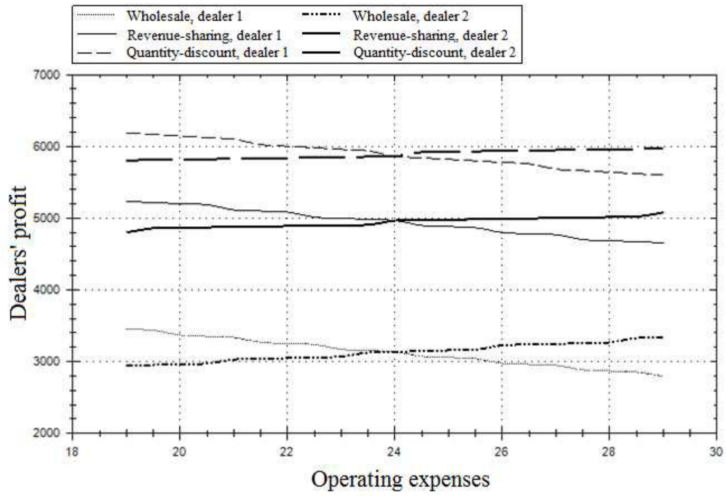

Fig. 95: ProtechDry dealers' profit function under volatility of operating expenses

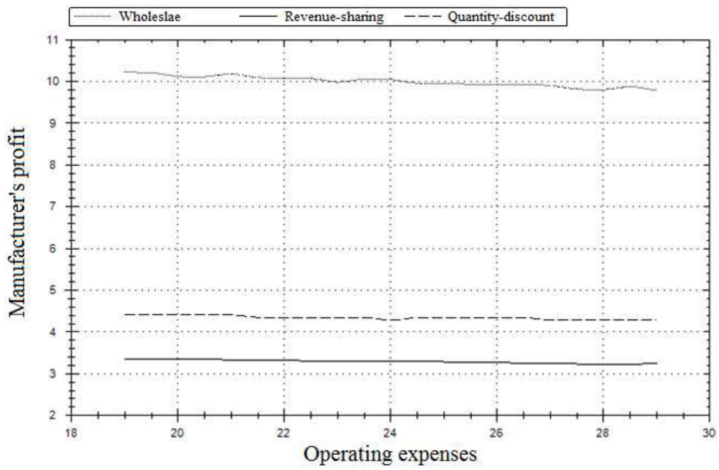

Fig. 96: ProtechDry profit function under volatility of operating expenses

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